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Review Article

Agroforestry systems and research in Eritrea (East Africa): A review

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ABSTRACT

The paper reviews the potential and significance of agroforestry systems in Eritrea with the objective of improving their adoption. The three basic Agroforestry systems are: agrisilviculture (crops + trees), silvopastoral (pasture/animal + trees), and agrosilvopastoral (crops + pasture/animals + trees). Other agroforestry systems include apiculture (bees + trees), aquaculture (fish + trees) and multipurpose tree lots. In Eritrea, the most important agroforestry practices are multipurpose trees on crop land, wind breaks and shelter belts, trees for soil conservation, living fencing, community wood lots, river banks and water ways and rangelands (protein banks). Agroforestry has been recognized as a land use system capable of yielding both wood and food, while conserving and rehabilitating natural ecosystems. Research reviews on agroforestry in Eritrea showed that the highest grain yield on barley was obtained from fallow land planted with *Crotalaria grahamiana* (1,165 kg ha⁻¹). Hedge row intercropping studies showed that a 4.5 m alley gave higher barley grain yield (793 kg ha⁻¹) than a 6 m alley. It is necessary to create community awareness on the benefits of agroforestry and to promote different agroforestry practices to preserve indigenous woody species. Furthermore, tree legumes are very important source of protein which provides animal feeds during dry periods. However, it is important that appropriate agroforestry research programs are co-designed with farmers so that relevant technologies and approaches can be adopted in farmers' real-world context.

Key words: Agroforestry systems, indigenous practices, concepts, research findings, Eritrea

The widespread land degradation caused by inappropriate land management, unsustainable agricultural practices, overgrazing and deforestation resulting in clearing of vegetation cover and increased soil erosion is the most serious environmental concern in Eritrea. The annual rate of soil loss from cropland is estimated at 12-17 t ha⁻¹ and crop yield is declining at the rate of 0.5 per cent per annum owing to soil erosion. The dependence on biomass (charcoal, firewood, agro-residues and cow dung) for domestic energy contributes significantly to forest and woodland clearance. A number of these unsustainable practices have resulted in a reduction in Eritrea's terrestrial biodiversity, although it appears that coastal and marine biodiversity resources have remained relatively stable.

The long history of sedentary rainfed agriculture has changed the land use/land cover systems and caused environmental degradation which has led to the degradation on forest ecosystems and loss of forest area, habitat fragmentation, soil degradation and biodiversity losses. There are various interventions carried out such as afforestation programs, area closures, soil and water conservation/water harvesting, agronomic practices and distribution of energy stoves to combat land degradation.

However, agroforestry can be an important alternative system that has to be dealt widely through the integration of trees on farms that will result in ecologically, socially and economically sustainable farming system (Lundgreen, 1982).

In Eritrea, a package known as the Minimum Integrated Household Agriculture is widely introduced at household level by the Ministry of Agriculture. This package enhances agroforestry practices at household level through the integration of crops, livestock and trees with multiple purposes. This is an indication that packages are implemented that could enhance agroforestry practices in combining trees, crops and livestock. Planting of more fodder trees would increase fodder availability, which would benefit both livestock and crop production. The above intervention ensures that woodlots are also established mainly for production of poles, and more fruit trees could improve nutrition (Ministry of Agriculture, 2007).

The objective of this paper is to review and compile the indigenous agroforestry practices that has been practiced for centuries and are available in scattered documents so that adequate intervention can be made in the farming system. Besides, there were limited research programs carried out in Agroforestry in Eritrea which have not been published. This

paper provides limited information on research efforts done and findings in order to enhance joint research cooperation with academic and research institutions in collaboration with regional and international institutions that are interested in agroforestry. It will also serve as a reference and source of information for extension workers, development agents and policy makers so that agroforestry could be given attention that it deserves for social, economic and environmental benefits.

Concepts of agroforestry

Agroforestry, social forestry, community forestry, village forestry and farm forestry are all terms used to describe tree growing that is undertaken outside forest areas. These terms are often used to describe very similar activities, but in theory they have slightly different meanings. The trees in an agroforestry system are not necessarily planted. Instead natural regeneration of trees may be protected, or mature trees may be deliberately left in the fields or pastures. Agroforestry systems often involve management of trees and shrubs and utilization of their products. The trees and shrubs will have an impact on the other components in the land-use system. Hence, agroforestry systems are normally characterized by ecological and economic interactions between woody perennials and crops or livestock (Tengnäs, 1994).

Agroforestry definitions and concepts have their own limitations but agroforestry practices usually possess the following features (Amonum *et al.*, 2009, Rocheleau *et al.*, 1988 and Lundgreen, 1982).

- i. Agroforestry is a distinct multiple land use system which includes a combination of agricultural, forestry, horticultural and animal husbandry sub systems and practices.
- ii. Agroforestry integrates trees with crops and or animals for reducing risk and increasing overall productivity. It is a risk aversion mechanism so that farmers could minimize the risk of crop failure by growing a variety of products on the same piece of land.
- iii. Agroforestry practices have greater diversity compared to monoculture and production could be distributed over a longer period. It could also provide income that is more stable with increased cash flow.
- iv. It provides benefit to farmers who may have difficulty storing or marketing farm produce.
- v. More efficient utilization of soil resources such as moisture, nutrients and sunlight is achieved in

agroforestry to get multiple products which is not possible under monoculture.

There are three basic types of agroforestry systems based on their compositions namely *agrosilviculture*, which is a combination of crops and trees, *silvopastoral*, it is a combination of pasture and or animals and trees and *agrosilvopastoral*, it is a combination of crops, pasture and trees. Other specified agroforestry systems practiced are apiculture, which is bees and trees, aquaculture fish with trees including shrubs and wood perennials as well as multipurpose wood lots (Rocheleau *et al.*, 1988).

The socio-economic and environment benefits of agroforestry systems can be summarized as follows (Baumer, 1990 and Lundgreen, 1982).

- i. Contribute to the supply of firewood better than monoculture.
- ii. Woody perennials are less affected than herbaceous plants by temporary water deficits, hence, agroforestry with woody perennials could increase directly or indirectly the production of food both in quality and quantity.
- iii. There is an increased stability of food supply due to the diversity of plants in the system.
- iv. The system contributes to the sustainability of the environment in maintenance of soil fertility, reduce wind speed and create a favourable microclimate to improve the productivity of crops/livestock.
- v. Woody perennials are selected not only to give wood products but also provide tannins, flowers, medicines, dyes, etc.
- vi. The farming systems contribute to the improvement of economic and social conditions in rural areas not only by increasing profitability, sustainability and food security including increasing the purchasing power.

Farmers have always grown trees on their land with the expectation that it will have beneficial effects for the soil and crop yields. This capacity of trees and other plants to restore soil fertility was observed in several farming systems. It is also proved that the topsoil in forests is usually rich in nutrients and has a good structure. It has been concluded that the cycles of carbon and other nutrients under natural vegetation are relatively closed with little leakage of carbon. However, much research work is needed to discover and verify the effect of trees on the properties of soil. The status of the soil is one of the most important factors that determine how a crop will perform in a certain site. The moisture

content in the soil is another important factor, and trees growing with the crops will also have an impact on the moisture content of the soil (Rocheleau *et al.*, 1988 and Tengnäs, 1994).

Agroforestry practices

Agroforestry has been practiced for many centuries in Eritrea. The indigenous practices have contributed to the reduction in environmental degradation for decades. It is better to build on the available indigenous knowledge of agroforestry which can be easily adopted by farmers rather than introducing a new one. In this section the most important existing indigenous agroforestry systems are described and the practices that should be used to improve the system are included so that some form of improvements could be introduced by farmers and extension agents.

(i) Multipurpose trees scattered on crop lands (Parkland)

Spatial arrangement: In most farming areas there are scattered trees growing in the fields. Often such trees were left when the land was cleared for agriculture, or naturally dispersed seeds may have germinated and the seedlings been deliberately protected during farming operations. In such cases, the spatial arrangement is a random one. The benefits to be obtained from the trees, in terms of soil fertility and soil structure, are normally more clearly seen in areas where little or no inorganic fertilizer is used (Bein, 1997, Habte and Araya, 2004 and Tengnäs, 1994).

Management: The system consists of 10-20 trees with a density estimated to be 40 to 60 trees per hectare; farmers normally pollard the branches of the trees to be used for fencing, fire wood and for construction. Tree-management practices will depend on the tree and crop species concerned and the need for tree products. With a light-demanding crop, pollarding or pruning is essential, but this does not apply to shade-tolerant crops or to trees that naturally only have light shade. An example of species that need and tolerate pollarding are *Balanites aegyptiaca* (Bein, 1997 and Tengnäs, 1994).

Some birds build their nests on trees and feed on grain and have long been a problem for cultivation of certain crops such as sorghum. Traditionally, both children and adults would spend much time guarding crops, but at this time it is not possible to get labour for such activity. The most destructive bird species in this respect is the red-billed quelea, *Quelea quelea*, which may sometimes invade cultivated areas in very large numbers in sorghum producing regions of Eritrea. Hence, proper pollarding or management of trees would solve the problem of shading and damage of crops by birds (Negassi *et al.*, 2002 and Tengnäs, 1994).

Benefits: A variety of products can be harvested from the trees, and among service functions soil improvement, wind-speed reduction and improved microclimate are important. Too many trees can cause reduced yields due to shade, and trees may attract birds which may be a threat to crops. Competitive trees with shallow roots, such as eucalypts, pines and *Acacia meurnsii* should be avoided. Trees that cannot be pollarded and which grow to a considerable size producing dense shade should also be avoided, e.g., *Acrocarpus fraxinifolius*. Other trees to avoid are *Croton megalocarpus*, *Cupressus lusitanica* and *Ficus benjamina*. Nematode build-up has been reported under *Sesbania sesban* (Bein, 1997, Habte and Araya, 2004 and Tengnäs, 1994).

Species: This is known as a parkland agroforestry in which widely spaced pollarded trees are grown in croplands of sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*) and taff (*Eragrostis tef*). Livestock rearing is also a part of this farming system which is similar to that of the semi-arid Sahelian zone of West Africa such as Burkinafaso and Niger. In the parkland agroforestry system in Eritrea, *Faidherbia albida*, *Balanites aegyptiaca* and *Acacia tortilis* and *Cordia africana* and *Olea africana* are traditionally managed in both



Fig. 1. Parkland agroforestry



Fig. 2. Agroforestry in soil and water conservation



Fig. 3. Range lands and protein banks

crops and pasture grasses growing beneath the trees for the provision of fuel, fodder, fruit, shade and shelter (Bein, 1997 and Negassi *et al.*, 2002).

(ii) Wind breaks and shelter belts

Preliminary surveys have shown that windbreaks and shelterbelts are planted to protect irrigated farms and settlements areas from strong and dry winds. Temporary thorny branches are used for protection of individual tree seedlings especially if the windbreak is a single row. Strips trees/shrubs planted to protect fields, homes or other areas from wind and blowing soil. Shelter belts reduce wind speed preventing soil erosion with about 50 per cent reduction in loss of soil nutrients. A wind break can consist either of a single row of trees with a spacing of 1.5 to 2.0 m or if it is more than one row the spacing used is 4-5 m within the rows (Bein 1997 and Negassi *et al.*, 2002). Trees normally used as a wind break in Eritrea are *Azadirachta indica* (neem) *Senna siamea*, *Delonix regia*, *Prosopis chilensis*, *Conocarpus lancifolius*, *Schinus molle*, *Eucalyptus camaldulensis*, *Eucalyptus cladocalyx* and *Eucalyptus globulus* (Bein 1997 and Habte and Araya 2004).

(iii) Trees on soil conservation structures

Spatial arrangement: Trees can be planted as biological soil-conservation measures (tree strips), either in combination with grasses or alone. Trees alone are effective enough only on gentle slopes (less than 8%). On steeper slopes combinations with grasses are desirable, trees can also be planted on terrace edges in order to stabilize the structure and make maximum use of the land. Trees planted on the edge of a terrace will not have ideal moisture conditions but are effective for stabilizing the soil. Fruit trees, which need the best moisture conditions, can be planted just below the edge of the terrace where they can benefit from run-off and more moisture generally (Tengnäs, 1994).

Benefits: The products and services obtained from the trees will depend on the choice of species. The role of stabilizing structures and making the land productive is essential. If perennials are grown on bunds, for example, the structures will become more permanent. Trees planted in the conservation structures could also reduce soil erosion but the trees and shrubs should be trimmed to hedgerows and placed above and between trees as a trash line. Limited plantations have been done in specific areas of Debub Zone, Eritrea with *Acacia polyacantha* (Bein 1997 and Negassi *et al.*, 2002).

Establishment of trees: The spacing for trees and shrubs intended to stabilize terraces can be 1.5-3.0 m for trees and 0.3-0.5 m or wider for shrubs if the farmer so wishes

(Tengnas, 1994). Initial establishment can always be more dense and thinning can be carried out later to obtain the final spacing. On steeper slopes an option is to grow trees on every second terrace to avoid having too great a density of trees. There is no quantitative data available to show the increase in crop yield and the degree of reducing soil erosion due to such practice.

(iv) Live fences and hedges

Spatial arrangement: Live fences may be established all around the farm, but it is most common to establish such a fence around the homestead. The live fences are also found around many schools, and church and mosque compounds (Habte and Araya, 2004, Lundgreen, 1982 and Negassi *et al.*, 2002). A live fence controls the movement of domestic animals. Live fences are also used as ornamental planting, improvement of the micro climate, demarcation of land, soil and water conservation, provision of security or privacy and to prevent shelter to backyard poultry.

Establishment and spacing: Very many individual shrubs are required to make a fence or a hedge. Thus, the propagation method must be simple and cheap. Direct seed sowing or use of cuttings (depending on species) is primarily recommended. It may be better to raise seedlings in an on-farm nursery since they have small seeds and are relatively slow starters (Tengnäs, 1994). It is best to plant seeds, seedlings or cuttings in two staggered rows so that an impenetrable fence or hedge is formed. The distance between the rows can be 15-30 cm with the same space within the rows. Directly sown fences must be well looked after and protected initially (Habte and Araya, 2004, Negassi *et al.*, 2002 and Tengnas, 1994).

Benefits: Fences and hedges are often multipurpose. Some of their uses are to provide shade and a windbreak for the compound, control movement of cattle, provide protection for chickens against birds of prey, provide privacy, production of mulch, fruit, bee forage or wood and help in soil conservation. There are few risks involved as live fences require labour for maintenance, and if they are not maintained they lose their intended function and begin to compete with crops. The latex of *Euphorbia tirucalli* is very poisonous and dangerous for the eyes. Fences and hedges may harbour snakes, and some shrub species may turn into weeds, e.g., *Lantana camara*. Another plant, *Thevetia peruviana* is also very poisonous (Tengnäs, 1994).

Species: The trees that are mostly used as live fence in Eritrea are *Euphorbia tirucalli*, *Opuntia ficus indica*, *Euphorbia abyssinica* and *Agave sisalana* depending on the location. Other benefits include production of fuel wood, fruit, fodder and fiber (Bein, 1997 and Habte and Araya, 2004).

(v) Wood lots in villages and community

The need for timber and poles for construction purposes is one of the most common reasons for people to plant and grow trees. Few indigenous tree species grow as straight as some of the exotics, hence, these exotic species are very popular for building materials. Eucalypts are commonly grown for poles since they are fast growing, straight, easily split and the wood is reasonably durable. Several farmers plant *Eucalyptus cladocalyx*, *Eucalyptus globulus* and *Eucalyptus camaldulensis* to make use of unused land and to contribute to wood supply. Eucalyptus has become a vital asset due to ease of establishment and production by coppicing, its wide range of uses and growth performance, which is preferable compared to other species (Bein, 1997 and Tengnäs, 1994). Wood lots are planted near the villages, on road sides and waste lands; it reduces the time needed for collecting fire wood leaving more time for the more productive activities such as soil cultivation, food preparation and cooking etc., the wood lot provides wood for fuel so that the dung and other organic matter used as fire wood will be applied in the crop fields to improve soil fertility (Bein, 1997).

As far as resistance to decay and termite attack is concerned, the best species are the indigenous ones. Many indigenous trees produce wood that can last for many years without treatment with preservatives. Many exotic trees are also problematic in areas where termites are common. Seedlings of eucalyptus and *Casuarina* spp. are very susceptible to termite attack, and grevillea may also be attacked. In such areas it is still recommended to promote the use of indigenous trees for construction, but continuous efforts have to be made to ensure regeneration for a sustainable supply (Tengnäs, 1994).

(vi) Trees along river banks and water ways

Spatial arrangement: River banks are prone to erosion if they are not well covered with vegetation. Furthermore many important indigenous trees are riverine, *i.e.*, they occur naturally only or mainly along water courses. Thus, vegetation along rivers is important both from an environmental point of view and for the production of special commodities, *e.g.*, medicine or fruits. There is no particular spatial arrangement needed to be used for that purpose (Tengnäs, 1994).

Benefits: It prevents erosion of stream banks which affects large areas of productive land every year, it decreases evapo-transpiration of water from the river; it provides shade, fodder for livestock, construction material, fiber, fruit and other products.

Species: Tree planting along river banks in the western lowlands of Eritrea is a common practice among farmers engaged in horticultural crops, the indigenous trees available naturally or left purposely along the river banks are *Acacia nilotica*, *Arundo donax*, *Prosopis species*, *Tamarix species*, *Ziziphus spina christi*, *Hyphaene thebaica* and *Cactus* are used to stabilize the soil (Bein, 1997, Habte and Araya, 2004 and Negassi *et al.*, 2002).

(vii) Trees on range lands

Spatial arrangement: Scattered trees in rangeland are beneficial in many ways, *e.g.*, providing shade for livestock and herdsman, fodder and wood. Normally such trees are scattered at random and there is no need to be particular regarding any regular spatial arrangement.

Establishment and spacing: Any propagation method may be applicable, but use of seedlings can be recommended since it is essential to minimize the period during which protection is needed. Natural regeneration should be considered before tree planting is recommended, but both the methods can be used at the same time. Protection of the existing vegetation is the first priority (Tengnäs, 1994). If there are already a few trees, protection of natural regeneration should be the second option to consider. If trees need to be actively planted or sown, priority should be given to indigenous trees since they are generally better conservers of water than exotics. Spacing will depend on species and purpose, but usually no large pieces of land should be put under trees. Hence, normally a few trees will be planted at selected places and a fixed spatial arrangement will not be relevant.

Management aspects: As always, protection during regeneration is important with young trees. Other management steps will depend on the species and the purpose for which the trees are intended. Sites along rivers are often fertile and, therefore, are often used for growing vegetables. Pollarding and pruning can then be considered for minimizing shade (Negassi *et al.*, 2002 and Tengnäs, 1994).

Benefits: The most important benefits are improved supply of fodder and environmental benefits, *e.g.*, shade. Certain species may suppress the growth of grass and such species should, of course, be avoided. In the central highlands, lowlands and western escarpment silvi-pasture is the dominant land use system, a tree protected for fodder also has other uses such as shade, firewood, gum and nectar for bees and protects the soil from erosion, the rangelands also provide food for humans during periods of famine due to moisture stress where the leaves are used as vegetables, *e.g.*, *Faidherbia albida* (Bein 1997 and Habte and Araya, 2004).

Species: The dominant species with high dry matter content and nutritive value (crude protein >20% of DM) have been identified as feed sources. These include *Acacia tortilis*, *Acacia senegal*, *Acacia seyal* and *Acacia nilotica*. Other non-leguminous species are *Balanitesaegyptica*, *Ziziphus spina christi*, *Dodoneaviscosa*, *Hyphaenethebaica* and *Cadabafarinosa* could be specified (Bein, 1997, Habte and Araya, 2004 and Negasi *et al.*, 2002).

Research on agroforestry in Eritrea

This paper focuses on research in agroforestry conducted from 1999 to 2002 in some locations of Eritrea. The research efforts did not continue as expected after 2002 due to shortage of resources. Limited and most relevant research topics were selected, reviewed and included in this paper. These are on hedgerow intercropping on barley, short duration improved fallow on barley and the effect of increasing distance and direction of *Faidherbia albida* on taff (*Eragrostis tef*).

(i) Effect of hedgerow intercropping on barley

Alley cropping is an agroforestry practice where crops are grown between lines of trees and/or shrubs that are managed and spaced at regular intervals in cropland. According to Tengnas (1994) this practice is labour intensive, relevant mainly in areas with small farms and a high population density or where labour is not a limiting factor. This practice has received much research attention and is regarded as having promise for solving problems of declining soil fertility in situations where farmers cannot afford to use inorganic fertilizers at the recommended rates. Research findings indicate that alley cropping is not feasible in areas where the average rainfall is less than 800 mm annually.

In this study, three spacing of *Leucaena leucocephala* at 4.5 m, 6 m and sole crop were tested at Halhale, Eritrea (1807 m altitude) to assess its effect on barley yield and biomass. The test was done as a Randomized Complete Block with four replications. The yield was very much affected by poor rainfall in some years. There were no statistical significance differences in biomass among different hedgerow intercropping. The results averaged for 1999 to 2002 showed that 4.5 m alley gave the highest biomass of 1,578 kg ha⁻¹, even though this was non-significant (Table 1).

The main benefits in conducting the research of alley cropping is the potential for sustaining or improving soil fertility. Other important benefits can be fodder, small-size wood and improved microclimate. Labour has sometimes been regarded as a constraint since the management of hedgerows requires a lot of work. Competition for moisture has been recognized as an obstacle, which is much more

Table 1. Effect of hedgerow intercropping on barley (average of 1999 to 2002)

Treatment	Biomass (kg ha ⁻¹)
4.5 m alley	1578
6.0 m alley	1372
Control	1522
Mean	1118
LSD 5%	NS

severe in drier conditions. This practice is not recommended in places where the annual average rainfall is less than 800 mm unless irrigation facilities are available. *Leucaena* often turns into a weed in warm and moist areas if it is not properly managed so adequate management practices are required (Tengnas, 1994).

(ii) Effect of short duration improved fallow on barley

When land is fallowed after certain period of cultivation in order to restore soil fertility, shrubs can be sown to speed up the process. These shrubs can fix nitrogen and add organic matter to the soil. The shrubs require little management once they are well established but protection from livestock is an absolute necessity. In situations when the shrubs are densely spaced thinning can be done for harvesting of staking materials and for firewood. When land is to be brought back under cultivation, some shrubs can be left to supply propagation materials for the next fallow period. The main benefits of improved fallow is quick restoration of soil fertility and wood production. The potential problems encountered are mainly damage of the vegetation by livestock and increased labour demand for the establishment as well as uprooting of shrubs (Tengnas, 1994).

A study on the effect of fallow on the grain yield and biomass of barley was conducted in the Eritrean highlands. The trees used for the one year fallow system were *Sesbania sesban*, *Crotalaria grahamiana*, *Cajanus cajan* and *Tephrosia vogelii*. Additional treatments tested were continuous cereals and natural weed fallow. The test was conducted in a Randomized Complete Block Design with four replications in a plot of 81 m². Trees were planted at a spacing of 1 x 1 m and the tree biomass was cut, chopped and incorporated in to the soil, which was cropped with barley. The results showed that there was significant differences with highest grain yield being obtained from the fallow land planted with *Crotalaria grahamiana* (1,165 kg ha⁻¹) followed by *Sesbania sesban* (1,152 kg ha⁻¹) with 708 kg ha⁻¹ increase when compared to continuous cropping and 383 kg ha⁻¹ increase compared to natural weed fallow (Table 2).

The grain yield (kg ha⁻¹) was the lowest for barley planted after continuous cropping of cereals. This is an

Table 2. Effect of one year improved fallow on barley

Treatment	Grain yield (kg ha ⁻¹)	Biomass (kg ha ⁻¹)
<i>Crotalaria grahamiana</i>	1165	3165
<i>Sesbania sesban</i>	1152	3075
<i>Cajanus cajan</i>	1140	3123
<i>Tephrosia vogelii</i>	1041	2963
Continuous cropping cereals	457	1514
Natural weed fallow	782	2152
Mean	956	2665
LSD 5%	335	791

indication that fallow planted with leguminous trees might increase the yield due to high nitrogen fixation in the soil that contributed to the yield increase of barley.

(iii) Effect of increasing distance and direction of *Faidherbia albida* on taff

Five increasing distance of 1, 3.5, 6, 8.5 and 11 m as well as direction of the tree on north, south, east and west were tested for the grain yield and biomass of taff. The grain yield and biomass of taff was not significant at an increasing distance from the tree. However, the grain yield and biomass were significantly different when the direction of the tree was taken into account. In general, it can be concluded that trees introduced in the farm have a complex interaction but might increase the relative humidity and suppress soil evaporation by shading effect of the tree canopy.

The grain yield was relatively the highest at increasing distance of the tree in 3.5 m with 1667 kg ha⁻¹ followed by a distance of 8.5 m with a yield of 1603 kg ha⁻¹ even though it was non-significant. The biomass was also highest at 3.5 m (4061 kg ha⁻¹) increasing distance from the tree followed by 6m (3822 kg ha⁻¹) which was consistent. The direction of the tree revealed that south direction from the tree gave the highest yield (1704 kg ha⁻¹) and biomass (3964 kg ha⁻¹). The lowest yield was obtained in the crop field located in the east direction of the tree (Table 3).

Several microclimate factors such as relative humidity, temperature and sunlight favors crops grown under *Faidherbia albida*. Much is still unknown on the effect of the species hence further research is essential to understand its agroforestry potential. *Faidherbia albida* is found mostly along the river banks and in woodland areas in Eritrea. The tree produces more leaves during the dry season. Farmers have different views on beneficial effect of the tree on crop yield. There are several farmers who claim that it increases crop yields grown in its vicinity.

Challenges in agroforestry system

- The most important obstacles in agroforestry are land/tree tenure, scarcity of water for seedling production

Table 3. Average yield of taff as influenced by the distance and direction from *Faidherbia albida* (1992-2002)

Treatment	Grain yield (kg ha ⁻¹)	Biomass (kg ha ⁻¹)
<i>Distance (m)</i>		
1.0	1389	3500
3.5	1667	4061
6.0	1567	3822
8.5	1603	3494
11.0	1472	3422
Mean	1540	3660
LSD 5%	NS	200
<i>Direction</i>		
North	1609	3769
South	1704	3964
East	1409	3444
West	1436	3462
Mean	1540	3660
LSD 5%	215	150

and erratic rains during the planting season. Direct seeding can also be done but it carries the risk of failure in poor-rainfall years. Active planting or seeding of trees should normally focus on trees for fodder, shade or fruit.

- Farmers who deal with agroforestry are not given incentives in kind, which could be in the form of farm tools, seed, fertilizers, etc. However, model farmers who are planting trees in watershed areas are given incentives like bicycles, solar panel, farm tools, etc. It will encourage them to plant more trees in the afforestation program but the same could be done particularly for agroforestry.
- Lack of adequate awareness, training and demonstration to farmers, particularly in agroforestry so that various tree species might not be planted in the wrong environment partly because of lack of information on suitable alternatives.
- The research on agroforestry was carried out from 1998 to 2002 but it did not continue as expected due to shortage of resources and facilities. Hence, there is an urgent need to continue the work provided resources and facilities are guaranteed.

Recommendations

- Create community awareness on the benefits of agroforestry; train farmers on the types of branches that can be removed during pollarding without damaging or killing the tree and suitable protection and management of young trees. Creating awareness on the wise utilization of the woody species in the area which is crucial in order to prevent the loss of valuable

tree species. The governmental and nongovernmental organizations should promote different agroforestry practices to conserve indigenous woody species.

- (ii) The need of indigenous practices of agroforestry should be realized because the techniques have been used for generations and have contributed to the environmental degradation. Thus, it is important to build on the available indigenous knowledge of agroforestry so that it can be easily adopted by farmers. The livestock breeds existing and the local landraces of crops have become adopted to the environment and are also accepted to the farming community.
- (iii) Proper care is required during tree planting such as wind break so that competition between trees and annual crops is minimized.
- (iv) Assessment and surveys to be done on the role of trees and shrubs in reducing soil erosion and improving crop productivity.
- (v) Relevant combinations of trees and crops need to be identified and agreed with farmers. Some trees compete severely with crops and trees like eucalyptus should not be planted on soil conservation structures in crop lands.
- (vi) It is necessary to establish demonstration sites to show the benefit of agroforestry practices and be able to show some of the suitable tree and shrub species for agroforestry practices.
- (vii) Tree planting along the river banks need to be combined with windbreak establishment. It is very important to consider the indigenous species rather than exotic species along water ways so that the biodiversity of local species might not get depleted.
- (viii) Tree legumes are very important source of high protein rich forage for subsistence and commercial livestock production. The forage trees provide animal feed during the dry periods when herbaceous species are not available. Thus, it is necessary to introduce drought tolerant leguminous trees which improve the forage production in dry areas.
- (ix) Research work on agroforestry need to be revitalized through a joint project proposals with regional research and academic institutions with the participation of farmers.

CONCLUSION

New trees are not planted in the parkland agroforestry and the trees available are naturally grown in the field, hence there could be a gradual decrease in the density of trees. In addition, assessment was not done on trees and shrubs planted on soil conservation structures in preventing the amount of soil loss and the extent on productivity of crops. The demonstration activities that were carried out were limited with regards to useful trees and shrubs that have agroforestry potential. Agroforestry is most used as an agricultural system for small scale farmers and is generally accepted for soil improvement and conservation. Agroforestry is recognized as a land use system which is capable of yielding both wood and food, while at the same time conserving and rehabilitating eco-system.

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Review Article

Impact of climate change on fruit and vegetable crops and its mitigation strategies

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ABSTRACT

The biggest challenge to humanity in the twenty-first century is global warming and climate change. Climate change reduces production and efficiency, while also increasing environmental stress on fruit and vegetable crops. Increased temperature, decreased irrigation water supply, flooding, and salinity are thought to be the limiting factors in improving fruit and vegetable productivity. The melting of the Himalayan ice cap would minimise the cooling effect needed for the flowering of many horticultural crops such as apples, saffron, rhododendrons, and orchids, among others. Commercial horticulture plant development especially that grown in open fields will be severely harmed. Integrated approaches such as fertiliser and tillage, residue management, water management, mulching, enhanced pest management, and breeding approaches such as production of genotypes resistant to high temperatures, salinity, modification of current horticultural practices, and increased use of greenhouse technology are to be adopted. Conservation agriculture, renewable energy, forest and water conservation, reforestation, and other methods are the most important.

Key words: Climate, global environment, fruit crops, vegetable crops, yield

Climate is defined as an average weather conditions of a particular place over several decades according to world meteorological organization. It includes information on rainfall, temperature, humidity and sunshine hours. Horticultural crops play a unique role in India's economy by increasing rural people's income. Fruits and vegetables are also high in vitamins, minerals, proteins, carbohydrates, and other nutrients that are essential for human nutrition. These referred to as protective foods have assumed great importance in nutritional security of the people. Thus, cultivation of horticultural crops plays a vital role in the prosperity of a nation and is directly linked with the health and happiness of the people. Climate change has an effect on the growing season and area of conventional crops in a given region. The rising accumulation of greenhouse gases such as CO₂, NO₂, CH₄, and SO₂ is a major limiting factor for climate change. Increasing green house gases are the resultant of direct and indirect activities of human to destroy or uncontrolled utilization of natural resources. IPCC has projected rise in temperature 0.5 to 1.2°C by 2020 and 1.56 to 5.4°C by 2080 (IPCC 2007). If the temperature rises, the ice on the Polar Regions melts, causing the sea water level to rise

more quickly. Extreme events such as drought and flooding become more common as rainfall varies. Climate change is also exacerbated by hailstorms and ice.

Impacts of climate change on crop production

While increased CO₂ in the atmosphere is beneficial to most crops, rising temperatures cause more vapour-transpiration and, as a result, water scarcity may affect agriculture production, posing a threat to food and nutritional security for the world's growing population. Reports of IPCC and a few other global studies indicate chances of 10-40 per cent loss in crop production in India due to increase in temperature by 2080-2100 (Rosenzweig and Parry, 1994).

Coastal flooding and salinity intrusion due to rising sea levels, as well as storm surge amplification from more powerful tropical cyclones in the Bay of Bengal.

Droughts that last longer and affect a larger region have a negative impact on crop production. Due to a combination of population growth and climate change, India's per capita freshwater supply is projected to decline from around 1900

cubic meters today to around 1000 cubic meters by 2025. Heat-related stress and vector-borne diseases have serious health consequences.

Climate change intensify other environmental pressures and impinge on sustainable development.

Impacts of climate change on fruit and vegetable crops

India is a major greenhouse gas emitter as well as one of the world's most at risk countries to climate change. India is already witnessing climate change and its consequences, such as water scarcity, heat waves and drought, extreme storms and floods resulting in negative effects on health and livelihoods.

Environmental stress is a primary cause of crop losses worldwide, reducing average yields for most major crops by more than 50 per cent. Frequently encountered climatic conditions include monsoon delays, dry spells of rain, and untimely rains during water stress periods, high temperatures during flowering and fruit development, and hailstorms. Unprecedented weather patterns reduce

horticultural crop production and quality. The commercial varieties of fruits, vegetables and flowers perform poorly in an unpredictable manner due to aberration of climate.

Reduced temperature has an effect on the chilling requirements of temperate fruit crops. Increased temperature causes dry conditions in plants due to increased evaporation rates, as well as a reduction in crop length due to a drastic rise in all metabolic processes. Higher temperatures affect the fruit set as well as bud drop, abnormal flower development, poor pollen production, dehiscence and viability, ovule abortion and poor viability, reduced carbohydrate availability and other reproductive abnormalities. Occurrence of physiological disorder in horticultural crops is more due to high temperature, *e.g.*, spongy tissue in mango, fruit cracking in litchi and flower and fruit abscission in solanaceous vegetables. Air pollution also reduces the yield of many of horticultural crops like tomato, tuber crops, watermelon, root crops, cashew, coconut, etc. Increasing CO₂ play a role in accumulation of more dry matter due to higher rate of photosynthesis and also reduce

Effect of climatic change on fruit crops

Climate factors	Crop	Affects	Source
Temperature	Apple, Apricot, Cherry Litchi	High temperature increase sunburn and cracking.	Kumar and Kumar (2007) and Mark and Martin (2016)
	Grape	Increase in 2-3°C avg. growing temperature results in 13-19 days acceleration in bloom, veraison, and harvest dates. Global warming is highly apparent with grape harvest starting fully two weeks earlier than ever before.	Tomasi <i>et al.</i> (2011) Anonymous (2016)
	Apple	Rise in 1°C temperature will reduce winter mortality of stink bug by 15 per cent.	Kiritani (2006)
	Mango	2°C higher temperature during the flower induction period in December seems to have detrimental effect leading to poor flowering and ultimately affecting the crop yield. Rate of transpiration and respiration of fruit influenced by high temperature and also lead to spongy tissue.	Peng <i>et al.</i> (2012) Hemanth <i>et al.</i> (2008)
		More CO ₂ and high temperature caused 12 and 35 per cent decrease in fruit yield at low and high nitrogen, respectively.	Parmar <i>et al.</i> (2016)
	Strawberry	Shift in flowering time in the present climate reported that, typically it takes place between the middle of May and the middle of June (weeks 20-24), while in the past it happened a week or two later (weeks 21-26) and in the future bloom events may be expected as early as the end of April (weeks 18-22).	Bethere <i>et al.</i> (2016)
	Custard apple	Minimum fruit retention (2.68%) recorded due to higher temperature. Maximum black spot (35.63%) on the skin of fruit reported due to high wind speed.	Varu <i>et al.</i> (2010)
	Citrus fruit	Due to high temperature, respiration rate increases and fruits mature quickly resulting in decline in acidity so that the soluble solids and acid ratio increases sharply, and the fruit quickly becomes insipid and dry.	Zekri (2011)
Drought	Apple	80 per cent fruit yield reduced due to irrigation water shortage and 20 per cent due to high evaporation rate, decrease in chill unit hours in the apple growing areas of Himachal Pradesh.	Singh <i>et al.</i> (2016)
Pollutants	Fruit crops	Rising atmospheric CO ₂ level and climate change may impact crops indirectly through effects on pests and diseases such as aphids, weevil and larvae.	Staley and Johnson (2008)

vapour-transpiration, thereby increase in water use efficiency. More disease and insect pests appear as a result of the unexpected climate. Because of the higher temperature, which affects the chilling requirement, apple orchards are shifting to higher elevations. Crop development has become more difficult in recent years as a result of climate change. Most of the vegetable crops are highly sensitive to flooding and genetic variation, Flooded crops, especially in tomato plants, accumulate endogenous ethylene that causes damage to the plants (Drew, 1979). High temperature reduces tuber initiation process in potatoes, reduce quality of tomato and pollination in many crops. It causes bolting in crucifers and anthocyanin production may be affected in apples and capsicum. Tip burn and blossom end rot in tomato are also due to temperature. High temperature ($>33.4^{\circ}\text{C}$) and low relative humidity ($<20\%$) during afternoon causes drying of flowers in cashew and leads to reduction in yield. Untimely rains during winter promote vegetative growth instead of flowering in citrus. Excess of rainfall during December and

January affects the productivity of coconut in Tamilnadu region. More heat in summer months directly effects pollen (Samra and Singh, 2003). Hailstorms at the time of small size of fruit causes heavy fruit drop.

Mitigation strategies to reduce the effect of climate change

Since all fruit crops are perennial in nature, orchard establishment requires long-term planning. If climate change has an effect on fruit production, it would be difficult to migrate or develop an orchard because most fruit crops take 3-4 years to bear fruits. As a result, implementing mitigation strategies is critical. Mitigation refers to process in which the emission of greenhouse gases is reduced or sequester and adaptation indicates different potential measures to protect the adverse effects of climate change such as planting dates, planting different varieties, developing new drought and heat resistant varieties, salt tolerant varieties, adoption of intercropping, using sustainable fertilizer, weed management, more use of water harvesting techniques,

Effect of climatic change on vegetable crops

Climate factors	Crop	Affects	Source
Temperature	Potato	Tuber yield may decline 16 per cent by 2050 in West Bengal if any special strategies are not adopted. Temperature above 21°C cause sharp reduction in potato tuber yield and at 30°C complete inhibition of tuber formation occurs.	Luck <i>et al.</i> (2017) Sekhawat (2001)
	Tomato	High temperature influences the photosynthetic functions of plants and causes lack of opening of the stromium, irregularities in the epidermis and endothesium and poor pollen formation. Pre-anthesis temperature stress is associated with development and change in the anther. High temperatures result in poor reproductive performance. High temperature inhibits ripening by inhibiting the accumulation of ripening related m-RNAs, thereby inhibits continuous protein synthesis including ethylene production, lycopene accumulation and cell-wall dissolution. Post pollination exposure to high temperature inhibits fruit setting, indicating sensitivity of fertilization process.	Abdalla and Verkerk (1968) Sato and Thomas (2002) Peet <i>et al.</i> (1997) Lurie <i>et al.</i> (1996)
	Chilli	High temperature affects red colour development in ripened chilli fruits and also causes flower drop, ovule abortion, poor fruit set and fruit drop. Low temperature (10°C) inhibits seed germination completely.	Erickson and Markhart (2002) Arora <i>et al.</i> (1987)
	Onion	Due to high temperature, duration of onion growth shortens and yield is reduced.	Flynn <i>et al.</i> (2002) Daymond <i>et al.</i> (1997)
	Onion and Okra	The prevalence of drought conditions adversely affect the germination of seeds.	Arora <i>et al.</i> (1987)
Drought	Potato	Drought conditions adversely affect sprouting of tubers. A moderate level of water stress could also cause reductions in tuber yield.	Arora <i>et al.</i> (1987) Jefferies and Mackerron (1993)
	Leafy vegetables	Drought conditions reduce water content in leafy vegetables like amaranthus and spinach thereby reducing their quality.	AVRDC (1990)
Salinity	Chilli	Chilli suffers from drought stress, leading to yield loss up to 50-60 per cent.	AVRDC (1990)
	Cabbage	Salinity causes a significant reduction in germination percentage, germination rate and head weight.	Jamil and Rha (2004)
	Chilli	The number of fruits per plant is more affected by salinity than individual fruit weight.	Lopez <i>et al.</i> (2011)
	Cucurbits	High salt concentration causes a reduction in fresh and dry weight with a decrease in relative water content and total chlorophyll content.	Baysal <i>et al.</i> (2004)

supplemental irrigation, drip irrigation, fertigation, better pest and disease management, etc.

Agronomical practices

Planting of wind breaks and shelterbelts on windward sides protect fruit and vegetable crops from heat and cold waves. Encouragement of afforestation is another important measure to control climate change. Use of anti-transparent for example PMA, Kaoline and 2,4-D also play a major role in reducing transpiration loss in water scarce regions. Change in sowing time of vegetable crops also reduce effects of climate change.

Use of tolerant varieties

The use of biotechnology for crop improvement has become increasingly common in recent years. Changes in a species genetic make-up that enable it to live in harsh climatic conditions, such as heat and cold tolerance, without affecting

List of some varieties and advanced lines tolerant to abiotic stresses

Tolerant	Crop	Variety	Advanced Line
High temperature	Capsicum		IIHR selection 3
	French bean		IIHR selection 19-1
	Peas		IIHR-1 and IIHR-8
	Cauliflower		IIHR-316 and IIHR 371-1
Photoinsensitive	Dolichus	Arka Jay, Arka Vijay, Arka Sambram, Arka Amogh, Arka Soumya	IIHR-16-2
	Cowpea	Arka Garima, Arka Suman, Arka Samrudhi	
Drought/rainfed	Tomato	Arka Vikas	RF-4A
	Onion	Arka Kalian	MST-42 and MST-46
	Chilli	Arka Lohit	IIHR selection 132

Source: Hazra and Som (1999) and Rai and Yadav (2005)

List of some fruit crop varieties tolerant to abiotic stresses

Crop	Variety	Tolerantance
Pomegranate	Ruby	Drought tolerant
Annona	Arka Sahan	Drought tolerant
Fig	Deanna and Excel	Drought tolerant
Grape (rootstock)	Dogridge	Salinity tolerant
Mango	Bappakai	Salinity tolerant
Lime	Rangpur lime and Cleopatra mandarin	Salinity tolerant

Source: Bose and Mitra (1996)

other characteristics. Abiotic stress tolerant varieties and dwarf rootstocks are also beneficial for increased development.

Soil and water conservation

The main goal of soil and water management practises in extreme moisture stress situations is to mitigate or prevent either water or wind erosion, while providing the necessary moisture for crop growth or development. In India's humid tropical and subtropical regions, water erosion is the most serious problem. In India, soil erosion has been taking place at an average rate of 16.35 t/ha/year (Dhruvanarayana and Rambabu, 1983), totaling an annual loss of 5334 million tonnes. In order to harvest the rainwater and to make it available to the plants during critical period, an *in situ* soil and water conservation and rainwater harvesting are very important. According to Badhe and Magar (2004), trapezoidal shaped staggered trenches (230/ha) having dimensions of 4.5 m length, 0.60 m top width, 0.30 m bottom width and 0.30 m depth were effective for reducing runoff and conservation of soil and nutrients.

Mulching

It is extremely beneficial to preserve soil moisture for an extended period of time in order to protect the soil from erosion and improve the soil organic carbon status. Soon after planting, mulch the water-stressed area with coconut coir pith, soil mulch, green or dry leaves, and weeds. Black polythene mulch was helpful to conserve soil moisture (Nawale *et al.*, 1985). Formation of terrace and crescent bund and mulching in drought area are helpful to conserve moisture.

Green manuring

Growing of green manure crops like sesbania, glyricidia, sunhemp and cover crops have potential to improve soil moisture retention capacity and nitrogen content.

Site specific nutrient management (SSNM)

It is another approach with potential to mitigate effects of climate change. SSNM practise has a number of advantages, including lower input costs, increased nutrient use efficiency, and reduced green house gases, especially N₂O. Application of fertilizers, especially nitrogen, during periods of water stress exacerbates the problem because higher N improves the leaf canopy, resulting in increased evapo-transpiration. Using nitrification inhibitors and fertilizer placement practices need further consideration for green house gases mitigation. For example, increased rainfall in regions that are already moist could lead to increased

leaching of minerals, especially nitrates. Increase in fertilizer applications would be necessary to restore productivity levels.

Intercropping

Growing field crops (groundnut, black gram and green gram), vegetables (cucumber and bottlegourd), tuber crops and fruit crops (pineapple), spices (turmeric, ginger and pepper) are suitable and profitable intercrops in an orchard. In east coast, crops like groundnut and cowpea are grown profitably under rainfed situations.

Carbon sequestration

Carbon sequestration is the process involved in carbon capture and long-term storage of atmospheric carbon dioxide or other forms of carbon to mitigate or differ global warming (Lal, 2004 and Srinivasarao *et al.*, 2013). This carbon transfer, also known as sequestration, aims to offset emissions from fossil fuel combustion and other carbon-emitting practises, while also improving soil quality and long-term agronomic productivity. The primary source of C in habitats is C fixed in plants by photosynthesis and applied to soil as above and below ground litter (Warembourg and Paul, 1977). Since carbon sequestration is an integral part of reducing greenhouse gas emissions, crop sequestration capacity must be evaluated. Soil organic carbon sequestration has been estimated to be capable of offsetting around 15 per cent of global CO₂ emissions.

CONCLUSION

Of all the tools, climate is the least controllable. Thus, to maintain productivity, changes to current horticultural practices and increased use of green house technology, such as soil, irrigation water, nutrients, crops, and crop management practices, are some of the technologies, that can be used to maintain productivity, ensure food, and mitigate the negative effects of climate change. Development of new cultivars of horticultural crops tolerant to high temperature, resistant to pests and diseases, and producing good yield under stress conditions. Long term and short term variations in climate and weather are most sensitive to agricultural crops. Crop yield is the product of a number of factors, including soil, seed, pests and diseases, fertilizers, and agronomic practices, all of which have a significant impact on crop yield. Climate change would have an economic impact on agriculture, affecting farm production, costs, supply, demand, and trade, among other things. The most effective way is to adopt conservation agriculture, using renewable energy, forest and water conservation, reforestation, etc.

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Studies on efficacy of liquid and carrier based biofertilizers on residual soil and plant NPK uptake and microbial count in tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Soil status was studied through pre-sown and post-harvest soil analysis. The influence of biofertilizer inoculation viz., Azotobacter, phosphate solubilizing bacteria and potassium solubilizing bacteria in different combinations with recommended dose of chemical fertilizer (NPK) and without any biofertilizers on tomato crop was tested during the rabi season (2018-19) at Horticultural Research Station, Venkataramannagudem to explore the possibility of reducing doses of chemical fertilizers for better soil health. The results revealed that the application of 100 per cent RDF along with NFB, PSB and KSB (liquid biofertilizers) recorded significant differences (386.33 N, 71.00 P, 208.14 K) in residual soil and plant NPK uptake (164.41 N, 25.59 P, 199.56 K) respectively. The application of 80 per cent RDF along with liquid biofertilizers recorded maximum colony forming units of NFB, PSB and KSB at 60 and 120 DAT when compared to other treatment combinations.

Key words: Residual soil, inoculation, soil health, uptake, tomato

In order to increase the unit area productivity of agricultural land, the role of different crop nutrients in contributing increased crop yields is vital. Among the crop nutrients, nitrogen as well as phosphorus play an important role in increasing the productivity. Biofertilizers are one of the best modern tools for agriculture. Biofertilizers are applied in agricultural fields as a replacement of our conventional fertilizers like compost, household wastes and green manure. These are not as effective as chemical fertilizers, so farmers often try to use chemical fertilizers in fields for crop development. But obviously the chemical fertilizers are not environment friendly. Biofertilizers contain microorganisms which promote the adequate supply of nutrients to the host plants to ensure their proper development of growth and regulation in their physiology. Living microorganisms are used in the preparation of biofertilizers (Mishra and Singh, 2013).

Liquid biofertilizer formulation is the promising and updated technology which inspite of many advantages over the agrochemicals left a considerable dispute among the farmer community in terms of several reasons, major being

the viability of the organisms. Shelf life is the first and foremost problem of the carrier based biofertilizer which is up to 3 months and it does not retain throughout the crop cycle. LBF on the other hand facilitates the long survival of the organisms by providing the suitable medium which is sufficient for the entire crop cycle (Mahdi *et al.*, 2010). Liquid biofertilizer is increasingly available in the market as one of the alternatives to chemical fertilizer and pesticide. Traditionally liquid biofertilizer produced from fermentation of effective microorganisms (EM) was recommended to be used within three months. Nowadays, the production of ready to use liquid biofertilizer from EM is becoming available in market. The "All India Network Project on Bio-fertilizers", initiated by ICAR with a focus on enhancing productivity and supplementing a part of chemical fertilizer needs of crops through inoculation of Biofertilizers. Though bio fertilizers cannot replace the chemical fertilizers completely, their application with them can improve soil quality, yield and reduce chemical fertilizers demand up to 35 per cent (Philips, 1972). In view of these, the present investigation was undertaken to study the nutritional and microbiological

status of pre-sown and postharvest soils with special reference to pH, electrical conductivity, available soil NPK, azotobacter, PSB and KSB.

MATERIAL AND METHODS

The experiment was conducted during rabi, 2018 at Horticultural Research Station, Venkataramannagudem, West Godavari District, Andhra Pradesh. It was laid out in Factorial RBD with two factors and three replications comprising nine treatment combinations viz., T₁ (100 % RDF + NFB + PSB + KSB carrier based biofertilizers), T₂ (100 % RDF + NFB + PSB + KSB liquid biofertilizers), T₃ (100 % RDF + NFB + PSB + KSB without biofertilizers), T₄ (80 % RDF + NFB + PSB + KSB carrier based biofertilizers), T₅ (80 % RDF + NFB + PSB + KSB liquid biofertilizers), T₆ (80 % RDF + without biofertilizers), T₇ (60 % RDF + NFB + PSB + KSB carrier based biofertilizers), T₈ (60 % RDF + NFB + PSB + KSB liquid biofertilizers), T₉ (60 % RDF + without biofertilizers). The Tomato cv Arka Samrat seedlings were transplanted at a spacing of 120 x 50 cm in a single row. The biofertilizers were applied at one week and one month after transplanting. RDF for tomato is 200:250:250 kg NPK ha⁻¹.

For measuring soil pH the soil sample was collected from each treatment before planting and after harvest and pH of the soil was determined from 1:2.5/5 (soil: water) suspension by glass electrode using pH meter and for soil EC the soil sample is to be collected from each treatment before planting and after harvest and suspension is made in the ratio of 1:2.5/5 (soil: water) and electrical conductivity is measured and expressed in dSm⁻¹ at 25^o C. Available nitrogen was estimated by Kjeldahl's method as described by Jackson (1973). It was determined by Olsen's method, using spectrophotometer as described by Jackson (1967). It was extracted and estimated by neutral normal ammonium acetate method using flame photometer (Jackson, 1967).

Microbial count in soil before planting and after harvest was done by using the following method:

Fresh soil sample is to be collected from each treatment. One gram of soil sample was diluted serially in test tubes containing 9 ml distilled water and the contents were shaken for ten minutes. Using sterilized pipette, 1 ml of the suspension was transferred to 9 ml of sterile distilled water till 10⁻³, 10⁻⁴, 10⁻⁵, 10⁻⁶, 10⁻⁷ were obtained. Aliquots of 1 ml of appropriate dilution were plated in Jensen's medium (39.1 g in 1000 ml distilled water and sterilize by autoclaving at 15 lb pressure and 121^oC for 15 minutes) for *Azotobacter*, Pikovskayas Agar (31.3 g in 1000 ml distilled water and sterilized by autoclaving for 15 minutes) for phosphate solubilizing bacteria and Aleksandrow Agar (29.60 grams in 1000 ml distilled water and sterilized by autoclaving) for

potassium solubilizing bacteria counts respectively. The plates were inoculated at 22.7^oC temperature and counts were made after 3 days for bacteria using digital colony counter.

Nitrogen uptake by plants (kg ha⁻¹)

Total nitrogen in leaves and root samples were determined by Kjeldahl's method as described by Jackson (1973). In this method, a powdered sample of 0.5 g was digested with 10ml of concentrated H₂SO₄ in the presence of digestion mixture (K₂SO₄:CuSO₄.5H₂O proportion of 5:1) and distilled under alkaline medium. The liberated NH₃ was trapped in boric acid containing mixed indicator and titrated against standard 0.01 N H₂SO₄. The nitrogen uptake was expressed in kg ha⁻¹.

Digestion of plant samples with di-acid mixture

A powdered sample of 0.5 g was pre-digested with 10 ml of concentrated HNO₃ and again digested with 5ml of di-acid mixture (HNO₃:HClO₄ in 9:4 ratio). It was kept overnight for digestion and then heated until evolution of white dense fumes leaving colourless clear solution in the conical flasks. It was cooled and the volume was made upto 100 ml with distilled water. The same sample was used for estimation of P and K (Jackson, 1973).

Phosphorus uptake by plants (kg ha⁻¹)

The total phosphorus content in sample was determined by taking a known volume of the di-acid digested samples by adopting the Vanadomolybdate phosphoric yellow colour method as described by Jackson (1973). The intensity of yellow colour was read in spectrometer (Systronics UV-VIS Spectrophotometer 118) at 470 nm. The Phosphorus uptake was expressed in kg ha⁻¹.

Potassium uptake by plants (kg ha⁻¹)

The total potassium content of the di-acid digested samples were estimated by atomizing the digested and diluted sample to a calibrated flame photometer under suitable measuring conditions as described by Jackson (1973). The potassium uptake was expressed in kg ha⁻¹.

The data was analyzed as per the method of variance outlined by Panse and Sukhatme (1985). Statistical significance was tested by F value at 5 percent level of significance. Critical difference at 0.05 level was worked out for the effects which were significant.

RESULTS AND DISCUSSION

Soil pH

Significant higher soil pH (7.35) was recorded in F₁ (100% RDF) followed by F₂ (80% RDF) with 7.24 and 60%

RDF (F_3) recorded the lowest soil pH (7.16) as shown in Table 1. The minimum soil pH (7.15) was recorded in B_2 (NFB + PSB + KSB liquid biofertilizers) followed by B_1 (NFB + PSB + KSB carrier based biofertilizers) with 7.20 when compared to without biofertilizers (7.41). There was no significant difference among the interactions of different levels of chemical fertilizers and biofertilizers on soil pH. The decline in soil pH with the application of biofertilizers might be due to the production of organic acids by the microbial activity (Singh, 2012). The similar results were obtained by Pawar *et al.* (2018) in tomato.

Table 1. Effect of biofertilizers in combination with different levels of NPK on soil pH in tomato hybrid Arka Samrat

Recommended dose of fertilizers	Biofertilizers			
	B_1	B_2	B_3	Mean
F_1	7.27	7.25	7.54	7.35
F_2	7.24	7.11	7.38	7.24
F_3	7.10	7.08	7.31	7.16
Mean	7.20	7.15	7.41	
Factors	F	B	F × B	
SE (m) ±	0.01	0.01	-	
C.D at 5 %	0.21	0.21	NS	

Initial pH in the soil – 7.60

Soil EC

The lowest soil electrical conductivity (0.15 dS m) was recorded with 100 per cent RDF application followed by 80 per cent RDF application with 0.19 dS m and the application of 60 per cent RDF recorded the maximum (0.23 dS m) soil electrical conductivity (Table 2). The minimum soil electrical conductivity (0.16 dS m) was recorded in plants treated with liquid biofertilizers (NFB + PSB + KSB) followed by the application of carrier based biofertilizers (NFB + PSB + KSB) with 0.17 dSm⁻¹ over control (0.22 dS m) and among the interactions of different levels of chemical fertilizers and

Table 2. Effect of biofertilizers in combination with different levels of NPK on soil electrical conductivity (dS m) in tomato hybrid Arka Samrat

Recommended dose of fertilizers	Biofertilizers			
	B_1	B_2	B_3	Mean
F_1	0.14	0.12	0.18	0.15
F_2	0.17	0.16	0.23	0.19
F_3	0.21	0.22	0.25	0.23
Mean	0.17	0.16	0.22	
Factors	F	B	F × B	
SE (m) ±	0.01	0.01	-	
C.D at 5 %	0.02	0.02	NS	

Initial EC in the soil – 0.26 dSm⁻¹

biofertilizers there was no significant difference on soil electrical conductivity. The decline in soil EC with the application of biofertilizers might be due to the production of organic acids by the microbial activity and the results were similar with the finding of Pawar *et al.* (2018) in tomato.

Nitrogen content in soil

The maximum residual soil nitrogen (360.56 kg ha⁻¹) was recorded with the application of 100 per cent RDF followed by the application of 80 per cent RDF with 318.11 kg ha⁻¹ and the lowest residual soil nitrogen (268.89 kg ha⁻¹) was recorded in 60 per cent RDF in tomato (Table 3). Significant higher soil nitrogen (340.67 kg ha⁻¹) was recorded in B_2 (NFB + PSB + KSB liquid biofertilizers) followed by B_1 (NFB + PSB + KSB carrier based biofertilizers) with 328.22 kg ha⁻¹ when compared to (B_3) without biofertilizers (278.67 kg ha⁻¹) in tomato. Among all the combinations the interaction with 100 per cent RDF + NFB + PSB + KSB liquid biofertilizers (F_1B_2) recorded the maximum nitrogen content (386.33 kg ha⁻¹) followed by 100 per cent RDF + NFB + PSB + KSB carrier based biofertilizers (F_1B_1) with 378.00 kg ha⁻¹. These results might be attributed to the synergistic effect of nitrogen fixing bacteria and mineralization of native organic matter, which resulted in higher accumulation of N in the soil. Asoken (2000) and Krishnappa (1993) demonstrated that microbial inoculants like azotobacter helped to fix atmospheric N and translocate minor elements like boron, magnesium, manganese, zinc, sodium, sulphur and calcium to the plant, produced plant growth promoting hormones, vitamins, minerals and control plant pathogenic fungi. The data regarding nitrogen content in soil was in accordance with the findings of Chatterjee and Bandyopadhyay (2014), Singh *et al.* (2015) and Pawar *et al.* (2018) in tomato.

Table 3. Effect of biofertilizers in combination with different levels of NPK on nitrogen content (kg ha⁻¹) in soil

Recommended dose of fertilizers	Biofertilizers			
	B_1	B_2	B_3	Mean
F_1	378.00	386.33	317.33	360.56
F_2	336.67	352.33	265.33	318.11
F_3	270.00	283.33	253.33	268.89
Mean	328.22	340.67	278.67	
Factors	F	B	F × B	
SE (m) ±	0.90	0.90	1.56	
C.D at 5 %	2.73	2.73	4.73	

Initial nitrogen content in the soil – 226.00 kg ha⁻¹

Phosphorous content in soil (kg ha⁻¹)

Significant higher phosphorous content (65.67 kg ha⁻¹) was recorded in F_1 (100% RDF) followed by F_2 (80% RDF) with 54.33 g ha⁻¹ when compared to (45.25 kg ha⁻¹) 60%

RDF. The maximum phosphorous content (58.99 kg ha^{-1}) was recorded with the application of liquid biofertilizers followed by the application of carrier based biofertilizers with 55.00 kg ha^{-1} over control (without biofertilizers) (51.26 kg ha^{-1}). The application of 100 per cent RDF along with NFB + PSB + KSB liquid biofertilizers (F_1B_2) recorded significant higher phosphorous content (71.00 kg ha^{-1}) when compared to other treatment combinations followed by 100 per cent RDF NFB + PSB + KSB carrier based biofertilizers (F_1B_1) with 66.00 kg ha^{-1} whereas minimum soil phosphorous content (42.77 kg ha^{-1}) was recorded in F_3B_3 60 per cent RDF + without biofertilizers was represented in Table 4. According to Lapeyrie *et al.* (1991) the activity of certain microbes (PSB) release organic acids which converts unavailable phosphorus to available form. The mineralization of soil organic matter by microbes also increased available phosphorus content in soil. Similar findings were obtained by Chatterjee and Bandyopadhyay (2014), Singh *et al.* (2015) and Pawar *et al.* (2018) in tomato.

Table 4. Effect of biofertilizers in combination with different levels of NPK on phosphorous content (kg ha^{-1}) in soil

Recommended dose of fertilizers	Biofertilizers			
	B ₁	B ₂	B ₃	Mean
F ₁	66.00	71.00	60.00	65.67
F ₂	54.00	58.00	51.00	54.33
F ₃	45.00	47.97	42.77	45.25
Mean	55.00	58.99	51.26	
Factors	F	B	F × B	
SE (m) ±	0.50	0.50	0.87	
C.D at 5 %	1.52	1.52	2.62	

Initial phosphorous content in the soil – 37.00 kg ha^{-1}

Potassium content in soil

Application of 100 per cent RDF showed significant higher ($200.32 \text{ kg ha}^{-1}$) potassium content followed by the application of 80 per cent RDF with $196.56 \text{ kg ha}^{-1}$ (Table 5). The maximum residual soil potassium content ($199.15 \text{ kg ha}^{-1}$) was recorded with NFB + PSB + KSB (liquid biofertilizers) application followed by NFB + PSB + KSB (carrier based biofertilizers) with $197.40 \text{ kg ha}^{-1}$ when compared to control ($180.45 \text{ kg ha}^{-1}$). The interaction effect of 100 per cent RDF and NFB + PSB + KSB liquid biofertilizers (F_1B_2) recorded the significant higher residual soil potassium content ($208.14 \text{ kg ha}^{-1}$) when compared to other interactions followed by 100 per cent RDF and NFB + PSB + KSB carrier based biofertilizers (F_1B_1) with $205.39 \text{ kg ha}^{-1}$ whereas, the interaction with 60 per cent RDF and without biofertilizers (F_3B_3) recorded the lowest residual soil potassium content ($170.41 \text{ kg ha}^{-1}$). The possible reason might be due to the

synergistic interaction between biofertilizers and organic manures which resulted in enhanced growth promoting substances like gibberellins, auxins and dihydrozeatin and positive influence on more uptake of potassium. Archana, (2008) reported that certain microbes (KSB) releases organic acids which made the conversion of unavailable potassium to available form. Similar findings were obtained by Chatterjee and Bandyopadhyay (2014) and Singh *et al.* (2015) in tomato.

Table 5. Effect of biofertilizers in combination with different levels of NPK on potassium content (kg ha^{-1}) in soil

Recommended dose of fertilizers	Biofertilizers			
	B ₁	B ₂	B ₃	Mean
F ₁	205.39	208.14	187.44	200.32
F ₂	202.54	203.63	183.50	196.56
F ₃	184.26	185.70	170.41	180.12
Mean	197.40	199.15	180.45	
Factors	F	B	F × B	
SE (m) ±	0.05	0.05	0.09	
C.D at 5 %	0.16	0.16	0.27	

Initial potassium content in the soil – $153.00 \text{ kg ha}^{-1}$

Nitrogen uptake by plant

The significant higher nitrogen uptake by the plant ($161.26 \text{ kg ha}^{-1}$) was recorded with the application of 100 per cent RDF followed by 80 per cent RDF application ($158.16 \text{ kg ha}^{-1}$) and the lowest nitrogen uptake by the plant ($152.34 \text{ kg ha}^{-1}$) was recorded with the application of 60 per cent RDF (Table 6). In tomato the maximum nitrogen uptake by the plant ($160.12 \text{ kg ha}^{-1}$) was recorded in NFB + PSB + KSB liquid biofertilizers (B_2) followed by NFB + PSB + KSB carrier based biofertilizers (B_1) with $158.80 \text{ kg ha}^{-1}$ when compared to without biofertilizers ($152.85 \text{ kg ha}^{-1}$). Among all the combinations the combination of 100 per cent RDF + NFB + PSB + KSB liquid biofertilizers (F_1B_2) and 100 per cent RDF + NFB + PSB + KSB carrier based biofertilizers (F_1B_1) recorded significant higher nitrogen uptake by the plant (164.41 and $163.05 \text{ kg ha}^{-1}$) when compared to other treatment combinations followed by 100 per cent RDF + NFB + PSB + KSB carrier based biofertilizers (F_1B_1) ($163.05 \text{ kg ha}^{-1}$) whereas, the minimum ($149.44 \text{ kg ha}^{-1}$) was recorded in F_3B_3 60 per cent RDF + without biofertilizers. The increase in nitrogen uptake by the plant might be due to the application of chemical fertilizers along with Azotobacter, which is capable of fixing nitrogen and making it available to the crop throughout the crop period. The increase in nitrogen uptake might be due to expanded root surface area and increased bacterial count that aided in more acquisition of nitrogen. The similar results were obtained by Chatterjee and Bandyopadhyay (2014) in tomato and Kumar and Devi (2016) in cauliflower.

Table 6. Effect of biofertilizers in combination with different levels of NPK on nitrogen uptake (kg ha^{-1}) by the plant

Recommended dose of fertilizers	Biofertilizers			Mean
	B ₁	B ₂	B ₃	
F ₁	163.05	164.41	156.33	161.26
F ₂	160.13	161.13	152.79	158.16
F ₃	153.20	154.39	149.44	152.34
Mean	158.80	160.12	152.85	
Factors	F	B	F × B	
SE (m) ±	0.27	0.27	0.47	
C.D at 5 %	0.82	0.82	1.42	

Phosphorous uptake by plant

In tomato the maximum phosphorous uptake (23.14 kg ha^{-1}) by the plant was recorded in F₁ (100 % RDF) followed by F₂ (80 % RDF) with 19.86 kg ha^{-1} and the application of 60 per cent RDF (F₃) recorded the lowest phosphorous uptake by the plant (16.67 kg ha^{-1}). Significant higher phosphorous uptake by the plant (22.14 kg ha^{-1}) was recorded in the treatment of NFB in combination with PSB and KSB liquid biofertilizers followed by the application of NFB in combination with PSB and KSB (20.86 kg ha^{-1}) over control *i.e.*, without biofertilizers (16.68 kg ha^{-1}). The interaction effect of 100 per cent RDF along with NFB, PSB and KSB liquid biofertilizers (F₁B₂) and 100 per cent RDF + NFB + PSB + KSB carrier based biofertilizers (F₁B₁) recorded the maximum phosphorous uptake by the plant (25.59 and 24.13 kg ha^{-1}) when compared to other interactions followed by (F₁B₁) 100 per cent RDF along with NFB, PSB and KSB carrier based biofertilizers application (24.13 kg ha^{-1}) and the lowest phosphorous uptake by the plant (14.26 kg ha^{-1}) was recorded in (F₃B₃) 60 per cent RDF and without biofertilizers in tomato (Table 7). The growth of bacteria around the plant rhizosphere dramatically increases the surface area of roots for exploration of nutrients particularly phosphorus. There are evidences to show that exudation of citrate and malate from roots effectively solubilizes unavailable phosphorus sources accompanied by extensive root hair. These

Table 7. Effect of biofertilizers in combination with different levels of NPK on phosphorous uptake (kg ha^{-1}) by the plant

Recommended dose of fertilizers	Biofertilizers			Mean
	B ₁	B ₂	B ₃	
F ₁	24.13	25.59	19.68	23.14
F ₂	20.90	22.58	16.11	19.86
F ₃	17.52	18.24	14.26	16.67
Mean	20.86	22.14	16.68	
Factors	F	B	F × B	
SE (m) ±	0.23	0.23	0.39	
C.D at 5 %	0.68	0.68	1.18	

biofertilizers were able to increase mobility and enhance absorption of P which should have increased the uptake of P. The data regarding phosphorus uptake was in accordance with the data obtained by Chatterjee and Bandyopadhyay (2014) in tomato and Kumar and Devi (2016) in cauliflower.

Potassium uptake by plant

The maximum potassium uptake by the plant ($194.85 \text{ kg ha}^{-1}$) was recorded with 100 per cent RDF application followed by 80 per cent RDF application with $190.47 \text{ kg ha}^{-1}$ while, it was recorded lowest ($187.98 \text{ kg ha}^{-1}$) in 60 per cent RDF application in tomato. The tomato plants treated with NFB, PSB and KSB liquid biofertilizers recorded significant higher potassium uptake by the plant ($194.45 \text{ kg ha}^{-1}$) followed by the application of NFB, PSB and KSB carrier based biofertilizers ($193.54 \text{ kg ha}^{-1}$) when compared to without biofertilizers ($184.32 \text{ kg ha}^{-1}$) as presented in Table 8. Among all the interactions 100 per cent RDF along with NFB, PSB and KSB liquid biofertilizers (F₁B₂) and 100 per cent RDF + NFB + PSB + KSB carrier based biofertilizers (F₁B₁) recorded the maximum potassium uptake by the plant (199.56 and $197.65 \text{ kg ha}^{-1}$) when compared to other treatment combinations followed by (F₁B₁) 100 per cent RDF along with NFB, PSB and KSB carrier based biofertilizers ($197.65 \text{ kg ha}^{-1}$) whereas, the application of 60 per cent RDF and without biofertilizers (F₃B₃) recorded the lowest ($181.80 \text{ kg ha}^{-1}$) potassium uptake. The well-developed root system, significant improvement in soil physical properties, better absorption of nutrient by the plant due to higher microbial and metabolic activity and higher photosynthesis rate might have enhanced the K uptake. Similar results were obtained by Chatterjee and Bandyopadhyay (2014) in tomato and Kumar and Devi (2016) in cauliflower.

Table 8. Effect of biofertilizers in combination with different levels of NPK on potassium uptake (kg ha^{-1}) by the plant

Recommended dose of fertilizers	Biofertilizers			Mean
	B ₁	B ₂	B ₃	
F ₁	197.65	199.56	187.33	194.85
F ₂	192.03	195.58	183.82	190.47
F ₃	190.93	191.22	181.80	187.98
Mean	193.54	194.45	184.32	
Factors	F	B	F × B	
SE (m) ±	0.37	0.37	0.64	
C.D at 5 %	1.12	1.12	1.95	

Fresh and dry weight of plant

Significant higher fresh weight (659.33 g) was recorded with the application of 80 per cent RDF followed by the application of 100 per cent RDF (593.89 g) and the lowest was recorded with the application of 60 per cent RDF (532.56

g). The maximum fresh weight (667.33 g) was recorded with the application of NFB along with PSB and KSB liquid biofertilizers (B₂) followed by (B₁) application of NFB along with PSB and KSB carrier based biofertilizers with 630.00 g when compared to control *i.e.*, without biofertilizers (488.45 g). The interaction effect of 80 per cent RDF along with NFB, PSB and KSB liquid biofertilizers (F₂B₂) recorded significant higher fresh weight of the plant (764.67 g) when compared to other treatment combinations followed by 80 per cent RDF in combination with NFB, PSB and KSB carrier based biofertilizers (F₂B₁) with 725.00 g whereas, the lowest fresh weight of the plant (467.00 g) was recorded in (F₃B₃) 60 per cent RDF + without biofertilizers.

The maximum dry weight (117.22 g) was recorded with the application of 80 per cent RDF which was on par with the application of 100 per cent RDF (116.44 g) and the lowest was recorded in 60 per cent RDF with 101.44 g (Table 9). The maximum dry weight (118.44 g) was recorded with the application of liquid biofertilizers (NFB, PSB and KSB) followed by carrier biofertilizers (NFB, PSB and KSB) with 115.33 g when compared to control (without biofertilizers) with 101.33 g. The interaction with 80 per cent RDF and NFB, PSB and KSB liquid biofertilizers (F₂B₂) recorded the maximum dry weight of the plant (127.33 g) which was on par with (F₂B₁) 80 per cent RDF and carrier based biofertilizers (NFB, PSB and KSB) with 124.33 g when compared to other

treatment combinations while, it was recorded lowest (94.00 g) (F₃B₃) in 60 per cent RDF + without biofertilizers.

In addition to macro and micronutrients, biofertilizers produce enzymes, vitamins and growth regulators like GA₃, which regulates the growth of plant and facilitates more branching, leaf production which in turn helps in increasing the accumulation of dry matter at the end of the harvest and these results were found to be similar with the findings of Anchal *et al.* (2008) in tomato, Singh *et al.* (2014) in chilli and Kamal *et al.* (2018) in tomato.

Microbial count of nitrogen fixing bacteria in soil

At 60 and 120 DAT there was significant difference in microbial count of NFB (*Azotobacter chroococcum*) with the application of chemical fertilizers of different levels in tomato as presented in (Table 10). Significantly higher colony forming units (12.33×10^{-7} CFU g soil⁻¹) were recorded with the application of 80 per cent RDF followed by 100 per cent RDF (11.33×10^{-7} CFU g soil⁻¹) at 60 DAT. Application of 80 per cent RDF recorded maximum CFU (15.33×10^{-7} CFU g soil⁻¹) followed by the application of 100 per cent RDF (13.33×10^{-7} CFU g soil⁻¹). The maximum soil microbial count of NFB (15.67×10^{-7} CFU g soil⁻¹) was recorded with the application of liquid biofertilizers of NFB, PSB and KSB at 60 DAT followed by the application of carrier based biofertilizers of NFB along with PSB and KSB (10.67×10^{-7}

Table 9. Effect of biofertilizers in combination with different levels of NPK on fresh and dry weight of plant (g) at final harvest in tomato hybrid Arka Samrat

Recommended dose of fertilizers	Biofertilizers							
	Fresh weight of the plant				Dry weight of the plant			
	B ₁	B ₂	B ₃	Mean	B ₁	B ₂	B ₃	Mean
F ₁	605.00	666.67	510.00	593.89	117.67	121.67	110.00	116.44
F ₂	725.00	764.67	488.33	659.33	124.33	127.33	100.00	117.22
F ₃	560.00	570.67	467.00	532.56	104.00	106.33	94.00	101.44
Mean	630.00	667.33	488.45		115.33	118.44	101.33	
Factor	F	B	F × B		F	B	F × B	
SE (m) ±	2.16	2.16	3.74		0.61	0.61	1.06	
C.D. at 5 %	6.52	6.52	11.30		1.85	1.85	3.21	

Table 10. Effect of biofertilizers in combination with different levels of NPK on microbial count (*Azotobacter* 1×10^{-7} CFU) in soil

Recommended dose of fertilizers	Biofertilizers							
	60 DAT				After final harvest			
	B ₁	B ₂	B ₃	Mean	B ₁	B ₂	B ₃	Mean
F ₁	11.00	15.00	7.00	11.00	15.00	20.00	5.00	13.33
F ₂	12.00	16.00	6.00	11.33	16.00	22.00	6.00	14.67
F ₃	9.00	13.00	6.00	9.33	13.00	17.00	6.00	12.00
Mean	10.67	14.67	6.33		14.67	19.67	5.67	
Factor	F	B	F × B		F	B	F × B	
SE (m) ±	-	0.67	-		-	0.70	-	
C.D. at 5 %	NS	2.01	NS		NS	2.13	NS	

Initial microbial count (*Azotobacter* 1×10^{-7} CFU)- 6×10^{-7} CFU

CFU g soil⁻¹), whereas, the soil microbial count of NFB at 120 DAT also followed the same trend with maximum (18.67×10^{-7} CFU g soil⁻¹) in NFB + PSB + KSB liquid biofertilizers (B₂) followed by NFB + PSB + KSB carrier based biofertilizers (B₁) with 14.67×10^{-7} CFU g soil⁻¹. Among all the interactions, application of 80 per cent RDF along with liquid biofertilizers recorded maximum CFU (18.00×10^{-7} CFU g soil⁻¹) followed by the application of 100 per cent RDF along with combination of liquid biofertilizers (16.00×10^{-7} CFU g soil⁻¹) at 60 DAT and at 120 DAT the maximum CFU (22.00×10^{-7} CFU g soil⁻¹) were recorded with the application of 80 per cent RDF and liquid biofertilizers of NFB, PSB and KSB followed by the application of 100 per cent RDF along with liquid formulations of NFB, PSB and KSB. Hence, application of biofertilizers resulted in increased secondary nutrients and micronutrients in the soil which might have helped to increase the microbial population (Ammaan and Subramanian, 2017).

Microbial count of phosphorous solubilizing bacteria in soil

In tomato, application of 80 per cent RDF showed significant higher difference in CFU of PSB (*Bacillus megaterium*) (7.67×10^{-7} CFU g soil⁻¹) followed by 100 per cent RDF (6.33×10^{-7} CFU g soil⁻¹) at 60 DAT and at 120 DAT the maximum CFU (9.67×10^{-7} CFU g soil⁻¹) was recorded with the application of 80 per cent RDF followed by the application of 100 per cent RDF (8.33×10^{-7} CFU g soil⁻¹) (Table 11).

The maximum soil microbial count of PSB (9.33×10^{-7} CFU g soil⁻¹) was recorded with the application of NFB along with PSB and KSB liquid biofertilizers followed by the application of NFB along with PSB and KSB carrier based biofertilizers (6.33×10^{-7} CFU g soil⁻¹) over control (3.00×10^{-7} CFU g soil⁻¹) at 60 DAT. At 120 DAT, maximum (14.00×10^{-7} CFU g soil⁻¹) microbial count of PSB was recorded in combination of NFB, PSB and KSB liquid biofertilizers followed by the combination of NFB, PSB and KSB carrier based biofertilizers (9.00×10^{-7} CFU g soil⁻¹) when compared

to without biofertilizers (2.67×10^{-7} CFU g soil⁻¹). At 60 DAT the combination of 80 per cent RDF along with biofertilizers of liquid formulations recorded maximum CFU (12.00×10^{-7} CFU g soil⁻¹) followed by the application of 100 per cent RDF along with combination of liquid biofertilizers (9.00×10^{-7} CFU g soil⁻¹) whereas, the lowest was recorded in 60 per cent RDF and without biofertilizers (2.00×10^{-7} CFU g soil⁻¹) and at 120 DAT the maximum CFU (16.00×10^{-7} CFU g soil⁻¹) were recorded with the application of 80 per cent RDF and NFB, PSB and KSB liquid formulations followed by the application of 100 per cent RDF + NFB, PSB and KSB (14.00×10^{-7} CFU g soil⁻¹) when compared to 60 per cent RDF and without biofertilizers (3.00×10^{-7} CFU g soil⁻¹). Application of biofertilizers resulted in increased secondary nutrients and micronutrients in the soil which might have helped to increase the microbial population (Ammaan and Subramanian, 2017).

Microbial count of potassium solubilizing bacteria in soil

Significant difference in microbial count of KSB (*Bacillus mucilaginosus*) was noticed with the application of various levels of chemical fertilizers (Table-12) at 60 DAT whereas, the maximum (9.67×10^{-7} CFU g soil⁻¹) was recorded with 80 per cent RDF followed by 100 per cent RDF (9.00×10^{-7} CFU g soil⁻¹) and the lowest (7.00×10^{-7} CFU g soil⁻¹) was in 60 per cent RDF and at 120 DAT the significantly higher CFU (12.00×10^{-7} CFU g soil⁻¹) were recorded in 80 per cent RDF followed by the application of 100 per cent RDF (10.33×10^{-7} CFU g soil⁻¹).

A range of 5.00 to 12.67×10^{-7} CFU g⁻¹ soil was observed with the application of biofertilizers. The maximum soil microbial count of KSB (12.67×10^{-7} CFU g soil⁻¹) was recorded in NFB + PSB + KSB liquid biofertilizers (B₂) followed by NFB + PSB + KSB carrier based biofertilizers (B₁) (8.00×10^{-7} CFU g soil⁻¹) over control (5.00×10^{-7} CFU g soil⁻¹) whereas, the soil microbial count of KSB at 120 DAT also followed the similar trend with maximum (16.67×10^{-7} CFU g soil⁻¹) in liquid biofertilizers (NFB, PSB and KSB). Among all the combinations the application of 80 per cent RDF in

Table 11. Effect of biofertilizers in combination with different levels of NPK on microbial count (PSB 1×10^{-7} CFU) in soil

Recommended dose of fertilizers	Biofertilizers							
	At 60 DAT				At 120 DAT			
	B ₁	B ₂	B ₃	Mean	B ₁	B ₂	B ₃	Mean
F ₁	5.00	9.00	4.00	6.00	9.00	14.00	2.00	8.33
F ₂	6.00	10.00	3.00	6.33	10.00	16.00	3.00	9.67
F ₃	4.00	8.00	3.00	5.00	8.00	12.00	3.00	7.67
Mean	5.00	9.00	3.33		9.00	14.00	2.67	
Factor	F	B	F × B		F	B	F × B	
SE (m) ±	-	0.67	-		-	0.67	-	
C.D. at 5 %	NS	2.02	NS		NS	2.01	NS	

Initial microbial count (PSB 1×10^{-7} CFU)- 3×10^{-7} CFU

Table 12. Effect of biofertilizers in combination with different levels of NPK on microbial count (KSB 1×10^{-7} CFU) in soil

Recommended dose of fertilizers	Biofertilizers							
	At 60 DAT				At 120 DAT			
	B ₁	B ₂	B ₃	Mean	B ₁	B ₂	B ₃	Mean
F ₁	7.00	13.00	6.00	8.67	11.00	17.00	3.00	10.33
F ₂	8.00	14.00	5.00	9.00	12.00	19.00	5.00	12.00
F ₃	6.00	10.00	4.00	6.67	10.00	14.00	4.00	9.33
Mean	7.00	12.33	5.00		11.00	16.67	4.00	
Factor	F	B	F × B		F	B	F × B	
SE (m) ±	-	0.44	-		-	0.67	-	
C.D. at 5 %	NS	1.34	NS		NS	2.02	NS	

Initial microbial count (KSB 1×10^{-7} CFU)- 4×10^{-7} CFU

combination with liquid biofertilizers recorded the highest CFU (15.00×10^{-7} CFU g soil⁻¹) followed by the application of 100 per cent RDF and NFB, PSB and KSB liquid biofertilizers (13.00×10^{-7} CFU g soil⁻¹) at 60 DAT while, at 120 DAT 80 per cent RDF + NFB + PSB + KSB liquid formulations recorded maximum CFU (19.00×10^{-7} CFU g soil⁻¹). Application of biofertilizers resulted in increased secondary nutrients and micronutrients in the soil which might have helped to increase the microbial population (Ammaan and Subramanian, 2017).

CONCLUSION

From this experiment it was concluded that the application of 100 per cent RDF along with NFB, PSB and KSB (liquid biofertilizers) recorded significant differences in residual soil NPK as well as plant NPK uptake respectively over other treatment combinations. Whereas, 80 per cent RDF along with liquid biofertilizers recorded maximum microbial count of nitrogen fixing bacteria, phosphate solubilizing bacteria and potassium solubilizing bacteria.

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Efficacy of organic nutrients on growth, yield and economics of rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of the year 2015 at the experimental site of Indian Institute of Technology, Roorkee to evaluate different soil nutrient management sources on growth, yield and economics of rice (*Oryza sativa*). The experiment was laid out in Randomized Block Design (RBD) with 8 treatments and 3 replications comprising different combinations of inorganic fertilizers and organic manures viz., T₁ - control, T₂ - recommended dose of chemical fertilizers (RDCF) @ 120:60:60, T₃ - FYM @ 20 t ha⁻¹, T₄ - vermicompost (VC) @ 5 t ha⁻¹, T₅ - 50% FYM + 50% RDCF, T₆ - 50% VC + 50% RDCF, T₇ - 50% VC + 50% FYM and T₈ - 25%VC + 25% FYM + 50% RDCF. Rice growth and development were observed better in the inorganic treated plot than the organic and INM treated plots. The response of FYM was observed better than vermicompost in respect of rice yield and yield attributes. The results suggested that complete organic incorporation may reduce rice yield, however, integrated nutrient management (INM) may be a better choice to sustain rice yield in the long term.

Keywords: FYM, vermicompost, integrated nutrient management (INM)

Rice, with a cultivated area of approximately 158 million hectares, is the most staple food worldwide. Rice is grown in more than a hundred countries producing more than 700 million tons annually. In Asia only, rice production is 640 million tons annually, which is 90 per cent of global rice demand. The world's largest rice producers are China and India. The highest productivity is 6710 kg ha⁻¹ of China, followed by Vietnam (5573 kg ha⁻¹), Indonesia (5152 kg ha⁻¹), and Bangladesh (4375 kg ha⁻¹). As per Agricultural Policy Research Institute (FAPRI) global rice demand increases, and we need approx. 555 million tons by 2035 to feed our vast population (Abdullah *et al.*, 2006 and Madison *et al.*, 2005). In Asia alone, we need about 465 million tons by 2035 despite a continuing decline in China and India's per capita consumption. Besides increasing population, declining soil ecosystem, global rise in temperature and climate change is additional challenges in rice production.

Rice plays a vital role in the Indian economy. India is the largest producer of rice in the world. According to Statistics, 2015, the total rice cultivation area in India is 44 million ha, which produce approximately 105 million tonnes rice with average productivity of 2390 kg ha⁻¹, which is very low as compared to China and other nearby Asian countries. After the green revolution, the use of genetically improved seeds, chemical fertilizers, and mechanization increased and

made India self-sustainable in rice production between the years 1961-62 to 2014-15. Modern intensive farming methods and high yielding varieties stripped out significant nutrients from the soil and further deteriorated the soil by causing an imbalance of pH, depletion of organic matter, and change in symbiotic association with soil microorganism. Due to the high level of soil depletion, genetic modification in crops and excessive use of chemical fertilizers grown today are much poor in nutrition than the decade before.

In conventional farming methods, dense cropping system, use of chemical fertilizers, cause low absorption of plant nutrient due to unhealthy root system and increase vulnerability to disease and pests due to unbalanced nutrient uptake. On the other hand, organic farming, in which soil nutrient and pest management is done naturally, develops a robust root system that helps absorb more soil nutrients in a balanced manner and produce nutrient-rich plant products. Although organic farming is good in terms of rich nutrient foods but various studies conducted in past refers the low yield in organic farming. The long-standing argument that organic farming would yield just one-third or one-half of conventional farming and may cost much was based on biased assumptions and lack of data. Thus, organic farming's potential is still unknown and should be known for feeding growing population with healthy nutrition. Keeping this in

mind, the current research work on evaluation of yield potential and economics of organic rice cultivation over conventional farming was conducted.

MATERIALS AND METHODS

The field experiments were conducted in the rainy (*khari*) season (June- October) of 2015 at the Experimental Farm of the Indian Institute of Technology, Roorkee, Uttarakhand, located at 29° 50' 7" N latitude, 77° 55' 18" E longitude and 262 m altitudes. The experimental site's soil was sandy loam with pH 7.9, low in organic C (0.49%) and available N (0.2%), and medium in available phosphorus (0.02%) and potassium (0.01%). Mean maximum and minimum temperature were 34.4 and 24.7°C, respectively, and total rainfall during the period was 722 mm. PR-114, a popular cultivar of Haridwar district, was selected for the field experiment. The experiment was laid out in Randomized Block Design (RBD) with 8 treatments and 3 replications comprising different combinations of inorganic fertilizers and organic manures, *viz.* T1 - control, T2 - recommended dose of chemical fertilizers (RDCF) @ 120:60:60, T3- FYM @ 20 t ha⁻¹, T4- vermicompost (VC) @ 5 t ha⁻¹, T5-50% FYM+ 50% RDCF, T6- 50% VC + 50% RDCF, T7- 50% VC + 50% FYM and T8- 25% VC + 25% FYM + 50% RDCF. A common procedure to raising seedbed was followed, and seedlings of 25 days were transplanted in the second week of July in the well puddled experimental plot as per treatment. The spacing was kept at 20 × 15 cm.

The nitrogen was applied in split-dose, whereas phosphorus and potassium were used at the time of paddy transplanting. FYM and VC were applied 15 days before in soil. Paddy crop matured in 110-120 days after transplanting and harvested separately when grain moisture percentage remains 15-20 per cent and becomes golden yellow in colour. Crop growth parameters, *viz.* plant height, the number of leaves and tillers, leaf length and leaf width were recorded at 30 days interval from the transplanting date. LAI was calculated based on the method proposed by Yoshida (1981). Active tillers, number of spikes per tiller and filled grain per spike and per panicle were recorded before harvesting. Crop was harvested from a 1m² area of each experimental plot and allowed to dry for about 10 days in the sun. When samples were dried to about 14 percent moisture, samples were threshed and total biomass and grain weight were measured. One thousand grains were randomly selected from each plot yield and weighted for the test weight. Harvest Index was calculated by dividing grain weight to straw weight for each plot. The cost involved in each step from nursery field preparation to crop harvest was recorded for cost-benefit analysis. The minimum support price (MSP)

declared by the government was used for the net worth of yield calculation for inorganic rice. However, net worth of organic rice was calculated on the basis of the market price.

The data were analyzed using OPSTAT, a web-based open-source application to analyze the variance (ANOVA), and wherever treatment differences were found significant (F Test), critical difference was worked out at 5 per cent probability level ($p > 0.5$) otherwise denoted as "NS" (Gomez and Gomez, 1984).

RESULT AND DISCUSSION

Effect of nutrient sources on rice growth

The data presented in Table 1 shows the effect of different nutrient sources on rice growth. The highest plant height was attained by inorganic treatment (T2) followed by INM (T8) treated plot at par ($p = 0.25$). FYM and VC treated plots produced significantly low (21% and 25.4%, respectively) height plants than inorganic treated plot (T2). The lowest plant height was produced by the control treatment, which was significantly lower than T2 ($p < 0.00$) and T8 ($p = 0.26$). FYM treated plot attained more height than VC treated plot but were at par ($p = 0.99$). The highest number of leaves were produced by inorganic treated plot (T2) followed by T5. All organic treated plots produced lower number of leaves than inorganic treated plots. The treated plot produced a significantly higher ($p < 0.05$) number of leaves than the FYM treated plot. T5 produced slightly higher number of leaves than T6. The highest leaf length was observed in T2 inorganic treated plot followed by T5≈T6 but were at par. FYM treated plot produced higher leaf length than VC treated plot but was at par. The control treatment had significantly lower leaf length (15%, $p = 0.04$) than inorganic treated plot (T2) but was at par with other organic and INM treated plots. Leaf width was observed highest in inorganic treated plot (T2) followed by T7 ($p = 0.98$).

FYM treated plots T3 and T5 produced higher leaf width than VC treated plots. VC treated plot produced lowest leaf width plants. The highest number of tillers were observed in T6, followed by INM treated plot T8. No significant difference in the number of tillers was observed among treatments. Leaf Area Index (LAI), a genuine index of overall plant growth, was observed highest (4.81) in inorganic treated plot (T2) followed by INM treated plot T8 (4.32) (at par $p = 0.16$). Adequate nutrient supply in all growth stages, facilitated more cell elongation and cell division, rendered better plant leaves, and thus maximum LRI in T2. The lowest LAI was observed in VC treated plot T4 (3.38), which was slightly lower than FYM treated plot T3 (3.54) (at par $p = 0.99$). The vegetative growth of plant is generally mediated by

nutrient supply thus, variations in vegetative growth were observed in different treatments. Chemical fertilizer offers readily available plant nutrients compared to organic manure thus, the treatment T2 (RDCF) attain most vegetative growth compared to organic and INM treatments. These experimental results are similar to the reports of Sarker *et al.* (2004) and Hasanuzzaman *et al.* (2010).

tillers and, thus, plant yield. A similar response of FYM and vermicompost in INM manner was also noticed by Nayak *et al.* (2007) and Rakshit *et al.* (2008). The highest number of spikes were observed in inorganic treated plot T2 (14) $\approx$ T5 followed by VC treated plot T4 (13.4). VC treated plot T4 was observed superior that FYM treated plot T3 (12.4), however, T5 produced higher number of spikes than T6. T7 had

Table 1. Rice growth parameter before harvest

Treatments	Plant height (cm)	No. of leaves hill ⁻¹	Leaf length (cm)	Leaf width (mm)	No. of tillers	LAI
T1-Control	85.9	31.6	48.9	14.7	12.0	3.82
T2-NPK 120:60:60	111.5	46.7	57.5	15.7	14.3	4.81
T3-FYM 20 t ha ⁻¹	95.0	35.6	51.3	13.0	12.8	3.54
T4-VC 5 t ha ⁻¹	92.1	42.5	50.1	12.7	12.7	3.38
T5-NPK 50%+ FYM 50%	97.6	43.9	55.0	14.0	14.0	4.10
T6-NPK 50%+ VC 50%	98.2	43.8	55.0	13.7	14.7	4.01
T7-FYM 50%+VC 50%	90.3	36.3	49.6	15.0	14.1	3.96
T8-NPK 50%+FYM 25%+VC 25%	101.3	39.4	54.1	15.0	14.6	4.32
Mean	96.5	40.0	52.7	14.2	13.6	3.99
C.D.	8.58	3.14	5.37	1.52	-	0.40
SE(m)±	2.80	1.03	1.75	0.50	0.71	0.13

Effect of different nutrient sources on rice yield attribute at the time of harvest

The data presented in Table 2 shows the rice yield attributes affected by different nutrient sources at the time of harvest. The highest number of plants/m² remain at harvest stage was observed in inorganic treated plot T2 (66.33) $\approx$ T5 followed by T6 (65.67) but were at par. FYM treated plot (T4) had more remaining plants than VC treated plot (T3) but at par ($p=0.96$) at the time of harvest. A similar trend was also shown between T5 and T6. T7 had more plant remains than VC treated plot (T4) but less than other organic treated plots. Overall, no significant difference was observed in the number of plants among treatments at the time of harvest. The productivity of rice greatly depended on the number of productive tillers rather than the total number of tillers plant produced (Hasanuzzaman *et al.*, 2010). The highest number of active tillers was observed in T6, VC with 50 per cent RDCF (14.5) than any other organic manure and RDCF treatments and followed by INM treated plot (14.3) (at par $p=0.99$). The lowest number of active tillers was observed in FYM treated plot (11.7) followed by control treatment (11.9). VC treated plots T4 and T6 were observed superior to FYM treated plots T3 and T5, respectively. T7 had produced more active tillers than FYM treated T3 and VC treated plot T4 but less than T5 and T6 organic treated with RDCF. The study revealed that organic manures integrated with chemical fertilizers might offer more balanced nutrition than RDCF and organic manure alone, which has caused better affective

produced higher number of spikes than FYM treated plot T3 but less than other organic treated plots. The number of grains per spike was observed maximum in inorganic treated plot T2 (13.2) followed by INM treated T8 (12.7). FYM treated T3 and T5 recorded higher number of grains per spike than VC treated plot T4 and T6 (at par). Higher number of grains per spike were observed in T7 than VC treated plot T4, but less than all other organic incorporated treatments. Overall, no significant difference in number of grains per spike was observed among treatments. Similarly, grains/spike and grains/panicle were also observed more in inorganic treatment T2 (182.7) followed by T5 (at par). VC treated plot T4 (162.3 produced more grain) than FYM treated plot T3 (144.7), however, T6 produced less grains/panicle than T5. T7 had produced higher number of grains/panicle than FYM treated plot T3 but less than other organic treated plots. Only the control plot was significantly different in terms of the number of grains per panicle.

Effect of different nutrient sources on rice yield attribute after harvest

The rice yield and associated attributes influenced by different nutrient sources are presented in Table 3. These yield attributes are directly correlated with plant's yield, and yield is ultimately a reflection of yield parameters. The test weight is generally considered as a genetic character. It does not affect by the external environment easily. Still, in present case, it declined significantly with manure treatments, and

Table 2. Rice yield parameter at the time of harvest

Treatments	Plant/m ²	Active tillers plant ⁻¹	Spike tillers ⁻¹	Grain spike ⁻¹	Grain panicle ⁻¹
T1-Control	59.67	11.9	11.7	11.2	124.7
T2-NPK 120:60:60	66.33	14.1	14.0	13.2	182.7
T3-FYM 20 t ha ⁻¹	65.00	11.7	12.4	11.9	144.7
T4-VC 5 t ha ⁻¹	62.00	12.1	13.4	11.4	162.3
T5-NPK 50% + FYM 50%	66.33	13.7	14.0	12.6	176.3
T6-NPK 50% + VC 50%	65.67	14.5	13.0	12.4	169.0
T7-FYM 50% + VC 50%	64.33	13.3	12.6	11.8	151.3
T8-NPK 50% + FYM 25% + VC 25%	60.67	14.3	12.9	12.7	167.0
Mean	63.8	13.2	13.0	12.1	159.8
C.D.	-	0.905	1.146	-	20.995
SE(m)±	2.06	0.296	0.374	0.409	6.855

control may be due to severe deficiency of plant nutrients, hence plants failed to produce good yield. The minimum grain weight was observed in inorganic treated T2 (23.6 mg) followed by INM T5 (23.1) (at par) FYM treated T3 and VC treated T4 produced almost similar weight, however, T5 had significantly higher ($p=0.46$) grain weight than T6. T7 produced the lowest weight (20.3 mg), which was significantly lower than all treatments except control, T6 and INM treated T8. FYM response was better than vermicompost in terms of grain weight which may be attributed to the high availability of plant nutrients compared to vermicompost. Grain yield, straw yield, and biological yield were significantly affected by different combinations of organic and inorganic sources of plant nutrition. Yang *et al.* (2004) reported that application of chemical fertilizers along with organic manure might increase weight of rice grain. The highest grain yield was recorded in T2 (4296 kg ha⁻¹) which was significantly ($p<0.003$) higher than all other treatments, followed by semi-organic FYM treated T5 (3795 kg ha⁻¹) followed by VC treated T6 (3554 kg ha⁻¹). Fully organic VC treated T4 produced lower yield than FYM treated T3 but was at par. The lowest yield was obtained in T1 control (2059 kg ha⁻¹) which may be attributed to low nutrient availability. A significant low yield of organic manures and control treatments may be due to low nutrient capacity which might not have the requirement of rice plants to produce fertile grain. Similar findings were also reported by Rakshit *et al.* (2008). The maximum straw yield was observed in T2 (8653 kg ha⁻¹), significantly ($p<0.003$) higher than all other treatments except semi organic VC treated T6 (8417 kg ha⁻¹) and FYM treated T5 (8303 kg ha⁻¹). Fully organic FYM treated T3 given better response than VC treated T4 (at par). T1 control produced a significantly ($p<0.003$) lower yield than all other treatments. Similar to straw yield, total biomass was obtained in T2 (13 t ha⁻¹), significantly ($p<0.003$) higher than all treatments except T5 (12 t ha⁻¹) and T6 (11.9 t ha⁻¹). No significant difference in biomass was observed between

FYM treated T3 and VC treated T4. The fully organic VC and FYM treated plot T7 performed better than FYM treated T3 and VC treated T4 alone in terms of grain, straw and total biomass yield. Channabasavanna and Biradar (2001) reported a similar result on rice yield under INM. Rahman *et al.* (2009) reported that the application of chemical fertilizers and organic manures increased the grain yield and biomass of rice. Ram *et al.* (2020) found INM response at par with RDCF on growth, yield and economics of rice. The highest harvest index was recorded in inorganic treatment T2 (49.7) followed by organic treatments T3 (48.9) and T4 (48.1). The lowest harvest index was observed in T6 (42.3) followed by T1 control due to less grain production as compared to biomass in respective treatments. Organic treatment T7 (46.2) response was better than semi-organic treatments T5 (45.7) and T6 (42.3) but lower than organic treatments T3 (48.9) and T4 (48.1). The sustainable yield index was calculated based on the highest yield produced by (T2) and treated as baseline yield to compute SYI for other treatments and presented in Table 3. The highest sustainability was observed in inorganic treatment T2 (0.97) which was at par with semi organic treatments T5 (0.91) and T6 (0.93). Organic treatment FYM T3 (0.70), VC treated T4 (0.67) and combined T7 (0.78) produced almost similar results. The results explain that even 50 per cent of RDCF combined applied with organic manure can give better result and maintain yield sustainability. Baishya *et al.* (2015) reported that incorporation of organic manures with chemical fertilizers can increase yield of rice and may reduce cost of cultivation.

Effect of different nutrient sources on rice yield attribute after harvest

The economic aspect was measured in terms of total cultivation cost, gross and net return, and B:C ratio (Table 4). B:C ratio represents the benefit per unit cost. On this aspect, the best response was obtained in inorganic treatment T2, in which B:C ratio was 2.12 due to low input cost. The response

Table 3. Rice yield attribute after harvest

Treatments	Grain weight (mg)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Total biomass (kg ha ⁻¹)	HI (%)	SYI
T1-Control	20.9	2058.9	4720.0	6778.9	43.6	0.51
T2-NPK 120:60:60	23.6	4296.3	8653.3	12949.7	49.7	0.97
T3-FYM 20 t ha ⁻¹	22.4	3171.2	6480.0	9651.2	48.9	0.70
T4-VC 5 t ha ⁻¹	22.2	2974.3	6186.7	9161.0	48.1	0.67
T5-NPK 50% + FYM 50%	23.1	3795.2	8308.3	12103.5	45.7	0.91
T6-NPK 50% + VC 50%	21.5	3554.2	8416.7	11970.8	42.3	0.93
T7-FYM 50% + VC 50%	20.3	3281.7	7093.3	10375.0	46.2	0.78
T8-NPK 50% + FYM 25% + VC 25%	22.1	3454.1	7200.0	10654.1	48.0	0.79
Mean	22.0	3323.2	7132.3	10455.5	46.6	0.78
C.D.	0.999	388.381	618.918	958.955	3.026	-
SE(m)±	0.326	126.815	202.091	313.12	0.988	-

Table 4. Rice cultivation economics

Treatments	Grain yield	Fixed cost	Variable cost	Total cost	Gross return	Net return	B:C ratio
T1-Control	2059	22540	0	22540	29854	7314	1.32
T2-NPK 120:60:60	4296	22540	6780	29320	62292	32972	2.12
T3-FYM 20 t ha ⁻¹	3171	22540	25000	47540	53911	6371	1.13
T4-VC 5 t ha ⁻¹	2974	22540	25000	47540	50558	3018	1.06
T5-NPK 50% + FYM 50%	3795	22540	15890	38430	60723	22293	1.58
T6-NPK 50% + VC 50%	3554	22540	15890	38430	56867	18437	1.48
T7-FYM 50% + VC 50%	3282	22540	25000	47540	55789	8249	1.17
T8-NPK 50% + FYM 25% + VC 25%	3454	22540	15890	38430	55266	16836	1.44

of FYM was observed better than VC treated plots as T3 (B:C-1.13) performed better than T4 (B:C-1.06) and T5 (B:C-1.58) performed better than T6 (B:C-1.48). The response of integrated plot T8 (B:C-1.44) was observed better than pure organic T3 and T4 but was slight by less than semi-organic plots T5 and T6. The main cause of the low B:C ratio in pure organic treated plots T3 and T4 is higher input cost, thus, their gross return and net return was low. Combined FYM and VC treated plot T7 (B:C-1.17) gave better response than pure organic T3 and T4 but less than the control plot T1 because of high input cost and low net return. The main reason for better B:C ratio in the control plot (B:C-1.32) over organic plots T3, T4 and T7 was high net return due to the lowest input cost where the variable cost was almost zero. A similar result on B:C ratio was also reported by Hasanuzzaman *et al.* (2010). Dissanayake *et al.* (2014) reported that incorporation of readily available organic manures with 50 per cent of chemical fertilizers gave similar response in yield but reduced the 50 per cent cost of chemical fertilizers.

CONCLUSION

The study concludes that organic production of rice is not only costly but also not sustainable due to low yield; however, integrated nutrient management (INM) can be

adopted for yield and environmental sustainability. Further research is required to obtain a breakeven point in INM treatment. Initially, 90 per cent of inorganic fertilizers may be used in INM, which may be reduced gradually by 30 per cent so that yield and environment should remain sustainable in long term.

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Effect of relative water content in rice genotypes after gypsum and bio-compost amended sodic soil

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ABSTRACT

Sodic soils have immense productivity potential, if managed through proper technology interventions. Bio-compost is prepared by composting pressmud (a sugar industry byproduct) received from cane juice filtration and spent wash received from distilleries through microbial aerobic decomposition and gypsum received from waste material of mining can be used to reclaim sodic soils. Field experiments were conducted during the *kharif* season of 2018 and 2019 at the ICAR-Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur). The promising results revealed that the mean of leaf relative water content at pre-flowering stage in the salt-tolerant genotypes ranged between 69.47 to 82.20 per cent during 2018 and 69.52 to 82.24 per cent during 2019. The mean of leaf relative water content at grain filling stage in all the genotypes varied between 77.55 to 85.45 per cent during 2018 and 75.49 to 85.16 per cent during 2019. Soil amendments and genotypes interaction were found significant in both the years at grain filling stage.

Key words: Gypsum, bio-compost, rice genotypes, sodic soils, relative water content

Salt affected soil is a major abiotic stress limiting plant growth and development. In crops known as glycophyte or salt susceptible (Hasegawa *et al.*, 2000 and Qadir *et al.*, 2007), it causes yield losses by depressing the uptake of water, and disturbing mineral and normal metabolism. Salt-affected soils are identified by excessive levels of water-soluble salts, especially sodium chloride (Tanji, 2002). Sodium chloride (NaCl) is a small molecule which when ionized by water, produces sodium (Na⁺) and chloride (Cl⁻) ions. Excess Na⁺ in plant cells directly damages membrane systems and organelles, resulting in growth reduction and abnormal development prior to plant death. The toxic ions cause ionic and osmotic stress at the cellular level in higher plants, especially in susceptible germplasm (Mansour and Salama, 2000 and Chinnusamy, 2005). Salinity reduces plant growth through osmotic effects and reduces the water uptake, thereby causing a reduction in growth.

Gypsum and pyrite are the most effective reclamation agents for sodic soils but are expensive and beyond the reach of poor farmers in rainfed lowland areas. Pressmud, a sugar industry by-product, is readily available in Bihar and Uttar Pradesh and less expensive compared to gypsum. Biocompost is prepared by composting pressmud received from cane juice filtration and spent wash received from distilleries through microbial aerobic decomposition. It

contains nutrients like N, P, K, Zn and big amounts of organic carbon. Calcium replaces Na⁺ from the cation exchange complex, and about 2-3 per cent sulphur converts into sulphuric acid and lowers soil pH. In addition, it contains bioagents like *Trichoderma* and *Azotobacter* which protect plants from several fungal pathogens, enhance growth and development through robust root formation, and enhance soil N availability through atmospheric N₂ fixation.

Recently released rice varieties in India, including CSR-30, CSR-63, CSR-27, Suwasini, Rajendra Bhagwati, Boro-3, Rajendra Neelam, CR-3884-244-8-5-6-1-1, CR-2851-SB-1-2-B-1 and Pusa-44, have shown great promise for cultivation in sodic/saline soils of Bihar. In addition, IRRI made considerable progress in developing a Marker Assisted Backcrossing (MABC) system for the major QTL Saltol, associated with salinity tolerance in rice. Through MABC, this locus is now introgressed into three popular varieties (BR11, BRRI dhan 28, and IR64). Trials conducted under field conditions showed that introgression of this QTL significantly improved the salt tolerance of these varieties, and seeds of these three varieties were now ready for testing in farmer's fields. The availability of these salt-tolerant varieties provide a great opportunity for increasing and stabilizing productivity in salt-affected areas. Particularly when combined with best management practices, specific

for salt-affected areas, salt tolerant rice varieties could become a great opportunity for improving productivity and soil quality of saline and sodic soils. Considering this, experiments were conducted to evaluate the benefits of combining biocompost, gypsum and salt tolerant varieties together to harness the sodic soil potential and increase water uptake by rice crop for metabolic activity.

MATERIALS AND METHODS

The field experiment was carried out during 23 June 2018 to 28 November 2018 and 23 June 2019 to 28 November 2019 (two *khari* seasons) at Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), which lies at 85°40'19.7"E latitude 25°59'06.2"N longitudes with an elevation of 55.00 meter above mean sea level. The experimental site was having hot and humid climate summers and cold winters with average rainfall of 1344 mm of which 70 per cent received during the monsoon period (mid June - mid September, 2018 and 2019).

The experiment was laid out in split plot design with four treatments T₁- control, T₂- gypsum @ 100% G.R., T₃- gypsum @ 50% G.R. + biocompost @ 2.5 t ha⁻¹, T₄- biocompost @ 5.0 t ha⁻¹ in main plots and ten genotypes G₁- Suwasini, G₂- Rajendra Bhagwati, G₃- Boro-3, G₄- Rajendra Neelam, G₅- CSR-30, G₆- CSR-36, G₇- CR-3884-244-8-5-6-1-1, G₈- CR-2851-SB-1-2-B-1, G₉- CSR-27 and G₁₀- Pusa-44 in sub plots and replicated thrice. The main plots and sub plots were permanent plots for both the years (2018 and 2019). Initial representative soil samples were analyzed and accordingly gypsum requirement and organic carbon had been calculated for application in soil. Inorganic and organic amendments were applied only in first year. After incorporation of inorganic and organic amendments in soil, each plot was irrigated little so that gypsum got dissolved and leaching of gypsum from upper layer to lower layer of soil take place. Then, field was left for 8-10 days for gypsum leaching before rice transplanting. Composition of gypsum and biocompost arc shown in Tables 1 and 2, respectively. After 8-10 days, rice was transplanted. Seedlings of different genotypes were raised using a seed rate of 30 kg ha⁻¹ and 25 days old seedlings were transplanted manually. Transplanted rice genotypes were taken with the recommended dose of N: P₂O₅: K₂O @ 120: 60:40 in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP). Fifty per cent of N, and full doses of P₂O₅ and K₂O were applied as basal and the rest fifty per cent of N was applied in two splits at 30 days interval.

The physico-chemical properties of soil were carried out as per methods described by Jackson (1967). The leaf samples were collected at pre-flowering and grain filling

Table 1. Gypsum composition

Properties	Value
Ca (%)	29.2
S (%)	18.6

Table 2. Biocompost composition

Properties	Value
Moisture content (%)	38.00
pH	7.68
EC (dS/m)	12.00
Organic carbon (%)	24.20
Organic matter (%)	42.11
C : N ratio	13.50
Available nitrogen (%)	1.80
Available phosphorous (P ₂ O ₅) (%)	1.72
Available potassium (K ₂ O) (%)	1.49
Calcium (%)	3.20
Magnesium (%)	1.10
Available sulphur (%)	1.30
Available Zn (mg kg ⁻¹)	30.89
Available Cu (mg kg ⁻¹)	14.21
Available Fe (mg kg ⁻¹)	123.53
Available Mn (mg kg ⁻¹)	64.29

stages of rice genotypes and RWC was calculated. For RWC calculation, fully expanded young leaves were selected from different plants. Ten leaves were sampled and weighed immediately to determine the fresh weight (FW) and afterwards immersed in distilled water in petri dishes for 4 hours in darkness and then turgid weight (TW) was determined. The leaves were dried in an oven at 68°C for 24 hours and the dry weight (DW) was taken. Afterwards RWC was calculated by using the methodology used by Whetherley *et al.* (1950).

$$\text{Relative Water Content (RWC) (\%)} = \frac{(\text{FW} - \text{DW})}{(\text{TW} - \text{DW})} \times 100$$

The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split plot design. ANOVA was found significant and accordingly results were presented at 5 per cent level of significance (P=0.05).

RESULTS AND DISCUSSION

Physico-chemical properties of experimental soil

The soil of the experimental site belonged to order *Entisol*, silt loam in texture at surface containing 10.45 per cent sand, 72.06 per cent silt and 17.49 per cent clay. The physico-chemical properties of soil were alkaline pH (9.69)

in reaction, electrical conductivity 2.12 dS/m and organic carbon 2.6 g kg⁻¹. The available N, P, K and S in soil were recorded as 136.8 kg ha⁻¹, 7.83 kg ha⁻¹, 93.2 kg ha⁻¹ and 3.53 kg ha⁻¹, respectively (Table 3). High pH and low EC of the experimental site might be from excessive accumulation of exchangeable Na⁺ in the soil particles. This indicated that the soil of the experimental site was sodic (USDA, 1954). The soil had very low organic carbon content indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Soils in salt-affected landscapes produce less biomass than non-saline soils resulting in less soil organic carbon (Wong *et al.*, 2010).

Table 3. Physico-chemical properties of experimental soil (0-15 cm depth before start of the experiment)

Properties	Value
Physical properties	
Sand (%)	10.45
Silt (%)	72.06
Clay (%)	17.49
Textural class	Silt loam
Bulk density (g cm ⁻³)	1.63
Water holding capacity (%)	38.62
Wet aggregate stability (%)	8.45
Chemical properties	
pH (1:2 soil : water) (0 -15 cm depth)	9.69
EC (dS/m)	2.12
Organic carbon (g kg ⁻¹ soil)	2.60
Available nitrogen (kg ha ⁻¹)	136.80
Available phosphorous (P ₂ O ₅) (kg ha ⁻¹)	7.83
Available potassium (K ₂ O) (kg ha ⁻¹)	93.20
Available sulphur (kg ha ⁻¹)	3.53

Plant water status at pre-flowering stage

It was observed that all genotypes had significantly higher relative water content (RWC) than Pusa-44 (G10) and Rajendra Bhagwati (G2) in both the years (Table 4). The mean of leaf relative water content at pre-flowering stage in all the genotypes ranged from 69.47 to 82.20 per cent during 2018 and 69.52 to 82.24 per cent during 2019. All the soil amendments had significantly higher leaf relative water content at pre-flowering stage as compared to the control plot in the first year, while in the second year it was significantly higher than the control plot (T1) and biocompost @ 5.0 t ha⁻¹ (T4) applications. The combination of gypsum @ 50% GR and biocompost @ 2.5 t ha⁻¹ had higher value than the other two amendments. However, gypsum @ 100% GR application had higher leaf relative water content at pre-flowering stage than the biocompost @ 5.0 t ha⁻¹ application in both the years. Amendment and genotype interaction was non-significant during 2018 and 2019. It might be due to increase in osmotic pressure of cytoplasm which was accompanied by the synthesis of osmolytes, which ultimately enhanced water flow into plant organs. Ca²⁺ helped in removal of excess sodium ion and biocompost increased water holding capacity.

Plant water status at grain filling stage

Leaf relative water content at grain filling stage in most of the genotypes were significantly higher than the varietal check Pusa-44 and Rajendra Bhagwati in the first year, while in the second year all the genotypes were found significantly higher than the varietal check Pusa-44 (Table 5). The mean of leaf relative water content at grain filling stage in all the

Table 4. The influence of organic and inorganic amendments and their combination on leaf relative water content (RWC) (%) at pre-flowering stage in different rice genotypes.

Rice genotypes	Year 2018					Year 2019				
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean
	T ₁	T ₂	T ₃	T ₄		T ₁	T ₂	T ₃	T ₄	
G ₁	66.29	75.69	78.27	74.18	73.61	68.36	76.82	76.45	72.88	73.63
G ₂	66.77	72.59	75.09	72.89	71.84	70.18	73.77	73.20	69.07	71.55
G ₃	68.57	75.68	79.10	73.51	74.22	70.26	78.10	76.64	73.63	74.65
G ₄	70.81	72.80	75.84	73.45	73.23	72.50	74.22	73.19	71.14	72.76
G ₅	70.37	75.11	78.53	73.84	74.46	73.43	76.38	78.19	72.50	75.12
G ₆	74.35	77.68	81.64	77.31	77.75	73.00	81.60	78.10	75.69	77.10
G ₇	71.81	76.94	80.33	74.69	75.94	73.84	78.65	77.77	75.62	76.47
G ₈	70.78	75.21	80.23	75.33	75.39	69.47	76.73	76.45	72.32	73.75
G ₉	76.11	86.61	84.85	81.25	82.20	74.35	84.69	87.01	82.93	82.24
G ₁₀	64.86	69.83	72.73	70.46	69.47	67.40	72.54	71.30	66.83	69.52
Mean	70.07	75.81	78.66	74.69		71.28	77.35	76.83	73.26	
	T	G	T×G	G×T		T	G	T×G	G×T	
CD (P = 0.05)	3.308	2.938	NS	NS		3.269	3.525	NS	NS	
SE(m) ±	0.938	1.040	2.965	2.184		0.927	1.248	2.931	2.542	

Table 5. The influence of organic and inorganic amendments and their combination on leaf relative water content (RWC) (%) at grain filling stage in different rice genotypes.

Rice genotypes	Year 2018					Year 2019				
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean
	T ₁	T ₂	T ₃	T ₄		T ₁	T ₂	T ₃	T ₄	
G ₁	78.86	82.90	84.50	80.66	81.73	78.90	84.37	87.29	81.77	83.08
G ₂	78.59	78.80	81.09	80.51	79.75	78.59	80.76	79.21	78.63	79.30
G ₃	80.74	81.39	86.43	82.43	82.75	80.80	83.51	86.50	81.27	83.02
G ₄	70.44	83.92	85.14	83.08	80.65	71.78	83.90	85.34	81.99	80.75
G ₅	81.22	83.92	84.78	83.13	83.26	81.93	84.37	85.70	83.61	83.90
G ₆	80.56	84.76	85.83	84.19	83.83	83.64	84.42	87.29	83.10	84.61
G ₇	82.04	84.70	85.37	84.94	84.26	82.29	85.20	84.95	84.02	84.12
G ₈	82.35	83.34	84.81	83.91	83.60	80.70	84.60	84.91	83.11	83.33
G ₉	83.87	86.53	85.86	85.52	85.45	83.83	85.57	86.55	84.70	85.16
G ₁₀	68.68	79.21	85.96	76.36	77.55	65.50	83.02	81.41	72.04	75.49
Mean	78.74	82.95	84.98	82.47		78.80	83.97	84.92	81.42	
	T	G	T×G	G×T		T	G	T×G	G×T	
CD (P = 0.05)	1.781	2.322	4.753	4.740		3.038	2.924	6.082	6.301	
SE(m) ±	0.505	0.822	1.596	1.639		0.861	1.035	2.723	2.144	

genotypes varied between 77.55 to 85.45 per cent during 2018 and 75.49 to 85.16 per cent during 2019. All the soil amendments had significantly higher leaf relative water content at grain filling stage as compared to the control plot in the first year, while in the second year it was significantly higher than the control plot and biocompost @ 5.0 t ha⁻¹ applications. The combination of gypsum @ 50% GR and biocompost @ 2.5 t ha⁻¹ (T3) had higher value than the other two amendments. However, gypsum @ 100% GR application had higher leaf relative water content at grain filling stage than the biocompost @ 5.0 t ha⁻¹ application.

Without application of any amendment all the varieties were found superior to Pusa-44 and Rajendra Neelam in both the years. The response of gypsum, biocompost and their combination varied between 78.80 to 86.53, 76.36 to 85.52 and 81.09 to 86.43 per cent, respectively in the first year, while in the second year it varied from 80.76 to 85.57, 72.04 to 84.70 and 79.21 to 87.29 per cent, respectively.

High salt concentration in root zone, which causes osmotic stress, restricted water absorption by the plants and caused cellular dehydration, seemed to be primarily responsible for decrease in RWC. Sodicty induced membrane damage and hence, reduction in RWC in leaves. Salt stressed plants exhibit damage of lipid membranes which often results in increased cell permeability and electrolyte leakage from cells. Almost similar results were reported by Singh *et al.* (2015), Kumar *et al.* (2016) and Taffouo *et al.* (2017).

CONCLUSION

Relative water content (RWC) at pre-flowering and grain filling stages of rice were significantly higher in genotypes CSR-27 followed by CSR-36 and CR-3884-244-8-5-6-1-1. The combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha⁻¹ application showed significantly higher RWC followed by gypsum application @ 100% G.R. adove, in sodic soil.

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Effect of foliar nutrition supplement on productivity and profitability of medium duration pigeonpea

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ABSTRACT

A field experiment was conducted under AICRP on Pigeonpea during three consecutive years of *kharif* 2016-17, 2017-18 and 2018-19 at the Centre for Pulses Research, OUAT, Berhampur, Odisha under rainfed conditions to study the effect of foliar nutrient supplement on productivity and profitability of medium duration pigeonpea. Pigeonpea variety TTB-7 was sown in Randomized Block Design with three replications. Recommended dose of fertilizers (RDF) @ 20:40:20 N, P₂O₅, K₂O kg ha⁻¹ was applied to each treatment as basal at the time of sowing. Altogether 12 treatments *viz.*, T1: absolute control, T2: water spray at 50% flowering (control), T3: 2% urea spray at 50% flowering, T4: 0.5% borax (10%) spray at 50% flowering, T5: 0.5% ZnSO₄ spray at 50% flowering, T6: 1% urea + 0.25% ZnSO₄ + 0.25 borax (10%) spray at 50% flowering, T7: multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation, T8: 2% DAP spray at flower bud initiation, T9: 2% MOP spray at flower bud initiation, T10: NPK (19:19:19) @ 1% spray at 50% flowering, T11: NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation, and T12: NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation were tested. Maximum grain yield (1683 kg ha⁻¹) was recorded with application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation (T11) followed by T12 [NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation] and T4 [0.5% borax (10%) spray at 50% flowering]. This treatment had also recorded high harvest index (33%), maximum net return (Rs. 58097 ha⁻¹) with high B:C ratio (2.78). It was concluded that foliar supplementation of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% at flower bud initiation stage in medium duration pigeonpea could be recommended under rainfed *kharif* upland situation in Odisha for obtaining maximum grain yield and net return.

Key words: Foliar nutrition, critical stage, harvest index, net return, B:C ratio

The pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the important protein rich legumes of the semi-arid tropics grown predominantly under rainfed conditions. It is one of the important pulse crops of India and 91 per cent of the world's pigeonpea is produced in the country. India grows large number of varieties of pulses in the world accounting for about 32 per cent of the area and 23 per cent of the world production (Chattopadhyay, 2016). Economically pigeonpea is the second most important pulse crop after chickpea in India accounting for about 20 per cent of total pulse production. In India, pigeonpea was cultivated on 4.78mha area with 4.25 mt of production at an average productivity of 8.89 q ha⁻¹ (Anonymous, 2018). In Odisha, pigeonpea is cultivated on 137.9 thousand ha area with 123.7 thousand tones of production at an average productivity status of 8.97 q ha⁻¹ (Anonymous, 2018). As a long duration rainfed *kharif* crop, it very often affected with the vagaries of monsoon. Flower bud initiation to pod development period is the most critical stage for nutrient and moisture. Climate change like uneven rainfall distribution and dry spells during this critical period heavily reduce the yield of the crop due to

terminal drought resulting flower drop and improper grain filling. Foliar application of nutrients could maintain crop health and enhance yield in pigeonpea. Studies on the mineral nutrition of pigeonpea especially micronutrients like boron is limited (Tayo and Togun, 1984, Ratnakalyani *et al.*, 1993). Plant nutrition is a key input to increase the productivity. Among different agronomic practices, foliar spray of micronutrients is most important factor in determining the yield (Malla Reddy *et al.*, 2010). In almost all the pulses, flower drop determines the yield and yield attributing characters. Retention of flowers produced by the plant helps to get more yield. Soil application of micronutrients and foliar spray of macronutrients are most important factors in determining the yield (Malla Reddy *et al.*, 2010). Retention of flowers is possible through foliar application of growth regulators as well as macronutrients during flower initiation and pod development stages along with soil application of micronutrients (Chaurasia *et al.*, 2005). Among all nutrients, nitrogen, phosphorus and potash are most important nutrients which contribute to proper growth and yield of crop and also has direct effect on

metabolism of plant. Foliar applied nutrients usually penetrate the leaf cuticle or stomata easily and enter the cells facilitating easy entry of nutrients. Foliar application is credited with remarkably rapid absorption and nearly complete utilization of applied nutrients, reduce leaching losses and fixation of nutrients and helps in regulating the uptake of nutrient by plants (Manonmani and Srimathi, 2009). Nutrient limitations to legume production results from deficiencies of not only major nutrients but also micronutrients such as molybdenum, zinc, boron and iron (Bhuiyan *et al.*, 1999). Inadequate nodulation of pigeonpea can be associated with low plant available molybdenum. Increase in flower numbers, pod set improvement and reduction in days to flowering are influenced by molybdenum (Prasad *et al.*, 1998). Application of recommended doses of fertilizers (RDF), the macro and micronutrients to pigeonpea is essential for enhancing yield and productivity. Keeping in view of these facts, an experiment was taken up to study the effect of foliar nutrient supplements on yield and economics of medium duration pigeonpea.

MATERIALS AND METHODS

The field experiment was conducted under AICRP on Pigeonpea during three consecutive years of *kharif* 2016-17, 2017-18 and 2018-19 at the Centre for Pulses Research, OUAT, Berhampur which comes under East and South Eastern Coastal Plain zone of Odisha with the objectives to study the effect of foliar nutrition supplement in rainfed medium duration pigeonpea for maintaining plant health during reproductive phase and yield enhancement. Pigeonpea variety TTB-7 was sown in Randomized Block Design with three replications. Altogether 12 treatments *viz.*, T1: No foliar nutrition supplement (absolute control), T2: Water spray at 50% flowering (control), T3: 2% urea spray at 50% flowering, T4: 0.5% borax (10%) spray at 50% flowering, T5: 0.5% ZnSO₄ spray at 50% flowering, T6: 1% urea + 0.25% ZnSO₄ + 0.25% borax (10%) spray at 50% flowering, T7: multi micronutrient spray @ 2 ml/L at flower bud initiation, T8: 2% DAP spray at flower bud initiation, T9: 2% MOP spray at flower bud initiation, T10: NPK (19:19:19) @ 1% spray at 50% flowering, T11: NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation and T12: NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation were tested. Recommended dose of fertilizers (RDF) @ 20:40:20 N, P₂O₅, K₂O kg ha⁻¹ was applied to each treatment as basal at the time of sowing. Crop was sown at 90 × 30 cm spacing during each year and recommended package of practice was followed. The soil was sandy loam with pH 6.2, low organic carbon (0.43%), low available N (220 kg ha⁻¹), medium available phosphorus (21.67 kg ha⁻¹) and high available potassium (292 kg ha⁻¹). Initial soil test report showed EC –

0.007 dS m⁻¹ (normal), available S 3.4 kg ha⁻¹ (low), Ca 2.4 meq 100g⁻¹ (low), Mg 1.9 meq 100g⁻¹ (average), Cu 2.7 mg kg⁻¹ (average), Fe 262.2 mg kg⁻¹ (average), Zn 0.36 mg kg⁻¹ (low) and B 0.32 ppm (low).

Observations on plant height, yield attributes, grain yield, *bhusa* yield, stick yield were taken at harvest and analysed as per statistical procedure described by Panse and Sukhatme (1985). Economics of the treatments were calculated and compared for economic feasibility.

RESULTS AND DISCUSSION

The pooled data for three years (2016-19) presented in Table 1 revealed that foliar application of nutrients at reproductive stage had no significant influence on enhancing plant height of pigeonpea at maturity. However, plant height increased due to nutrient sprayings and maximum height (206.3cm) was recorded with spraying of urea (2%) at 50% flowering stage which was 5 per cent more than that recorded with absolute control plots (197.2 cm). Foliar application of nutrients at reproductive stage enhanced number of pods per plant significantly, but number of branches per plant and number of seeds per pod did not differ much. Nevertheless, the maximum branches (10.4) and maximum seeds per pod (3.61) were associated with application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% (T11) spray at flower bud initiation. Conspicuous variation on number of pods per plant was recorded among various treatments. The maximum pod per plant (210.9) was recorded with application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% (T11) spray at flower bud initiation which was 41 per cent higher than that recorded with the absolute control plot (149.3 pod plant⁻¹), closely followed by spraying NPK (19:19:19) @ 1% + multi micronutrient spray @ 2ml L⁻¹ (T12) at flower bud initiation (204.8 pod plant⁻¹). The study also revealed that spraying of only water at 50% flowering stage enhanced number of pods per plant to an extent of 4.2 per cent. Spraying boron at 50% flowering stage (T4) had significant effect on increasing pod numbers per plant (204.0), which might be due to retaining more flowers by reducing flower drop.

The data presented in Table 1 revealed that spraying of nutrients at flowering stage in addition to RDF enhanced grain yield (average 1460.3 kg ha⁻¹), *bhusa* yield (855.6 kg ha⁻¹), stick yield (2319.9 kg ha⁻¹) and total dry matter production (4635.8 kg ha⁻¹) of pigeonpea significantly over absolute control (RDF) to a tune of 29, 22, 16 and 21 per cent, respectively, and also over control (RDF + water spray at 50% flowering) by 26, 16, 15 and 19 per cent, respectively. Application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation stage (T11) registered maximum grain yield (1682.6 kg ha⁻¹), *bhusa* yield (946.3 kg

Table 1. Effect of foliar nutrient management on growth, yield attributes and yield of pigeonpea

Treatments	Pl.ht. (cm)	No of br plant ⁻¹	No of pod plant ⁻¹	No of seed pod ⁻¹	Grain yield (kg ha ⁻¹)	Blusa yield (kg ha ⁻¹)	Stick yield (kg ha ⁻¹)	TDMP (kg ha ⁻¹)	HI (%)
T1: Control (No foliar nutrition)	197.2	9.33	149.3	3.22	1129.0	702.7	1996.6	3828.3	29.5
T2: Water spray at 50% flowering	198.4	9.53	155.7	3.25	1159.9	735.8	2014.7	3910.5	29.7
T3: 2% urea spray at 50% flowering	206.3	9.79	170.1	3.26	1364.7	878.6	2459.4	4702.7	29.0
T4: 0.5% borax spray at 50% flowering	197.1	9.76	204.0	3.51	1638.9	926.9	2336.2	4902.1	33.4
T5: 0.5% ZnSO ₄ spray at 50% flowering	198.7	9.43	154.6	3.33	1190.4	732.3	2000.3	3923.0	30.3
T6: 1% urea +0.25% ZnSO ₄ +0.25 borax (10%) spray at 50% flowering	201.9	9.70	173.9	3.48	1335.0	801.0	2342.8	4478.8	29.8
T7: Multi micronutrient spray @ 2ml L ⁻¹ at flower bud initiation	201.0	9.58	182.4	3.40	1534.4	895.3	2377.8	4807.4	31.9
T8: 2% DAP spray at flower bud initiation	195.7	9.78	174.6	3.39	1373.1	794.4	2228.6	4396.0	31.2
T9: 2% MOP spray at flower bud initiation	197.2	9.74	168.1	3.38	1304.6	780.9	2225.4	4310.9	30.3
T10: NPK (19:19:19) 1% spray at 50% flowering	201.6	9.67	185.0	3.52	1523.0	868.5	2325.2	4716.7	32.3
T11: NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation	204.5	10.04	210.9	3.61	1682.6	946.3	2468.0	5096.9	33.0
T12: NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L ⁻¹ spray at flower bud initiation	201.4	9.92	204.8	3.58	1656.4	931.4	2385.4	4973.2	33.0
S.E.m(±)	NS	NS	9.1	NS	87.15	50.8	146.7	236.3	
S.E.d.			12.9		123.25	71.9	207.4	334.2	
CD(5%)			26.9		257.34	150.1	437.0	697.8	
CV(%)			11.3		13.14	13.01	12.1	13.4	

ha⁻¹), stick yield (2468.0 kg ha⁻¹) and total dry matter production (5096.9 kg ha⁻¹) of pigeonpea. This treatment produced 49 per cent more yield than that obtained from absolute control plot (1129 kg ha⁻¹) and 45 per cent more than that obtained from control plot with only water spray (1159.9 kg ha⁻¹). The next best treatment was NPK (19:19:19) @ 1% + multi micronutrient spray @ 2ml L⁻¹ at flower bud initiation (T12) with grain yield of 1656.4 kg ha⁻¹ closely followed by 0.5% borax (10%) spray at 50% flowering (1638.9 kg ha⁻¹). Similar results with application of multi-micronutrients were recorded by Priyanka *et al.* (2019). The increase in grain yield of pigeonpea might be due to mitigation of nutrient and moisture deficiency of pigeonpea at reproductive stage, resulting in reduction of flower drop and enhancement of pod numbers per plant. As the soil was deficient in boron content (0.32 ppm) the effect of treatments with boron applications might have showed conspicuous result. The gap in yield between control plot and treated plots indicated the quantum of abiotic stress the crop suffered due to terminal drought and nutrient deficiency at reproductive phase. Dixit and Elamathi (2007), Mondal *et al.* (2011) and Ganapathy *et al.* (2008) also reported similar results.

Harvest index (HI) for each treatment combination was calculated on proportion of grain yield to biological yield, *i.e.*, total dry matter production of above ground parts on percentage basis to find out the dry matter partitioning to grain as influenced by foliar nutrient supplement in medium

duration pigeonpea. The maximum harvest index (33%) was recorded with application of 0.5% borax (10%) spray at 50% flowering (T4), NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation (T11) and NPK (19:19:19) @ 1% + multi micronutrient spray @ 2ml L⁻¹ at flower bud initiation (T12) which might be due to higher grain yield obtained from these treatments. At the time of reproductive stage where the nutrient demand was at peak due to indeterminate growth habit of the crop, foliar application of nutrients reduced the flower drop and ultimately enhanced the pod setting and resulted in higher seed yield. As pod number is considered to be the major yield determinant in pulses, foliar feeding of N through urea, P through 2% DAP and other micronutrients was able to increase the pod number in this experiment. It was also reported by Barik and Rout (1990) that foliar application of nutrients at flowering and pod development stages might have been easily absorbed and better translocated in the plant and maintained constant requirement of nutrients at the reproductive stage of the crop. The increase in straw yield was directly related, mainly to increase in the vegetative growth of the plant. Higher supply of nutrients at 50% flowering of crop growth might have caused efficient translocation of photosynthates from source to sink. Flower drop decreased due to foliar spray of boron, multi-micronutrient and other nutrients. Pod number plays an important role in yield determination. It might be due to continuous supply of nutrients as basal and as nutrient spray which in turn increased the photosynthate partitioning and

Table 2. Profitability of pigeonpea as influenced by foliar nutrient spray at reproductive stage

Treatments	Yield (kg ha ⁻¹)	% yield increase over control	Gross return (Rs.)	Cost of production (Rs.)	Net return (Rs.)	% NR increase over control	B:C ratio	Exp. over control (Rs.)	Profit over control (Rs.)	Profit (Rs.) per extra rupee invested
T1: Control (No foliar nutrition)	1129	0	60876	30000	30876	0	2.03	0	0	0
T2: Water spray at 50% flowering	1160	2.75	62547	30600	31947	3.47	2.04	600	1671	2.79
T3: 2% urea spray at 50% flowering	1365	20.88	73585	30700	42885	38.89	2.40	700	12709	18.16
T4: 0.5% borax spray at 50% flowering	1639	45.16	88369	31725	56644	83.46	2.79	1725	27493	15.94
T5: 0.5% ZnSO ₄ spray at 50% flowering	1190	5.44	64186	32250	31936	3.43	1.99	2250	3310	1.47
T6: 1% urea +0.25% ZnSO ₄ + 0.25 borax (10%) spray at 50% flowering	1335	18.25	71983	32050	39933	29.33	2.25	2050	11107	5.42
T7: Multi micronutrient spray @ 2 ml L ⁻¹ at flower bud initiation	1534	35.91	82735	31500	51235	65.94	2.63	1500	21859	14.57
T8: 2% DAP spray at flower bud initiation	1373	21.61	74032	31050	42982	39.21	2.38	1050	13156	12.53
T9: 2% MOP spray at flower bud initiation	1305	15.59	70366	30900	39466	27.82	2.28	900	9490	10.54
T10: NPK (19:19:19) 1% spray at 50% flowering	1523	34.90	82120	31750	50370	63.14	2.59	1750	21244	12.14
T11: NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.1% spray at flower bud initiation	1683	49.07	90747	32650	58097	88.16	2.78	2650	29871	11.27
T12: NPK (19:19:19) @ 1% + multimicronutrient @ 2 ml L ⁻¹ spray at flower bud initiation	1656	46.68	89292	32400	56892	84.26	2.76	2400	28416	11.84

Cost of pigeonpea grain was Rs. 50.50 (16-17), 54.50 (17-18) & 56.75 (18-19) and average 53.92 kg⁻¹ as per MSP

dry matter accumulation. Similar finding was reported by Mondal *et al.*, (2012). The better performance of RDF+NPK (19:19:19) @ 1%+ Solubor (B 20%) @ 0.2% (T11) or multi-micronutrient spray @ 2 ml L⁻¹ (T9) might be attributed to better vegetative growth and pod retention over RDF (absolute control). These findings were corroborated with Muthal (2016).

Economics of all the treatments were calculated and placed in Table 2. The highest net return (Rs. 58,097/-) was registered with the application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation (T11) which was 88 per cent higher than that of control (Rs. 30,876/-). The next best treatment was NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation (T12) with net return (Rs. 56,892/-) which was closely followed by 0.5% borax (10%) spray at 50% flowering (T4) (Table 2). However, maximum B:C ratio (2.79) was obtained in the application of 0.5% borax (10%) spray at 50% flowering (T4) which might be due to higher productivity with lesser investment. Maximum expenditure over control (Rs. 2650 ha⁻¹) and maximum profit over control (Rs. 29871 ha⁻¹) were also associated with application of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% spray at flower bud initiation (T11). Nevertheless, profit per extra rupee invested (Rs. 18.16) was obtained from spraying of 2% urea at 50% flowering.

CONCLUSION

It was concluded that in medium duration pigeonpea foliar supplementation of NPK (19:19:19) @ 1% + Solubor (B20%) @ 0.2% at flower bud initiation stage might be recommended under rainfed *kharif* upland situation in Odisha, with low soil boron content for obtaining maximum grain yield and net return. The next best treatment was application of NPK (19:19:19) @ 1% + multi micronutrient spray @ 2 ml L⁻¹ at flower bud initiation stage.

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Novel resource conservation technologies for increasing the production and productivity of rice-wheat cropping system in Indo-Gangetic plains of India

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ABSTRACT

The rice-wheat cropping system (RWCS) is the predominant cropping system, covering about 13.5 million hectares area in South Asia, out of which 10.3 million hectares is in the Indo-Gangetic Plains (IGP) of India. Rice and wheat crops are the main staple food for the people of the country and considered as the backbone for food grain security. Contributing 70 per cent to total cereal production in India due to its wider adoption, it has depleted soil organic carbon status, ground water, decreased soil fertility and has overall reduced factor productivity. Efforts to sustain higher productivity with focused approach on reversing the trend in natural resource degradation by adopting resource conservation technologies (RCTs) like direct seeded rice (DSR), system of rice intensification (SRI), aerobic rice, brown manuring, crop residue incorporation, furrow irrigated raised bed system (FIRBS), zero tillage (ZT) and leaf colour chart (LCC) that not only improved the production and productivity but also maintained the soil health. The RCTs helped in soil and water conservation, weed control and nutrient supplementation with brown manuring, reduction in seepage, deep drainage losses and water saving (10-30%) with AWD, reduced global warming potential of rice-wheat system by 41 per cent as compared to conventional system under DSR-ZT wheat. Apart from this, new emerging technologies like system of wheat intensification (SWI), LCC application for nitrogen management, bed transplanting in rice followed by laser levelling in wheat with zero tillage wheat with incorporation of rice residues over conventional transplanting also showed promising results. Thus, adoption of RCTs led to sustainable improvement in RWCS by improving soil health, nutrient and water use efficiency with higher sustained yields along with reduction in cost of cultivation and also helped to minimize environmental pollution.

Key words: Resource conservation technologies, zero tillage, productivity, SWI, nutrient management, RWCS

The rice-wheat cropping system is one of the major agricultural production systems in Asia, occupying about 18 million ha, of which 13.5 million ha are in the Indo-Gangetic plains (IGP) of Bangladesh, India, Nepal and Pakistan (Ladha *et al.*, 2003). The intensively cultivated irrigated rice-wheat system is fundamental to employment, income, and livelihoods for hundreds of millions of rural and urban poor of South Asia. In South Asia, rice-wheat systems produce more than 30 per cent of the rice and 42 per cent of the wheat consumed (RWC-CIMMYT, 2003) and cover about 14 million ha of cultivated land with most of the area located in India (Table 1).

In the last few decades, annual increases in growth rates for food grain production (wheat 3.0%, rice 2.3%) in the IGP have kept pace with population growth. But evidence is now appearing that rice-wheat system productivity is plateauing because of a fatigued natural resource base (Ladha *et al.*, 2003). Thus, the region's food security is threatened by the emerging challenges of post Green Revolution and the rising population.

Emerging challenges in rice-wheat cropping systems

Conventionally, rice in the region is established by repeated wet tillage (puddling) followed by transplanting of the seedlings in the puddled soil, while wheat established (in rice residue burned fields) by broadcasting/drilling seed after disking, tilling and planking operations (Bhatt, 2015). Seed bed preparation operation oxidise the once hidden organic matter, break the macro-aggregates into the micro-aggregates which adversely affect the soil properties (Das *et al.*, 2014). Furthermore, soil perturbation by conventional tillage makes the soil to serve as a source rather than a sink of atmospheric pollutants and thus is not sustainable and environment friendly. But the conventional practices adopted for establishing wheat and rice by the farmers as per their indigenous knowledge are water, capital and energy intensive and leads to many issues which are a serious threat to the sustainable agriculture.

Degrading soil structure: Rice is conventionally established through tillage under wet conditions with an aim of reduction in percolation losses, ease in transplanting

Table 1. Area under rice-wheat system in South Asia

Country	Area (mha)	Area (%)		Contribution (%) in total cereal production
		Rice	Wheat	
India	10.3	23	40	85
Pakistan	2.3	72	19	92
Bangladesh	0.5	5	85	100
Nepal	0.6	35	84	71
Total	13.7			

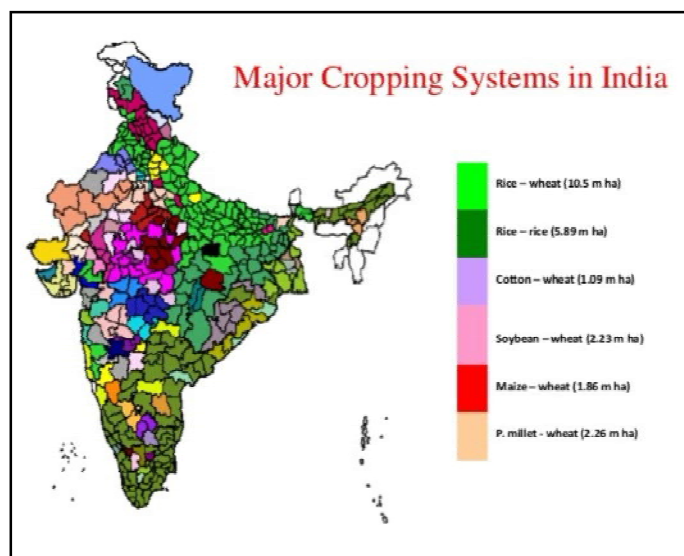


Fig. 1. Major cropping systems in India

and suppression of weeds. However, its pessimistic effects through structural degradation on upland crops are of concern (Kukul and Aggarwal, 2003a). Apart from the extensive labour requirement and repeated puddling of coarse textured soils has led to the sub-surface compaction which has been proving detrimental for the upland crops like wheat. The soil compactness at 15-20 cm depth formed due to repeated puddling restricts the root growth of wheat in addition to creating aeration stress. Thus, puddle transplanted system of rice cultivation is water, capital and energy intensive and leads to the structural deterioration of the soil. In wheat crop traditionally seed bed are prepared by disking, tilling and finally planking was done which resulted in the exposure of the once hidden organic matter to the air which ultimately leads to the oxidation of organic matter. These practices in RWCS ultimately lead to the overall structural degradation of the soil structure.

Declining soil health: Soil health is declining at an alarming rate resulting in not only macro-but micro-nutrient deficiencies in soils of the country. Kukul and Aggarwal (2003a) stressed on puddling operation intensity to reduce losses where soils are highly permeable and coarse textured.

However, its negative effects on the structural properties of soil on upland crops are of concern (Aggarwal *et al.*, 1995). Intensive tillage operations reduced the potential yields by breaking of large aggregates in soil. Thus, puddling operations are water, capital and energy intensive which finally deteriorates the soil structure. The intensive RWCS disturbed the nutrient balance in upper soil zone. Conventional practices of burning of crop residues particularly of rice resulting in serious consequences on, loss of nutrients and emission of greenhouse gases. Farmer has to put more fertilizers to have potential yields, finally resulting in higher cost of cultivation in the short term and reduction in soil quality and productivity in the long term.

Reduction in land productivity: With ever increasing population to feed at hand, decreasing land productivity might be quite dangerous. At present about 2.5 per cent growth in cereal production will be required to meet the future food demands. For the higher production goal to be able to keep pace with population growth, an increase in the area (by bringing wasteland areas under agriculture by levellings) and yield growth (with increased cropping intensity) are required. The increased demand by urban areas and industry creates a competition for land allocation to different sectors including agriculture. Some studies reported stagnant or even lesser yields in RWCS because of different factors and their compounded effect. Farmers have to apply more fertilizers to have potential yields because of declining total factor productivity. Decreased land productivity is an issue needing urgent attention by using different technologies *viz.*, bed planting, laser land levelling, direct seeded rice, mechanical transplanting, direct drilling of wheat seeds in the untilled soils in standing rice stubbles and implementing of new breeding programmes throughout the region to breed some higher yielding, nutrient and water use efficient, water stress and salt tolerant, disease resistant varieties.

Environment pollution: Over 628 million tons of crop residues is generated every year in India (MNRE, 2014) as above 90 per cent the area under wheat-rice crop sequence is harvested using combine harvesters, which left loose straw in wind rows. Management of the rice stubble (more than 7 t ha⁻¹) is a major challenge. Smouldering is widely practiced by the farmers being easy and quick method of disposing off of rice residues (417 Mt year) thereby causing air pollution (Gupta *et al.*, 2004). As a result of the advanced technologies and better quality seeds agricultural production increased many times but along with it residue production has also jumped substantially. Cereal contribute 70 per cent of the total crop residues (352Mt) comprising 34 per cent by rice and 22 per cent by wheat crops. About 25-30 per cent of N

and P, 35-40 per cent of S, and 70-75 per cent of K uptake are retained in wheat residue. Important nutrients in rice straw at harvest are 5-8 kg N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1.0 kg S per ton of straw on a dry weight basis (Dobermann and Witt, 2000). The burning of left out residues is a major contributor to reduced air quality, human respiratory ailments, and the death of beneficial soil fauna and microorganisms. Solution to avoid burning of rice straw would be to employ it as a mulch material in the upcoming wheat crop to improve crop yields, conserve, and save environment.

Outbreak of diseases and insect-pest: Both wheat and rice crops are grown under lavish environment. The green crops with higher dose of N-fertilizers and wet conditions, because of frequent irrigations, are the paradise for the outbreak of insect-pest and diseases. Further, farmers act as per the advice of the dealers further increases the complexity of the system and this effect is further compounded under the effect of monoculture system. Outbreak of the diseases and insect-pests attack is mainly responsible for the lower water and land productivity and is considered a serious issue in the way to sustainable agriculture. Decline in factor productivity and decreased input use efficiency with increased cost of cultivation also increased the risk probability. Some more important issues regarding the insect-pests under the rice-wheat cropping systems are blast and stem borer which cause damage to only long saturated basmati varieties, sheath blight disease, false smut, bacterial leaf blight in rice and powdery mildew and rusts in wheat might be the reasons for declining yields. Thus, keeping these points in view, the emerging diseases and insects are really seems to be responsible for lowered land productivity.

Resource conservation technologies in rice-wheat cropping system

The resource conservation technologies (RCTs) primarily focus on resource savings through minimal tillage, ensuring soil nutrients and moisture conservation through crop residues and growth of cover crops, and adoption of spatial and temporal crop sequencing. Resource conserving technologies (RCTs) play a major role in sustaining and enhancing the productivity of the rice-wheat system at a lower cost of production. Some of the RCTs that are being promoted in the rice-wheat belt of the Indo-Gangetic plains have been discussed below. Effect of different resource conservation technologies on grain yield and water productivity and soil properties of rice and wheat cropping system have been presented in Tables 2, 3 and 4.

Resource conservation technologies in rice

Alternate wetting and drying (AWD): Alternate wetting and drying (AWD) has been commonly used as a water-

saving practice in many parts of the world for more than a decade. In this system, the soil is allowed to dry for a few days within irrigation events depending on plant developmental stages. Savings in irrigation water in the AWD treatments were 53-87 mm (13-16%) compared with the continuously submerged regime. Water productivity was significantly higher in the AWD regime than in the continuously submerged regime. Yield penalty was commonly observed under AWD compared with continuously flood-irrigated (CF) rice (Bouman and Tuong, 2001). However, the water consumption is still high in AWD since the soils need to be submerged at least during the irrigation period.

Laser land leveler: Laser leveling is a process of smoothening the land surface (± 2 cm) from its average elevation using laser equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2 per cent. This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level. A review of various studies suggested that laser land leveling in Pakistan resulted in about 25 per cent reduction in irrigation water application and an increase of about 30 per cent in wheat yield as compared to conventional practices (Humphreys *et al.*, 2010). Similarly increased yield and reduced irrigation water application in the case of zero tillage wheat and laser land leveling were reported in India and China (Jat *et al.*, 2009 and Humphreys *et al.*, 2010). For instance, Jat *et al.* (2009) showed that the use of RCTs, including zero tillage and laser leveling reduced irrigation water applications between 23 and 45 per cent while increasing the yield.

Leaf colour chart (LCC): LCC developed in Japan, used to measure green colour intensity of rice leaves to assess the nitrogen requirements by non-destructive method (Nachimuthu *et al.*, 2007), is being standardized with chlorophyll meter. In hybrid as well as inbred rice, N management through LCC proved superior to locally recommended N application in three splits. It was found possible to curtail 20-30 kg of fertilizer N/ha without sacrificing rice yield, when N is applied as per LCC values. N application at LCC<3 in Basmati and at LCC<4 in coarse and hybrid rice was found optimum. Moreover, in LCC-based N management, basal application of N can be skipped without any disadvantage in terms of grain yield, and agronomic, physiological or recovery efficiency of fertilizer N. The studies indicated that nitrogen can be saved from 10

to 15 per cent using the LCC (Sharma *et al.*, 2008).

Direct seeded rice (DSR): The shortage of labour and water, and soil fertility issues are causing increasing interest in shifting from puddling and transplanting to direct seeded rice (DSR). According to Pandey and Velasco (2005), low wages and adequate availability of water favour transplanting, whereas high wages and low water availability favour DSR. The recent shift from transplanting to DSR in Southeast Asian countries has been caused by labour shortage and rising wages. DSR can reduce the labour requirement by 50 per cent compared with transplanting. The DSR system provides incentives for saving water (Humphreys *et al.*, 2005). In Northwest India, about 35-57 per cent water savings have been reported in research experiments in DSR sown into un-puddled soils. Direct-seeded and transplanted rice grown on raised beds decreased water use by 12-60 per cent when compared with flooded, transplanted rice in the IGP (Gupta *et al.*, 2002). In a 6-year study conducted in Modipuram on sandy-loam soil, it was observed that dry DSR can be irrigated safely at the appearance of soil hairline cracks (Gathala *et al.*, 2011). The direct seeded rice (DSR) on raised beds decreased water use by 12-60 per cent, and increased yield by 10 per cent as compared to puddle transplanted rice, in trials at both experimental stations and on-farm (Gupta *et al.*, 2002).

Table 2. Effect of different resource conservation technologies on grain yield of rice.

Resource conservation technologies	Grain yield (t ha ⁻¹)	Location
System of rice intensification	5.42	IARI, New Delhi
Direct seeded rice (DSR)	7.21	UAS, Raichur, Karnataka
Alternate wetting and drying	5.10	ICAR-IIRR, Hyderabad
Wet seeded rice	3.50	IGKV, Chattisgarh
Normal transplanted rice	6.59	UAS, Raichur, Karnataka

Aerobic rice: Aerobic rice is a new way of production system in which specially developed, input-response rice varieties with aerobic adaptation are grown in well-drained, non-puddled, and non-saturated soils without ponded water. It is a fundamental approach to reduce water inputs in rice and is like growing in an irrigated upland crop, such as wheat or maize. Main driving force behind aerobic rice is the economic water use. Kadiyala *et al.* (2012) reported that the total amount of water applied (including rainfall) in the aerobic plots was 967 and 645 mm compared to 1546 and 1181 mm in flooded rice system, during 2009 and 2010, respectively. This resulted in 37 to 45 per cent water savings

with the aerobic method. Jinsy *et al.* (2015) found that compared to conventional flooded rice, the average water productivity of aerobic rice (0.68 kg/m³) was 60.7 per cent higher. Reddy *et al.* (2010) reported that water productivity was higher under aerobic (0.20 to 0.60 kg/m³ of water) than that under transplanted (0.14 to 0.43 kg/m³ of water) condition.

Nevertheless, decline in yield was observed when aerobic rice was continuously grown and the decline was greater in the dry than in the wet season (Peng *et al.*, 2006). In crux, aerobic rice is an attractive option to the traditional rice production system. Yield penalty and yield stability of aerobic rice have to be considered before promoting this water-saving technology.

System of rice intensification: SRI that evolved in the 1980s and 1990s in Madagascar permits resource limited farmers to realize paddy yields of up to 15 t ha⁻¹ even on infertile soils, with greatly reduced rates of irrigation and without external additional inputs. The main features of this system are transplanting young seedlings singly in a square pattern with wide spacing, using organic fertilizers and hand weeding, and keeping the paddy soil moist during the vegetative growth phase. Significant phenotypic changes occur in plant structure and function and in yield and yield components under SRI cultivation. SRI increase yields substantially (50-100% or more), while requiring only about half as much water as conventional (Uphoff *et al.*, 2010), while not needing the purchase of additional external inputs. At present, SRI methods have been adopted in almost 50 countries, including major rice-producing nations such as India, China, Vietnam and the Philippines. SRI produce higher yields with less water and seeds. Moreover, studies found rice under SRI to be more robust against extreme weather events, pests, and diseases due to improved plant vigour and root strength. Alternating irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering (Thakur *et al.*, 2010). However, a few studies identified higher labour requirements of SRI as a constraint to adoption (Senthilkumar *et al.*, 2008). Other studies showed that higher labour inputs occurred only in the early phase of adoption, labour requirements seem to decrease with growing SRI experience.

Resource conservation technologies in wheat

Zero tillage: It has been established as cost saving, yield boosting and eco-friendly RCT in the entire IGP. A major driver for adoption is increased profitability as a result of lower establishment costs. In this system, no preparatory tillage (ploughing, harrowing, planking) is done and there

is slight soil disturbances associated with creating a narrow slit for planting seeds. ZT is generally reported to save irrigation water in the range of 20-35 per cent in the wheat crop compared to conventional tillage (CT), reducing water usage by about 10 cm/ha, or approximately 1 million liters/ha (Mehla *et al.*, 2000). ZT typically improves soil quality in various dimensions, including soil structure, soil organic carbon, higher stability of soil aggregates, soil fertility and soil biological properties. Studies have reported that the upper soil surface for ZT was comparatively soft, had higher moisture content, and there was no significant difference in bulk density under ZT and CT systems.

Furrow irrigated raised beds (FIRBS): Furrow irrigated raised bed system (FIRBS), another RCT, has the potential to conserve significant quantities of water (30–50%) (Kukul *et al.*, 2005). Other benefits of bed-planting include, reduced seed rates, conserved rainwater, facilitated mechanical weed control, minimized lodging in the wheat crop (Gupta *et al.*, 2000), cost reduction and conservation of resources. Fertilization is also easily performed by trafficking in the furrow bottoms and the fertilizers can be banded through the surface residues, reducing thereby potential nutrient losses under permanent raised bed planting (Limon-Ortega *et al.*, 2002). The raised bed planting technique also provides an opportunity for crop diversity through inclusion of different crops as well as feasibility of inter or relay cropping, thereby opening avenues for generating alternate sources of productivity growth through efficient use of resource base. Bed-planting is widely adopted in the Indo-Gangetic plains, proved to be a successful conservation technology. In Pakistan, Akbar *et al.* (2007) reported water saving of 36 per cent for broad-beds and about 10 per cent for narrow-beds compared to flat sowing, and increased grain yield of wheat by 6 percent and maize by 33 per cent. In both cases, the furrows acted as pathways for drainage during excessive rains and conserve rainwater in dry spells. However, the use of direct dry seeding on flat and raised beds, while resulting in considerable water savings, generally had negative impact on rice yield (Choudhury *et al.*, 2007 and

Humphreys *et al.*, 2010). Gathala *et al.* (2013) reported that irrigation water productivity (IWP) was significantly higher in beds (13.9%) than flat puddled planting (13.16%).

System of wheat intensification (SWI): Wheat contributes most towards public distribution system and has become a backbone of country's food security (Prasad and Gupta, 2012). During the past two decades, productivity gains from the usual wheat sowing methods with their substantial input dependence have unfortunately been declining due to which the farmers are facing the difficulties in coping with the high demand of costly inputs to meet the requirements of recommended technologies for increasing production. Under these circumstances, alternative methods of crop establishment and management that could deal with these conditions resulted in higher productivity of wheat with minimum cost is system of wheat intensification (SWI). SWI is a new practice of wheat cultivation manipulating the soil's environment favourably for the better root and shoot growth of the crop. SWI is feasible and can prove to be a boon for poor and marginal community of eastern IGP, where average productivity is low. This method is more labour-intensive than traditional techniques, but it requires less seeds, water, pesticide and fertiliser. Modified practices adopted in SWI are lower seed rate, sowing of seeds at proper spacing, good control of water in the crop field, hoeing for weed control, higher ratio of tillers to mother seedlings and increased number of effective tillers/hill. Moisture availability in soil is required when the germinated seeds are sown @ 2 seeds/hill. System of wheat intensification enhance 54 per cent more yield and give better economic returns than available best conventional sowing practices (Uphoff *et al.*, 2011).

Surface seeding: Surface seeding is a simple no tillage system in which seed placement is done on the saturated soil surface without any land preparation. Actually this is

Table 3. Effect of different resource conservation technologies (RCT) on grain yield of wheat.

Resource conservation technologies	Grain yield (t ha ⁻¹)	Location
Zero tillage	4.73	IARI, New Delhi
System of wheat intensification	5.10	BAU, Ranchi
Conventional wheat sowing	3.74	BAU, Ranchi
Furrow irrigated raised bed sowing (FIRBS)	4.70	IARI, New Delhi
Reduced tillage	4.14	SVPUA&T, Meerut

Table 4. Effect of different resource conservation technologies of rice- wheat cropping system on grain yield and water productivity of rice and wheat crop.

System of rice cultivation	Grain yield (kg ha ⁻¹)	Water productivity (kg/m ³)
Zero tillage	4435	1.30
System of rice intensification	6682	0.47
Alternate wetting drying	5796	0.42
Direct wet seeded rice	5500	0.35
Aerobic rice	3933	0.42
Furrow irrigated raised bed sowing (FIRBS)	4457	1.79
Reduced tillage	4149	1.12

our traditional farmer's practice for growing wheat, legume and other crops mostly in eastern parts of India. In fine textured soils with very poor drainage condition, land preparation becomes difficult and often a cloddy tilth is formed after the harvest of paddy. Seeds of wheat are broadcasted before paddy is harvested (relay cropping) or after harvest. Residual soil moisture after rice crop can be properly utilized and in case soil moisture is insufficient for good germination and initial crop stand, pre-soaked seeds (about 8-10 hours in fresh water) can be sown. Broadcasting of dry seeds needs to be done during afternoon hours because it facilitates good imbibition of water and swelling of seeds in cold favourable condition in absence of sunlight. Straw mulch can be applied on the soil after sowing of seeds as practised in other South Asian countries to check evaporation losses, manage weeds and provide better protection to germinating seeds.

Precision farming: Precision agriculture refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides, etc. at the correct time to the crop for increasing its productivity and maximizing its yield. The benefits of so doing are twofold, *i.e.*, the cost of producing the crop in that area can be reduced and the risk of environmental pollution from agrochemicals applied at levels greater than those required by the crop can be reduced. Thus, it helps to improve input use efficiencies, economy, and sustainable use of natural resources, because it minimizes wastage of inputs. In other words, it may also be referred to 'site-specific farming'. The practice of precision farming is viewed as comprising of four stages, information acquisition related to variability in environmental and biophysical parameters, their interpretation for input application, evaluation and control. To support precision farming, the important information technology tools are Global Positioning System (GPS), Geographical Information System (GIS) and Simulation Modeling for Decision Support System (DSS), remote sensing, yield monitor and variable rate technology. Global Positioning System provides accurate site information and is highly useful in locating the spatial variability. An average benefit of £38.60/ha was reported by Schmerler and Basten (1999), when wheat was grown on a farm scale trial, where both seed and agrochemical rates were varied.

Diversification/Intensification: A shift from sole cropping to a diversified/intensified farming system is highly warranted. The increased cropping intensity/diversification is intended to minimize risk, improve biodiversity and diversify income sources and enhance resource sustainability. It will be a key strategy for future gains in crop production. Short duration pulses, oilseeds

and other high value crops will find their definite niche as sequential or intercrops, rather than replacing the major cereal crops having higher yield stability. Hence, an increased cropping intensity will contribute substantially to additional demands of food and cash crops. Pigeonpea, the most important wet season grain legume crop in South Asia, has shown potential for rice crop diversification in Indo-Gangetic plain. The introduction of extra short duration (ESD) pigeonpea (ICPL-88039) and furrow irrigated raised bed planting technique in the region has shown tremendous potential for increasing the water productivity and economic growth of the farmers with limited resources. Development of new crop varieties with more efficient photosynthetic apparatus and shorter duration would be of massive help in increasing cropping intensity. Similarly, bio-intensive diversified cropping systems would enable small and marginal farmers to utilize limited land and water resources in more efficient manner.

Crop residue management in RWCS: About 400 million tons of crop residues are produced in India alone. In areas where mechanical harvesting is practised, a large quantity of crop residues are left in the field, which can be recycled for nutrient supply. About 25 per cent of nitrogen (N) and phosphorus (P) and 75 per cent of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient sources. Both rice and wheat are exhaustive feeders, and the double cropping system is heavily depleting the soil of its nutrient content. Traditionally, wheat and rice straw were removed from the fields for use as cattle feed and for other purposes in South Asia.

With the advent of mechanized harvesting, farmers have been burning *in situ* large quantities of crop residues left in the field as crop residues interfere with tillage and seeding operations for the next crop. Recently, happy seeder has been developed to manage crop residues (Fig. 3). Unlike



Fig. 3: Crop residue management by happy seeder

removal or burning, incorporation of straw builds up soil organic matter, soil N, and increases total and available P and K contents in the soil. Application of 15 to 20 kg N ha⁻¹ as starter dose with straw incorporation increases yields of wheat and rice compared to either burning of straw or its incorporation in the soil.

CONCLUSION

Rice-wheat cropping system in South Asia has contributed immensely to fill the increasing empty stomachs but has consequently led to many sustainability issues viz., declining water resources, degrading soil health and environment degradation, which is further responsible for stagnating/ decreased land and water productivity. Hence, alternate tillage and establishment methods must be invented, tested and recommended for the sustainable establishment of rice-wheat cropping system as a whole including the intervening period so that land and water productivity, soil health and environment must be improved for overall lifting of the livelihoods of the farmers of South Asia. Performance of these technologies is, however, site-specific and changes depending upon the soil textural classes and agro-climatic conditions. Conventional indigenous age-old practices are responsible for all the earlier discussed unsustainability issues which must be replaced with more advanced and sustainable resource conservation technologies (RCTs). Adoption of these technologies can substantially conserve resources at the field level, while increasing productivity for a sustainable food future.

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Impact of integrated nutrient management and fertigation on growth parameters of papaya (*Carica papaya* L.) cv. Arka Prabhath under net house

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ABSTRACT

An experiment was conducted under insect proof net to assess the impact of integrated nutrient management and fertigation levels on growth parameters of papaya cv. Arka Prabhath. The experiment was laid out in CRD with three replications and twelve treatments. Results indicated that crop growth such as plant height, girth, number of leaves and leaf petiole length were significantly higher in treatment containing 100 per cent RDF through Fertigation + Trichokavach (50 g plant⁻¹) + Chitosan (20 g plant⁻¹) + Seaweed extract (20 g plant⁻¹) + *Penicillium pinophilum* (20 g plant⁻¹) + *Pseudomonas putida* (4 ml L⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300 ppm) + Power plus (5 ml L⁻¹) at compared to control.

Key words: Papaya, biofertilizers, fertigation, RDF

Papaya (*Carica papaya* L.) belongs to the genus *Carica*, of the family *Caricaceae* with 48 species. It is one of the most important fruit crops cultivated in the tropical and subtropical regions of India. Papaya grows relatively easily and quickly from seeds and can reach up to 10 or 12 ft in height. Fruits are ready to be harvested within 9 to 12 months after planting and tree can continue to produce fruits for about 2-3 years. The fruit is a good source of vitamin A and C. Ripe fruits are largely used as a fresh dessert, while green fruits are often used in salads and pickled or cooked as a vegetable. Papain, a proteolytic enzyme present in the latex, collected mainly from green fruits, has various uses in the beverage, food and pharmaceutical industries (Chan and Tang, 1978).

Papaya is reported to be susceptible to various maladies caused by fungi, bacteria, nematode and viruses. Among them Papaya Ring Spot Virus (PRSV) is a serious threat to papaya cultivation in India and various parts of the world. This disease is observed in almost all the states of India like, Bihar (100%), Maharashtra (3-100%), Karnataka (60%), Kerala (35-66%) and West Bengal (40%) (Yeh *et al.*, 2010). The production of papaya is limited by this destructive disease which ultimately limits the large-scale exportation

due to this fact, papaya lags behind banana and pineapple in the world market. These problems can be managed to some extent by selection of improved cultivars and growing under protected conditions along with use of biostimulents and biofertilizers.

The productive cultivation incorporating several intensive and high-tech practices, serve as an alternative to open-field cultivation. It is most contemporary approach of producing high value crops of good quality by alternating biotic and abiotic constraints like insects, diseases, extremes of temperature, rainfall and light intensity. It facilitates the grower to obtain premium prices from their produce. Hence, the present study was conducted to grow papaya under insect proof net and use of integrated nutrient management along with fertigation for controlling PRSV incidence.

MATERIALS AND METHODS

The present investigation was conducted at Yelwala, Mysuru during 2020-21 located at a latitude of N 12°35'90" and longitude of E 76°54'31" with an altitude of 770 meters above mean sea level in the southern dry zone (Zone-6). Arka Prabhath seeds were collected from IIHR, Bengaluru. The seeds were treated with 100 ppm of GA₃ for better germination

and were grown under insect net proof cages for 45 days with proper care to obtain virus free seedlings. An insect proof net house of 50 m length, 13 m width and 3.2 m height was constructed using wooden and iron poles. All the sides were covered with insect proof net (40 mesh) for natural ventilation and protection from the pests.

The study was conducted under insect proof net and design opted was CRD (complete randomized design) having twelve treatments with three replications. The treatments were, T₁: NPK supplied through FYM, vermicompost and neem cake, T₂: 100% RDF of NPK plant⁻¹ through soil application+ micronutrient spray, T₃: 75% RDF of NPK plant⁻¹ through Fertigation+ Trichokavach (50g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20 g plant⁻¹), T₄: 75% RDF of NPK plant⁻¹ through Fertigation+ Trichokavach (50 g plant⁻¹) + Seaweed extract (20 g plant⁻¹) and spray (0.2%) + *Pseudomonas putidida* (4 ml L⁻¹) + *Penicillium pinophilum* (20g plant⁻¹), T₅: 75% RDF of NPK plant⁻¹ through Fertigation+ Trichokavach (50 g plant⁻¹) + Chitosan (20 g plant⁻¹) + *Penicillium pinophilum* (20 g plant⁻¹), T₆: 75% RDF of NPK plant⁻¹ through Fertigation+ Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) and spray

(0.1%)+ *Pseudomonas putidida* (4 ml L⁻¹) + *Penicillium pinophilum* (20g plant⁻¹), T₇: 75% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Salicylic acid (300ppm) + *Penicillium pinophilum* (20g plant⁻¹), T₈: 75% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + *Penicillium pinophilum* (20 g plant⁻¹), T₉: 75% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Power plus (5 ml L⁻¹) + *Penicillium pinophilum* (20 g plant⁻¹), T₁₀: 100% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20g plant⁻¹) + *Pseudomonas putidida* (4 ml L⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L⁻¹), T₁₁: 75% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20g plant⁻¹) + *Pseudomonas putidida* (4 ml L⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L⁻¹) and T₁₂: 50% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20g plant⁻¹) + *Pseudomonas putidida* (4 ml L⁻¹) +

Table 1. Effect of fertigation level and integrated nutrient management on plant height (cm) of papaya cv. Arka Prabhath under net house condition

Treatments	Days after transplanting		
	30	60	90
T ₁ : NPK is supplied through FYM, vermicompost, neem cake	30.33	51.67	86.00
T ₂ : 100% RDF of NPK plant ⁻¹ through soil application+ micronutrient spray	30.67	54.50	88.67
T ₃ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	31.00	55.33	90.17
T ₄ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) and spray (0.2%) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	31.22	56.33	90.67
T ₅ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	30.33	55.33	89.33
T ₆ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) and spray (0.1%) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	31.00	56.00	90.00
T ₇ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Salicylic acid (300ppm) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	30.00	54.33	89.00
T ₈ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	31.00	56.00	90.00
T ₉ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Power plus (5 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	31.23	56.00	90.00
T ₁₀ : 100% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	32.67	58.67	93.00
T ₁₁ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	32.10	57.17	92.17
T ₁₂ : 50% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	30.33	51.83	86.50
S.Em ±	0.34	0.65	NA
CD@ 1%	1.00	1.91	NA

Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L⁻¹). Except treatment T₁ and T₂, rest were applied with neem cake (250g plant⁻¹) along with VAM (5g plant⁻¹), vermicompost (3kg plant⁻¹) and micronutrient spray in common.

The recommended dose for papaya is N, P, K with 250, 250, 500 g plant⁻¹ year⁻¹. The basal dose of 90 g urea, 250 g SSP and 140g MOP alongwith bio-fertilizers and biostimulent were applied to the pits as per the treatment details and rest were supplied through urea, SSP and MOP, respectively, in twenty equal split doses at bi-monthly intervals through fertigation.

Four plants were selected from each replication for recording observations in each treatment. The growth parameters plant height, stem girth, number of leaves and petiole length were recorded at 30 days interval up to flowering and data was analysed statistically.

RESULTS AND DISCUSSION

The maximum plant height of 32.67 and 58.67 cm were recorded in plants applied with 100% RDF of NPK plant⁻¹

through Fertigation + Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20g plant⁻¹) + *Pseudomonas putida* (4 ml L⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L⁻¹) (T₁₀) and was at par with 75% RDF of NPK plant⁻¹ through Fertigation + Trichokavach (50g plant⁻¹) + Chitosan (20g plant⁻¹) + Seaweed extract (20g plant⁻¹) + *Penicillium pinophilum* (20g plant⁻¹) + *Pseudomonas putida* (4 ml L⁻¹) + Phosphoric acid (20 ml L⁻¹ plant⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L⁻¹) with plant height of 32.10 and 57.17 cm at 30 and 60 days after transplanting, respectively. The minimum plant height of 30.33 and 51.67 cm were found in T₁ [NPK is supplied through FYM, vermicompost and neem cake] at 30 and 60 days after transplanting, respectively (Table 1). The minimum plant height of 1.83 and 3.76 cm were found in T₁ at 60 and 90 days after transplanting, respectively. Similarly, maximum stem girth of 2.13 and 4.30 cm were observed in T₁₀ and was at par with T₁₁ having stem girth of 2.13 and 4.30 cm at 60 and 90 days after transplanting, respectively (Table 2).

The application of biofertilizers and biostimulents

Table 2. Effect of fertigation level and integrated nutrient management on stem girth (cm) of papaya cv. Arka Prabhat under net house condition

Treatments	Days after transplanting		
	30	60	90
T ₁ : NPK is supplied through FYM, vermicompost, neem cake	1.30	1.83	3.76
T ₂ : 100% RDF of NPK plant ⁻¹ through soil application+ micronutrient spray	1.41	1.92	4.07
T ₃ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	1.40	1.87	4.14
T ₄ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) and spray (0.2%) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	1.40	1.93	4.18
T ₅ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	1.42	1.88	4.07
T ₆ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) and spray (0.1%) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	1.33	1.91	4.17
T ₇ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Salicylic acid (300ppm) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	1.37	1.87	4.00
T ₈ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	1.43	1.87	4.19
T ₉ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Power plus (5 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	1.40	1.93	4.17
T ₁₀ : 100% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	1.60	2.33	4.43
T ₁₁ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	1.53	2.13	4.30
T ₁₂ : 50% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	1.33	1.85	4.00
S.Em ±	NS	0.07	0.08
CD@ 1%	NS	0.21	0.23

Table 3. Effect of fertigation level and integrated nutrient management on number of functional leaves (no.) of papaya cv. Arka Prabhath under net house condition

Treatments	Days after transplanting		
	30	60	90
T ₁ : NPK is supplied through FYM, vermicompost, neem cake	14.58	14.17	17.08
T ₂ : 100% RDF of NPK plant ⁻¹ through soil application+ micronutrient spray	14.62	14.68	17.75
T ₃ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	14.27	14.63	16.67
T ₄ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) and spray (0.2%) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	14.60	14.73	17.00
T ₅ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	14.20	14.23	16.42
T ₆ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) and spray (0.1%) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	14.47	14.67	17.17
T ₇ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Salicylic acid (300ppm) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	14.52	14.58	17.67
T ₈ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	14.50	14.63	17.00
T ₉ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Power plus (5 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	14.67	14.71	17.00
T ₁₀ : 100% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	14.92	15.33	18.92
T ₁₁ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	14.67	15.00	18.50
T ₁₂ : 50% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	14.55	14.67	17.67
S.Em ±	NS	0.20	0.27
CD@ 1%	NS	0.59	0.80

along with recommended dose of fertilizer through fertigation produced variety of growth substances and antifungal substances, which ultimately helped in promoting vegetative vigour of the plants. Similar finding was observed by Meena *et al.* (2014) in guava. The increase in plant height and stem girth might be due to improvement of physical properties of soil, higher nutrient uptake and increased activity of microorganisms, which were manifested in the form of enhanced growth and higher carbohydrates production (Yadav *et al.*, 2011). And, it could also be because of continuous supply of available nutrient from organic and inorganic sources and effect of bio active substance produced by common application of bio fertilizer and biofertilizers. Similar results were also reported by Suresh *et al.* (2010) in papaya.

The maximum number of functional leaves (15.33 and 18.92) were observed in T₁₀ and was at par with T₁₁ (15.00 and 18.50) at 60 and 90 days after transplanting, respectively. The minimum number of functional leaves (14.17 and 17.08) were found in T₁ at 60 and 90 days after transplanting, respectively (Table 3). The maximum leaf

petiole length (36.67 cm) was observed in T₁₀ and was on par with T₁₁ (36.00 cm) at 60 days after transplanting (Table 4). The minimum leaf petiole length (34.20 cm) was found in T₁ at 60 days after transplanting.

The enhanced growth under drip might be due to better turgidity of the cells, leading to cell enlargement and better cell wall development (Viers, 1972). This might have attributed to higher availability of nutrient particularly nitrogen and subsequent uptake by crop. This resulted in higher biomass production and reflected by production of additional leaves (Kuttamani, *et al.*, 2013). Similar results were reported by Yadav *et al.* (2011) in papaya. Probably, the application of biofertilizers and biostimulents along with fertigation produced variety of growth substances and antifungal substances, which ultimately helped in promoting vegetative vigour of the plants. The result in higher biomass production was showed by production of petiole length.

CONCLUSION

The study concluded that integrated use of 100 per cent of NPK plant⁻¹ through fertigation + trichokavach (50 g

Table 4. Effect of fertigation level and integrated nutrient management on leaf petiole length (cm) of papaya cv. Arka Prabhath under net house condition

Treatments	Days after transplanting		
	30	60	90
T ₁ : NPK is supplied through FYM, vermicompost, neem cake	25.01	34.20	40.10
T ₂ : 100% RDF of NPK plant ⁻¹ through soil application+ micronutrient spray	25.00	35.00	41.45
T ₃ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	25.40	35.20	41.60
T ₄ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) and spray (0.2%) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	25.80	35.50	41.95
T ₅ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	25.40	35.00	41.40
T ₆ : 75% RDF of NPK plant ⁻¹ through Fertigation+ Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) and spray (0.1%) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	25.80	35.10	41.80
T ₇ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Salicylic acid (300ppm) + <i>Penicillium pinophilum</i> (20g plant ⁻¹)	25.70	35.20	41.64
T ₈ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	25.60	35.21	41.80
T ₉ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Power plus (5 ml L ⁻¹) + <i>Penicillium pinophilum</i> (20 g plant ⁻¹)	25.40	35.50	41.87
T ₁₀ : 100% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	25.90	36.67	42.40
T ₁₁ : 75% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	25.40	36.00	42.10
T ₁₂ : 50% RDF of NPK plant ⁻¹ through Fertigation + Trichokavach (50g plant ⁻¹) + Chitosan (20g plant ⁻¹) + Seaweed extract (20g plant ⁻¹) + <i>Penicillium pinophilum</i> (20g plant ⁻¹) + <i>Pseudomonas putidida</i> (4 ml L ⁻¹) + Phosphoric acid (20 ml L ⁻¹ plant ⁻¹) + Salicylic acid (300ppm) + Power plus (5 ml L ⁻¹)	25.30	34.70	40.18
S.Em ±	NS	0.54	NS
CD@ 1%	NS	1.45	NS

plant⁻¹), chitosan (20 g plant⁻¹) + seaweed extract (20 g plant⁻¹) + *P. pinophilum* (20 g plant⁻¹) + *P. putidida* (4 ml L⁻¹) + phosphoric acid (20 ml L⁻¹ plant⁻¹), salicylic acid (300 ppm) + power plus (5 ml L⁻¹) could lead to significant increase in papaya plant height, girth, number of leaves and petiole length attributing to higher papaya yield.

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Quantity-intensity parameters of potassium and their relationship with potassium fractions, soil properties and wheat (*Triticum aestivum* L.) yield under integrated nutrient management system in a typic ustifluvents

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ABSTRACT

Fertilizer use in India is highly unbalanced especially with respect to potassium (K) and the soil shows significant responses to K application, even in alluvial soils dominated by K bearing minerals. Potassium availability to the plant is influenced by internal soil properties and other external properties. Quantity intensity characteristics are one of the satisfactory measures of potassium dynamics and its availability. So quantity intensity characteristics of potassium were studied to quantify the potassium availability in soil classified as typic ustifluvents. Soil samples (0-15 cm) were collected from the experimental plot located at Mandan Bharti Agriculture College, Agwanpur, Saharsa, Bihar after harvest of wheat during *rabi* 2015-16. The experiment was laid out in split plot design with four levels of NPK *viz.*, 0, 50, 100 and 150 per cent recommended NPK in main plot and four levels of organic sources of nutrients *viz.*, no organic manure, vermicompost, water hyacinth compost and vermicompost + water hyacinth compost in sub plot treatment in three replications. Soil K pool quantity intensity relationship, K release kinetics along with grain yield and K uptake of wheat were studied. Equilibrium K activity ratio was positively correlated with available, water soluble, exchangeable, non-exchangeable and total K. Non-significant and negative relationship of PBC^K with all forms of K were obtained. ΔG showed non-significant but positive correlation with water soluble, exchangeable, available and total K. The Q/I parameters were significantly interrelated with each other. Equilibrium activity ratio was positively significantly correlated with grain yield, straw yield, K uptake and organic carbon. The sand, silt and clay showed significant relation either positive or negative with all quantity-intensity parameters. The result suggested that integrated use of organics and K input regularly sustain a steady supply of K to successive crops.

Key words: Quantity, intensity, potassium dynamics, soil properties, wheat

In spite of the fact that the total potassium of most soils is high but a small portion of this element is accessible for plants. Availability of K to plant depends on its intensity capacity and removal rate of soil. Intensity is the total amount of K in solution, capacity consists mainly of exchangeable K and removal rate is the K transfer rate from capacity to intensity. The Q/I relation of soil describes the relation between K availability or intensity (I) in soil to the amount (Q) present in soil that is, changes of K sorbed to changes of K in solution concentration (Uddin *et al.*, 2011). The potassium content in soil depends mainly on type and degree of soil weathering and the forms in which it exists in the soil. Hence, the K availability in the soil solution and the inherent capacity of soil to buffer this concentration against changes are among the important parameters that determine effective availability of K to plant (Raheb and Heidari, 2012).

Availability of K to plant depends not only on its availability but also its dynamics. Misunderstanding of these dynamics leads to mismanagement of soil fertility. Potassium potential is one of the intensive characteristics of soil potassium dynamics which describes the intensity of potassium release from the soil solid phase into the soil solution. However, to assess the conditions of potassium uptake by plants, the extensive parameters that is the content of potassium and other soil properties are also required. In this case, the activity ratio described by Beckett (1964) is one of the satisfactory measures of the K dynamics and its availability because it measures both the chemical potential of labile K present to the chemical potential of labile (Ca + Mg) in the same soil. Various efforts have been made to determine the relationship between intensity and capacity of soil K buffering capacity. It was reported that higher value of labile K indicated a

greater K release into soil solution resulting from a larger pool of soil K. A higher potential buffering capacity (PBC^K) for potassium is an inductive of a good K availability, while a low (PBC^K) of soil would suggest a need for potassium fertilization (Wang *et al.*, 2004).

Recent surveys in agriculturally important areas off Gangetic plains of India revealed that majority of the farmers applying N at more than recommended rates, along with phosphorus at nearly recommended rates but much less, if apply at all, K than the recommended rates (Singh *et al.*, 2015). The main reason behind such a neglect of K fertilizer application in India, as pointed out by Sanyal (2014), was the existence of general notion that Indian soils are rich in K reserve. Due to mismatch between crop K uptake and K input, huge amounts of K have regularly been removed from the Indian soil. Long term fertilizer experiments have shown that even the recommended rate of K application with N and P have failed to maintain the initial levels of available K in some soils (Singh *et al.*, 2017). In such conditions, one might have to apply more than recommended rate of K fertilizer or combine organic manures along with recommended NPK to obtain desired crop yields without any adverse impact on soil health. The objectives of the present study were to evaluate potassium dynamics of soil by applying the quantity-intensity (Q/I) concept and evaluating the relationship of soil properties with potassium quantity-intensity parameters.

MATERIALS AND METHODS

A field experiment to assess the effect of water hyacinth compost, vermicompost and inorganic fertilizers, was conducted during *rabi* 2015-16 in light textured sandy loam soil at Mandan Bharti Agriculture College, Agwanpur, Saharsa. The experiment site was located in agro climatic zone-II of Bihar in between 25°52'50' North latitude and 86°48'62' East longitude having hot moist sub humid climate with medium to high water capacity with average annual rainfall of 1050 mm and mean yearly temperature of 33.8°C. The experiment comprised of 16 treatments replicated thrice in split plot design with four levels of NPK in main plot and four levels of organic sources in sub plot treatments. Wheat (*cv.* DBW 14) was grown as a test crop during the reported period of 2015-16. Vermicompost, water hyacinth compost alone or in combination with different levels of NPK *viz.*, 0, 50, 100 and 150 per cent of recommended dose of fertilizer. Different doses of fertilizers in terms of N, P₂O₅ and K₂O were applied @ 120:60:40 kg ha⁻¹, respectively. Nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate and muriate of potash. Soil samples were collected after harvest of wheat during 2015-16 and air

dried, processed and analyzed for available P and K, water soluble K, exchangeable K, non-exchangeable K and total K. Available potassium in soil was determined by neutral normal ammonium acetate extraction method using flame photometer (Jackson, 1973). Water soluble K was determined by extracting the soil with distilled water in soil: water ratio (1:5) and potassium in the filtrate was estimated with the help of flame photometer as per method described by MacLean (1961). Exchangeable K or normal neutral ammonium acetate-K of soil was estimated in the leachate which was obtained by equilibrating the soil with the extractant 1N neutral NH₄OAC for 5 minutes as per method described by Muhr *et al.* (1965). Exchangeable K was determined by deducting water soluble K from normal neutral NH₄OAC-K. The non-exchangeable K known as fixed K or 1N HNO₃ (boiling) extractable K was estimated in the soil as per standard method of Helmke and Sparks (2000). Non-exchangeable K was determined by deducting 1 N neutral NH₄OAC-K from boiling 1N HNO₃-K. For determination of total K finally ground soil sample was placed in a 30 ml platinum crucible and digestion was carried out using HF and HClO₄ as described by Jackson (1973).

The quantity and intensity parameters of K in the soil were measured according to the procedure given by Beckett (1964). Five gram sample of each soil was established with 50 ml of 0.002 M CaCl₂ and also equilibrated with 50 ml of 0.002 M CaCl₂ without K solution. The solution was equilibrated overnight and then filtrated. In the filtrate Ca + Mg was determined by EDTA titration and K with the help of flame photometer. After determining the concentration of Ca + Mg and K in the filtrate, their activity ratio (ARe^K) was determined as follows

$$\frac{aK}{\sqrt{a(Ca + Mg)}} = \frac{cK}{\sqrt{c(Ca + Mg)}} \times \frac{fK}{\sqrt{f(Ca + Mg)}}$$

Where, a = activity (m/L), c = concentration (m/L) and f = activity coefficient.

Activity coefficient was calculated on the basis of Debye-Hückle equation.

Free energy change (ΔG) was determined as

$$\Delta G = -RT \ln ARe^K$$

Where, ΔG = free energy change, T = absolute temperature, R = gas constant and ARe^K = equilibrium activity ratio.

The differences between the amount of K added and recovered in the extract solution in m.e. per 100 g of soil was also calculated (ΔK). The ARe^K was plotted against ΔK. The

Q/I curve resolved into lower curved and upper curved parts. The difference between the lower and upper part represented the K held at specific site (K_x) at zero activity ratio. Further, an extension of the lower curve to the ΔK axis given the total amount of K in labile pool (K_L). The linear part of the curve was interpolated to X-axis and this X intercept represented the equilibrium activity ratio (AR_e^K) when ΔK is zero. The linear part was also interpolated to Y-axis and this Y-intercept represented the amount of K held in the soil on sites or surface which exchange equilibrium was described by the linear part of Q/I retention (-ΔK). The other Q/I parameters were calculated as follows:

$$PBC^K = \frac{-\Delta Ko}{AR_e^K}$$

Where, PBC^K = potential buffering capacity, -ΔK = labile K and AR_e^K = equilibrium activity ratio of K.

RESULTS AND DISCUSSION

Correlation between different soil quantity-intensity characteristics

The interrelationship among Q/I parameters are presented in Table 1. The Q/I parameters were significantly interrelated with each other and significant positive correlation of AR_e^K with K_L (0.984**), Ko (0.963**) and K_x (0.932**) were obtained. Das *et al.* (1993) and Dhillon *et al.* (1986) also reported similar observations. AR_e^K showed negative and significant correlation with PBC^K and positive correlation with ΔG. It was because of increased available potassium saturation which given has rise to increase in AR_e^K. Significant positive correlation of K_L with Ko (0.960**) and K_x (0.932**) indicated that with increase in labile pool of K, there was increase in K saturation at both non-specific and specific adsorption sites. K_L showed negative non-significant correlation (-0.382) with PBC^K and positive non-significant correlation with ΔG. A significant and positive correlation among Q/I parameters and negative and significant relation between Q/I and PBC^K were also observed by Wani *et al.* (2012). Ko showed significant

Table 1. Correlation between different soil quantity-intensity characteristics

Soil characteristics	K _L	Ko	K _x	PBC ^K	ΔG
AR _e ^K	0.984**	0.963**	0.932**	-0.434*	0.392
K _L	-	0.960**	0.946**	-0.382	0.383
Ko	-	-	0.842**	-0.363	0.338
K _x	-	-	-	-0.383	0.358
PBC ^K	-	-	-	-	0.254
ΔG	-	-	-	-	-

*Significant at 5%, **Highly significant at 1%

correlation with K_x (0.842**) and negative non-significant correlation with PBC^K (0.338). K_x also showed negative non-significant correlation (-0.383) with PBC^K and positive non-significant correlation (0.358) with ΔG. Free energy exchange (ΔG) and potential buffering capacity (PBC^K) were non-significantly negatively correlated. Niranjana *et al.* (2000) and Panda and Patra (2018) also reported significant correlation coefficient between potassium fraction and potassium Q/I parameters.

The interrelationship among Q/I parameters with different potassium fractions were presented in Table 2. Equilibrium K activity ratio was positively correlated with available (0.818**), water soluble (0.918**), exchangeable (0.985**), non-exchangeable (0.676**) and total K. Similar results were reported by Das *et al.* (1993) and Niranjana *et al.* (2000). Other parameters like labile K, non-specific K and specific K were positively and significantly correlated with different forms of K. Non-significant and negative relationship of PBC^K with all forms of K were obtained. ΔG exhibited non-significant but positive correlation with water soluble, exchangeable, available and total K, whereas non-significant negative correlation with non-exchangeable K. Prasad (1992) has also reported similar result. It was due to increased available potassium saturation which has given rise to increase in AR_e^K (Lalitha and Dhakshinamoorthy, 2015). Rupa *et al.* (2003) have also reported similar relationship.

Table 2. Correlation coefficient between potassium fractions and potassium quantity-intensity parameters

Parameters	AR _e ^K	K _L	Ko	K _x	PBC ^K	ΔG
Available K	0.818**	0.902**	0.842**	0.862**	-0.287**	0.302
Water soluble K	0.918**	0.913**	0.862**	0.867**	-0.162**	0.366
Exchangeable K	0.985**	0.975**	0.945**	0.915**	-0.413**	0.340
Non-exchangeable K	0.676**	0.676**	0.642**	0.646**	-0.406**	0.005
Total K	0.838**	0.867**	0.778*	0.855**	-0.161**	0.190

*Significant at 5%, **Highly significant at 1%

Highly significant and positive correlation between AR_e^K and non-exchangeable K, water soluble K, exchangeable K and total K indicated their significant contribution towards enrichment of AR_e^K in the soil. Lower number of specific sites for K⁺ adsorption with less ability of the soil to supply K⁺ over an extended period of time might have encouraged the higher value of AR_e^K in the soils for adequate plant K⁺ nutrition (Panda and Patra, 2018).

Correlation between Q/I characteristics, yield and K uptake

Equilibrium activity ratio (AR_e^K) was positively and significantly correlated with grain yield (0.972**), straw yield

(0.925**) and K uptake (0.963**) (Table 3). K_L , Ko and Kx showed positive significant correlation with grain yield, straw yield and K uptake. All measured parameters except PBC^K , correlated positively and significantly with dry matter yield and K uptake. Non-significant correlation between ΔKo and ARE^K with K uptake by wheat and strong correlation between PBC^K value and K uptake and relative wheat yield was reported by Ghanavati *et al.* (2012). The results were in conformity with those of Ram and Prasad (1981) and Wani *et al.* (2012).

Table 3. Correlation between Q/I characteristics yield and K uptake

Parameters	Grain yield	Straw yield	K-uptake
ARE^K	0.972**	0.925**	0.963**
K_L	0.986**	0.932**	0.957**
Ko	0.957**	0.884**	0.921**
Kx	0.942**	0.920**	0.923**
PBC^K	-0.360	-0.183	-0.320
ΔG	0.332	0.355	0.333

*Significant at 5%, **Highly significant at 1%

Correlation between selected properties of soil and potassium Q/I characteristics

Correlation between soil properties and potassium quantity intensity parameters are presented in Table 4. ARE^K was significantly and positively correlated with organic carbon (0.745**), positively correlated with sand (0.183) and clay (0.281) and negatively with silt (-0.262). Correlation of ARE^K with organic carbon and clay content was also reported by Ghanavati *et al.* (2012). K_L , Ko and Kx showed positive significant correlation with organic carbon, positive correlation with sand and clay content and negative correlation with silt content of the soil. Similar observations were reported by Singh *et al.* (2019). Soils with higher clay content have higher exchange surface and offer a selective or specific binding sites for K compared to other soil (Dutta and Joshi, 1990). PBC^K was positively correlated with organic carbon (0.096) and negatively correlated with sand, silt and

Table 4. Correlation between selected properties of soil and potassium quantity-intensity characteristics

Parameters	Sand	Silt	Clay	Organic carbon
ARE^K	0.183	-0.262	0.281	0.745**
K_L	0.236	-0.282	0.202	0.793**
Ko	0.292	-0.333	0.276	0.717**
Kx	0.194	-0.221	0.105	0.767**
PBC^K	-0.205	-0.158	-0.312	0.096**
ΔG	0.037	-0.331	0.016	0.163**

*Significant at 5%, **Highly significant at 1%

clay content in soil. Non-significant correlation between PBC^K and organic carbon was also reported by Jalali (2007). Niranjana *et al.* (2000) reported that soil with high clay content recorded higher PBC^K value. Buffering capacity of a soil depends primarily on the surface area available for ion exchange and to a lower degree on the character and charge density of soil surface. Since, major exchange surfaces in soil include inorganic clays and organic humic substances, it was expected that soil with relatively more crop residue and organic manure would exhibit higher PBC^K value than others. Correlation showed that whenever exchangeable sites were more in soils, intendency and capability of them for K adsorption was more. As a result, potential buffering capacity of soil would also increase. ΔG was positively correlated with organic carbon, sand, and clay content, while negatively correlated with silt content in soil. Positive correlation of ΔG with clay content of soil was also reported by Abaslou and Abtahi (2008).

The lack of significant positive relationship between PBC^K with soil parameters may be attributed to the relative high variation in the physico-chemical properties of the soils studied, which resulted in inconsistent PBC^K values (Panda and Patra, 2018). The significant positive correlation of ΔG with soil organic carbon indicated that increase in this and soil K^+ parameters resulted in increase in ΔG value in soil (Yawson *et al.*, 2011). The non-significant correlation of K_L with some soil parameters or forms of soil K indicated that selected soil variables and K^+ forms did not play any role in the combination of K_L , rather K^+ dynamics in these soil might be controlled by soil mineral constituents (Abaslou and Abtahi, 2008).

CONCLUSION

Some of the quantity-intensity characteristics were significantly correlated with each other. All the quantity-intensity parameters showed positive significant correlation with different form of K except PBC^K and ΔG . Among the various quantity-intensity parameters ARE^K , K_L , Ko and Kx exhibited positive significant correlation with grain and straw yield and K-uptake by wheat and also with organic carbon. The results implied that quantity-intensity parameters provide useful information for understanding K^+ availability in light textured sandy loam soil and can be used for K^+ fertilizer recommendation.

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Effect of integrated nutrient management on yield and nutrient uptake of sesame (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted with ten treatments, replicated thrice, in Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar to study the effect of integrated nutrient management on yield and nutrient uptake of sesame during *rabi* 2020. Maximum crop growth rate (9.29 g/m²/day) was observed within 45-60 DAS under STBFR+ lime @ 5q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5 t ha⁻¹ + NPK consortia @ 1 L ha⁻¹. The highest number of capsules plant⁻¹ (51.20), longer capsules (2.63 cm), highest number of seeds capsule⁻¹ (71.33), test weight (3.43g) and seed yield (830 kg ha⁻¹) were witnessed from integrated nutrient management practice of STBFR+ lime @ 5 q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5 t ha⁻¹ + NPK consortia 1 L ha⁻¹ closely followed by STBFR+ lime @ 5 q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5 t ha⁻¹ application and was significantly superior to all other treatments. Maximum uptake of N (19.53 and 27.33 kg ha⁻¹), P₂O₅ (8.74 and 13.91 kg ha⁻¹), K₂O (4.81 and 17.86 kg ha⁻¹) and S (12.45 and 16.92 kg ha⁻¹) in seed and stalk were observed under application of STBFR + lime @ 5 q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5 t ha⁻¹ + NPK consortia 1 L ha⁻¹, respectively.

Key words: STBFR, INM, CGR, RGR, nutrient uptake

Major sesame growing country is India. The diversity in agro-ecological conditions of the country is favourable for growing oilseed crops. Sesame (*Sesamum indicum* L.) is commonly called as til and is also known as “queen of oilseeds”. It belongs to family Pedaliaceae. Due to presence of antioxidants in sesame, it is also known as “seeds of immortality”. Out of different fatty acids of sesame, linoleic acid (35-45%), oleic acid (40-50%), palmitic and stearic acids are major constituents. Its oil is highly resistant to oxidative rancidity and is characterized for its stability and quality. In India, sesame is cultivated in an area of 16.22 lakh hectares with production of 6.57 lakh tonnes. The average productivity of the crop is 405 kg ha⁻¹ (Oilseed Division, Dept. of Agriculture & Farmers Welfare, 2019-20). Sesame is cultivated in one or more seasons, but nearly 75 per cent of annual average production comes from *kharif* season.

The major reasons for lower productivity of sesame are use of sub-optimal rate of fertilizers, poor management and cultivation of sesame in marginal and sub-marginal lands where deficiency of macronutrients and micronutrients are predominant. This indicates that there is a need to increase the productivity of sesame. Integrated use of organic and inorganic fertilizer materials in sesame were found to be promising not only in maintaining higher productivity but also in providing stability in crop production, besides

improving soil physical conditions (Deshmukh *et al.*, 2002 and Verma *et al.*, 2012). Deficiencies in secondary and micronutrients have been linked to the decline in productivity of intensive agricultural systems over time. Integrated use of inorganic and organic fertilizers in balanced proportion for sustainable production of sesame was emphasized by Duhoon *et al.* (2005). Sustainability of crop production is not possible either through use of organic manures or chemical fertilizers alone (Singh *et al.*, 2009). Chemical fertilisers alone increased agricultural yields in the initial year, but had a negative impact on long-term sustainability. Bio inoculants provide an alternate technique and several workers have reported beneficial results of incorporating bio-fertilizers on crop growth, yield and maintenance of soil fertility.

Azospirillum, an associative diazotroph, has been identified as potential microbial inoculant for increasing the productivity of various non-legume crops. *Azospirillum* increases dry matter production and yields in sesame (Verma *et al.*, 2012). *Azotobacter* is another important non-symbiotic N-fixing microorganism and considered to be very important for fixation of N in non-leguminous plants. In addition, it also secretes growth promoting substances like gibberellins, indole acetic acid, *etc.* Higher seed yield of sesame was obtained by integrated use of fertilizer along with FYM and *Azospirillum* (Purushottam, 2005 and Jaishankar and Wahab,

2005). Integrated approach in present investigation by using both organic and inorganic source of nutrients along with bio fertilizers could be a viable and suitable method to obtain higher yield with better quality oil.

MATERIALS AND METHODS

The experiment was conducted in Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar during *rabi* 2020. The experimental site was located at 20°26' North Latitude and 85° 80' East Longitude at an elevation of 25.9 meters above the mean sea level. The location comes under East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. Soil was sandy loam in texture, slightly acidic (pH5.70), low in organic carbon (0.47%), low in available nitrogen (238.5 kg ha⁻¹), high in available phosphorus (38.5 kg ha⁻¹) and medium in available potassium (261.4 kg/ha).

The sesame variety "Amrit" was sown on 29th September 2020 as *rabi* crop after harvesting early duration paddy under residual soil moisture conditions. The soil moisture during sowing time was 20.8 per cent. The experiment comprised of ten treatments T₁- Soil Test Based Fertilizer Recommendation (STBFR-50:20:20 N:P₂O₅:K₂O kg ha⁻¹), T₂- STBFR+ lime @ 5q ha⁻¹, T₃- STBFR+ gypsum @ 2.5 q ha⁻¹, T₄-STBFR + FYM @ 5 t ha⁻¹, T₅- STBFR+ NPK consortia @ 1 L ha⁻¹, T₆- STBFR+ lime @ 5q ha⁻¹ + gypsum @ 2.5q ha⁻¹, T₇- STBFR+ lime @ 5q ha⁻¹ + FYM @ 5t ha⁻¹, T₈- STBFR+ lime @ 5q ha⁻¹ + NPK consortia @1 L ha⁻¹, T₉- STBFR+ lime @ 5q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM@ 5t ha⁻¹ and T₁₀-STBFR+ lime @ 5q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5t ha⁻¹ + NPK consortia @1 L ha⁻¹, replicated thrice and laid out in Randomized Block Design. Seed inoculation with liquid NPK consortia containing bio fertilisers (*Azotobacter* or *Azospirillum*, PSB, KMB) was done @ 1 L ha⁻¹ and kept for 20 minutes under shade. The seeds were mixed with sand and line sown manually using seed rate 5 kg ha⁻¹.

Crop growth rate (CGR) is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was expressed as g /m²/day. RGR is an index of the amount of plant growth per unit dry weight of plant per time. It expresses the dry weight increase in time interval in relation to the initial weight and is expressed in g /g /day. It is also called efficiency index. It was proposed by Watson (1952).

Nitrogen content in plant sample was determined by modified Micro-Kjeldahl distillation method (Jackson, 1973) after digestion of 0.5 g of oven dried (70°C) finely ground seed and stalk samples separately. The phosphorus and potassium contents were determined after digestion of 0.5 g

stalk and 0.5g seed in mixture of nitric acid, sulphuric acid and perchloric acid and diluting the digested material after filtering to a standard solution. Phosphorus content was determined by vanadomolybdo phosphoric yellow colour method in Spectrophotometer and potassium by Flame photometer method (Jackson, 1973). The sulphur content in the digest of plant was determined by turbidimetric method using 0.15 per cent CaCl₂ extractant, 6.25 per cent nitric acid, barium chloride and gum acacia solution (Chesnin and Yein, 1951).

The nutrient content in seed and stalk obtained from plant analysis were multiplied with the seed and stalk yield to get the nutrient uptake (kg ha⁻¹).

All data were subjected to statistical analysis as per the procedure prescribed for Randomized Block Design (RBD) to obtain the analysis of variance (ANOVA) table. The treatment variations were tested for significance by 'F' test. The standard error of mean SEm (±) and critical difference (CD) at 5 per cent possibility level (P=0.05) were calculated (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The crop growth rate increased gradually with advancement of crop age reaching maximum within 45-60 DAS followed by a gentle decrease towards harvesting (Fig. 1). Different integrated nutrient management practices had significant effect on crop growth at all the growth stages. The maximum crop growth rate (9.29 g/m²/day) was observed within 45-60 DAS under STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹+ NPK consortia @1 L ha⁻¹ (T₁₀) being at par with T₉ (9.16g/m²/day), T₆ (9.00 g/m²/day) and T₇ (8.82 g/m²/day). The lowest value of CGR (5.59 g /m²/day) was recorded in STBFR treatment. This might be due to more synthesis of amino acids, increase in chlorophyll content and improvement in the photosynthetic activity which ultimately enhanced cell division and thereby increased the crop growth rate.

The relative growth rate showed a gradual increase in RGR within 45-60 DAS interval and a slight decline thereafter towards harvesting (Fig. 1). It was evident that integrated nutrient management practice of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹+ NPK consortia @1 L ha⁻¹ and STBFR + lime @5q ha⁻¹ + gypsum @2.5q ha⁻¹ + FYM @5t ha⁻¹ were found more effective than other treatments with maximum RGR of 0.068 g/g/day at interval of 45-60 DAS. During the same period the lowermost value of RGR (0.062 g/g/day) was recorded in STBFR (T₁) treatment. The influence of different integrated nutrient management practices on relative growth rate of sesame was significant

within 30-45 DAS, 45-60 DAS, 60-75 DAS, whereas it was non-significant within 75DAS- harvest (Fig. 1).

The data presented in Table 1 revealed that different integrated nutrient management practices influenced yield parameters of sesame significantly. The highest number of capsules plant⁻¹ (51.20), longer capsules (2.63 cm), highest number of seeds capsule⁻¹ (71.33) and test weight (3.43g) were witnessed from integrated nutrient management practice of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹+NPK consortia 1 L ha⁻¹ (T₁₀) closely followed by STBFR+ lime @ 5q ha⁻¹ + gypsum @ 2.5 q ha⁻¹+ FYM @ 5t ha⁻¹ application and was significantly superior to all the treatments. Only STBFR treatment (T₁) produced minimum number of capsule plant⁻¹ (27.13), lowest capsule length (2.07cm), number of seeds capsule⁻¹ (54.00) and minimum

test weight (3.05 g). The effect of yield parameters might be due to combined effect of organic, inorganic and bio-fertilizers as activities of meristematic tissues of the plant, increase in number and size of the cell, assimilation rate, enhanced branching and facilitated more flowers formation, later on adequate supply of metabolites and nutrients complementing to the demands of reproductive structures for their growth and development were enhanced. This ultimately led to increase in number of capsules, seeds per capsule in sesame plant. Similar results were observed by Jain *et al.* (2007), Lakhran *et al.* (2015), Kulkarni *et al.* (2019) and Parmar *et al.* (2020). The test weight of sesame was largely dependent on source (photosynthesis) and sink (seed) relationship, as it was directly related to nutrients. The results were in close similarity with those of Barik and Fulmali (2011). Application

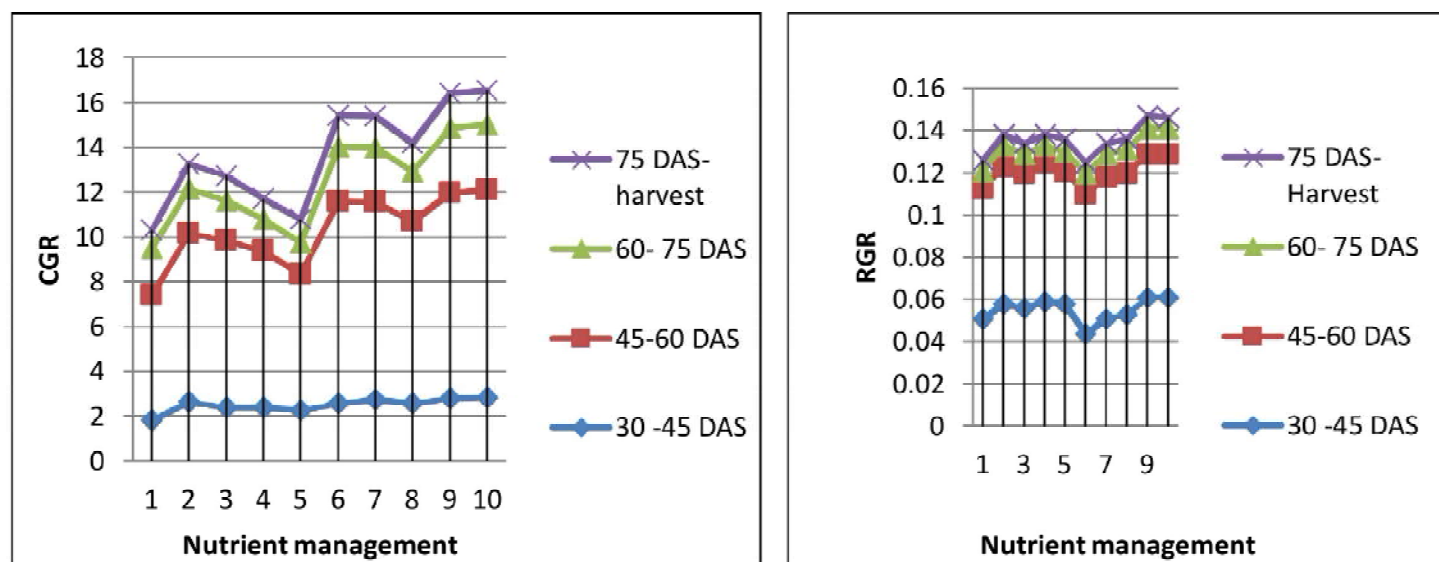


Fig. 1. Crop growth rate (g/m²/day) and relative growth rate (g/g /day) of sesame at different growth stages

Table 1. Yield attributing characters of sesame at harvest as influenced by integrated nutrient management practices

Treatments	No. of capsules plant ⁻¹	Length of capsule (cm)	No. of seeds capsule ⁻¹	Test weight (g)
T ₁ - Soil test based fertiliser recommendation (STBFR)	27.13	2.07	54.00	3.05
T ₂ - STBFR+ lime @ 5 q ha ⁻¹	38.37	2.33	61.20	3.14
T ₃ - STBFR+ gypsum @ 2.5 q ha ⁻¹	36.97	2.29	58.97	3.13
T ₄ - STBFR + FYM @ 5 t ha ⁻¹	34.53	2.25	57.77	3.11
T ₅ - STBFR+ NPK consortia @ 1 L ha ⁻¹	32.60	2.10	56.75	3.09
T ₆ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹	46.83	2.61	67.77	3.29
T ₇ - STBFR+ lime @ 5q ha ⁻¹ + FYM @ 5 t ha ⁻¹	44.43	2.54	64.50	3.23
T ₈ - STBFR+ lime @ 5q ha ⁻¹ + NPK consortia @ 1 L ha ⁻¹	42.70	2.56	62.87	3.15
T ₉ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹ + FYM @ 5t ha ⁻¹	48.93	2.58	69.47	3.36
T ₁₀ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹ + FYM @ 5t ha ⁻¹ + NPK consortia @ 1 L ha ⁻¹	51.20	2.63	71.33	3.43
SE m (±)	0.64	0.03	0.52	0.03
CD (P= 0.05)	1.90	0.10	1.55	0.09

of sulphur enhanced the uptake and translocation of food assimilates from source to sink effectively (Selvakumar *et al.*, 2012).

Integrated nutrient management practice of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ (T₁₀) produced maximum seed yield (830 kg ha⁻¹) followed by T₉ (810 kg ha⁻¹) being at par (Table 2). Similarly, STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹ (T₆) produced seed yield (780 kg ha⁻¹) being at par with T₇ (745 kg ha⁻¹). The minimum seed yield (490 kg ha⁻¹) was produced from STBFR treatment (T₁). The increase in yield due to STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ with NPK consortia @1 L ha⁻¹ (T₁₀) and without NPK consortia @1 L ha⁻¹ (T₉) was 69.39 and 65.31 per cent over STBFR (T₁). A variation in stalk yield from 1386 to 2152 kg ha⁻¹ was recorded in different treatments. Maximum stalk yield of 2152 kg ha⁻¹ was obtained in the integrated nutrient management practice of STBFR+ lime @ 5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ (T₁₀) which was at par with T₉ (2134 kg ha⁻¹) and T₆ (2081 kg ha⁻¹). The minimum stalk yield of 1386 kg ha⁻¹ was recorded in STBFR alone (T₁). No significant variation in harvest index was noticed due to different integrated nutrient management practices in sesame. The higher harvest index of 27.83 per cent was recorded with integrated nutrient management practice of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ (T₁₀) followed by T₉ (27.51%) and the lowest of 26.12 per cent from STBFR alone (T₁). Significantly higher seed yield (830 kg ha⁻¹) in combined application of STBFR+ lime @ 5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ might be due to balanced fertilization throughout the lifecycle of plants resulting in improvement of tissue differentiation from somatic to reproductive stage which helped in the formation of more flowers and number of capsules per plant thereby

resulting in increased seed yield of sesame. It was also stimulatory effect on the synthesis of chloroplast and protein, which promoted accelerated photosynthesis and enhanced the growth of sesame crop thereby increasing yield attributes. The above explanation was backed by findings of Takar *et al.* (2017), Maruthupandi and Jayanthi (2017) and Kulkarani *et al.* (2019). Only STBFR application produced minimum seed and stalk yield which might be due to less availability of nutrients and their translocation (Samant, 2020). Combined application of macro and micro-nutrients and sulphur also helped for higher yield (Sahu *et al.*, 2017). Application of sulphur improved plant metabolism and photosynthetic activity resulting in better growth and development of plant and ultimately led to higher seed yield. Higher stalk yield of sesame might be due to overall improvement in plant height and branches along with faster and uniform vegetative growth of the crop under the influence of integrated nutrient management treatments as compared to use of chemical fertilizers only.

Numerically higher harvest index (27.83%) in the sesame was found in combined application of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹. It might be due to the synergistic relationship between nutrients and balanced fertilization coupled with increased net photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures on the other hand, which might have increased the yield significantly (Lakhran *et al.*, 2015). These findings are corroborated with the findings of Javia *et al.* (2010).

The nitrogen uptake by stalk was distinctly higher than the uptake by seed. Maximum uptake of nitrogen was recorded in seed (19.53 kg ha⁻¹) with STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ (T₁₀) application and a minimum value (8.57 kg ha⁻¹) was due to STBFR treatment (Table 3). Similar trend of

Table 2. Seed yield, stalk yield and harvest index of sesame as influenced by integrated nutrient management practices

Treatments	Seed yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Harvest index (%)
T ₁ - Soil test based fertiliser recommendation (STBFR)	490	1386	26.12
T ₂ - STBFR+ lime @ 5q ha ⁻¹	620	1687	26.88
T ₃ - STBFR+ gypsum @ 2.5 q ha ⁻¹	590	1633	26.54
T ₄ - STBFR+ FYM @ 5 t ha ⁻¹	580	1614	26.43
T ₅ - STBFR+ NPK consortia @ 1 L ha ⁻¹	525	1467	26.35
T ₆ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹	780	2081	27.26
T ₇ - STBFR+ lime @ 5q ha ⁻¹ + FYM @ 5 t ha ⁻¹	745	2000	27.18
T ₈ - STBFR+ lime @ 5q ha ⁻¹ + NPK consortia @ 1 L ha ⁻¹	725	1965	26.92
T ₉ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹ + FYM @ 5 t ha ⁻¹	810	2134	27.51
T ₁₀ - STBFR+ lime @ 5q ha ⁻¹ + gypsum @ 2.5 q ha ⁻¹ +FYM @ 5 t ha ⁻¹ + NPK consortia @ 1 L ha ⁻¹	830	2152	27.83
SE m (±)	16.64	36.80	0.52
CD (P= 0.05)	49.43	109.33	NS

Table 3. Nutrient (N, P, K and S) uptake of sesame as influenced by integrated nutrient management practices

Treatments	Nitrogen uptake (kg ha ⁻¹)			Phosphorus uptake (kg ha ⁻¹)			Potassium uptake (kg ha ⁻¹)			Sulphur uptake (kg ha ⁻¹)		
	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total
T ₁ - Soil test based fertiliser recommendation (STBFR)	8.57	15.25	23.81	2.94	4.16	7.10	2.30	6.84	9.14	1.37	3.04	4.41
T ₂ - STBFR+ Lime @ 5 q ha ⁻¹	12.09	19.40	31.49	4.15	6.91	11.06	3.16	10.96	14.12	4.22	8.77	12.99
T ₃ - STBFR+ Gypsum @ 2.5 q ha ⁻¹	11.15	18.65	29.80	3.77	5.87	9.65	2.95	10.28	13.23	6.79	9.44	16.23
T ₄ - STBFR + FYM @ 5 t ha ⁻¹	10.50	18.07	28.57	3.60	5.16	8.76	2.84	9.52	12.36	3.01	7.47	10.48
T ₅ - STBFR+ NPK Consortia @ 1 lit ha ⁻¹	9.24	16.28	25.52	3.20	4.59	7.79	2.52	7.92	10.43	1.73	3.52	5.25
T ₆ - STBFR+ Lime @ 5 q ha ⁻¹ + Gypsum @ 2.5 q ha ⁻¹	17.47	25.18	42.65	6.63	11.23	17.86	4.13	16.14	20.27	9.98	14.77	24.75
T ₇ - STBFR+ Lime @ 5 q ha ⁻¹ + FYM @ 5 t ha ⁻¹	16.16	23.60	39.76	5.88	10.00	15.88	3.87	14.40	18.27	7.89	12.07	19.96
T ₈ - STBFR+ Lime @ 5 q ha ⁻¹ + NPK consortia @ 1 lit ha ⁻¹	15.56	22.79	38.35	5.39	9.03	14.42	3.91	13.55	17.47	6.16	11.00	17.16
T ₉ - STBFR+ Lime @ 5 q ha ⁻¹ + Gypsum @ 2.5 q ha ⁻¹ + FYM @ 5 t ha ⁻¹	18.42	26.74	45.16	7.58	12.80	20.53	4.52	17.28	21.80	10.93	16.05	26.98
T ₁₀ - STBFR+ Lime @ 5 q ha ⁻¹ + Gypsum @ 2.5 q ha ⁻¹ + FYM @ 5 t ha ⁻¹ + NPK consortia @ 1 lit ha ⁻¹	19.53	27.33	46.86	8.74	13.91	22.65	4.81	17.86	22.67	12.45	16.92	29.37
SE m (±)	0.10	0.22	0.28	0.07	0.23	0.21	0.02	0.09	0.09	0.16	0.24	0.30
CD (P=0.05)	0.31	0.67	0.84	0.20	0.68	0.63	0.07	0.26	0.25	0.48	0.70	0.90

observations on nitrogen uptake were also detected in the case of stalk. Total uptake of N ranged between 23.81 kg ha⁻¹ in STBFR to 46.86 kg ha⁻¹ in STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ treatments. These results were in line with the findings of Sahu *et al.* (2017) and Yadav *et al.* (2021). The higher N uptake might be due to the consequence of enhanced availability of nitrogen to the crop, greater biomass production, higher chlorophyll content and leaf nitrogen, escalating photosynthesis.

Uptake of phosphorus in stalk was distinctly higher than the uptake in seed. Maximum uptake of phosphorus in seed (8.74 kg ha⁻¹) was found in integrated application treatment T₁₀ and a minimum value (2.94 kg ha⁻¹) in STBFR treatment (Table 3). Similar pattern of phosphorus uptake was also observed in case of stalk. Total uptake of phosphorus ranged between 7.10 to 22.65 kg ha⁻¹. The increase in nutrients content and uptake by plant with the integrated application of STBFR, lime, gypsum, FYM and NPK consortia might be due to quickly build up of soil micro flora and fauna which has consequently increased the enzymatic activity and helped in mineralization, solubilisation of native and applied nutrients and making them available in the soil for plant uptake. Further, INM practice with FYM, lime, gypsum and bio-fertilizers improved the physical, chemical and biological environment of the soil which might have helped in vigorous growth of the plant. These findings were in close conformity with the results of Sahu *et al.* (2017), Mokariya *et al.* (2020) and Takar *et al.* (2017).

Maximum uptake of potassium in seed (4.81 kg ha⁻¹) was noted in response to integrated nutrient management practice of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ (T₁₀), while a minimum value of (2.30 kg ha⁻¹) in STBFR only (T₁). Similar trend of potassium uptake was also found in stalk, confined within the limits of 6.84 kg ha⁻¹ (minimum uptake) and 17.86 kg ha⁻¹ (maximum uptake). Total uptake of potassium ranged between 9.14 kg ha⁻¹ in T₁ treatment to 22.67 kg ha⁻¹ in T₁₀ treatment. Uptake in stalk was distinctly higher than the uptake in seed (Table 3).

The uptake of sulphur by stalk was higher as compared to seed (Table 3). S uptake in seed was marked by the lower limit of 1.37 kg ha⁻¹ and upper limit of 12.45 kg ha⁻¹, where as in stalk it ranged from 3.04 to 16.92 kg ha⁻¹. The combined application of STBFR+ lime @5q ha⁻¹+ gypsum @2.5q ha⁻¹+ FYM @5t ha⁻¹ + NPK consortia @1 L ha⁻¹ proved to be the significant one with maximum S uptake in seed (12.45 kg ha⁻¹) and stalk (16.92 kg ha⁻¹). Total sulphur uptake also followed similar trend i.e. maximum 29.37 kg ha⁻¹ in treatment and minimum (4.41 g ha⁻¹) in STBFR treatment. Purushottam (2005) concluded that sulphur has a great role in increasing the uptake in sesame. The results corroborate with the findings of Sahu *et al.* (2017) and Patel (2016).

CONCLUSION

It was concluded that the application of STBFR + lime @ 5 q ha⁻¹ + gypsum @ 2.5 q ha⁻¹ + FYM @ 5 t ha⁻¹ + NPK consortia @ 1 L ha⁻¹ was best for the overall growth of sesame.

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Genotypic and phenotypic correlation and path analysis studies in portulaca (*Portulaca oleracea* L.)

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ABSTRACT

The Experiment was conducted at Kittur Rani Channamma College of Horticulture, Arabhavi, UHS, Bagalkot during the year 2018-19. The experiment was laid out using randomized block design (RBD) with twenty five genotypes of portulaca and three replications. The observation on plant growth parameters indicated that, plant height has positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlation with foliage yield per plant ($r_P = 0.301$), number of leaves per plant ($r_P = 0.304$), number of branches per plant ($r_P = 0.613$), number of nodes ($r_P = 0.297$), stem girth ($r_P = 0.808$), fresh weight of plant ($r_P = 0.396$) and vitamin-A content ($r_P = 0.383$). It was also significantly (at $p = 0.05$) and positively correlation with secondary branches ($r_P = 0.268$). Number of leaves per plant had positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlated with foliage yield per plant ($r_P = 0.606$). Vitamin A content had positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlated with foliage yield per plant ($r_P = 0.352$) and found that negatively significant correlated with Iron ($r_P = 0.217$). Plant height had positive and significant correlation with foliage yield per plant ($r_g = 0.301$) and it had high positive and direct effect (4.54) on foliage yield per plant, it had high positive indirect effect through secondary branches (2.483), plant spread e-w (1.21), number of leaves (0.442) and number of branches (0.717).

Key words: Genotypic, phenotypic correlation, path analysis, *Portulaca oleracea*

Portulaca (*Portulaca oleracea* L.), an important underutilised leafy vegetable crop, belongs to family Portulacaceae with an chromosome number $2n=6x=54$. It has been originated in western Asia and Europe (Mitich, 1997).

Portulaca is a rich source of potassium ($494 \text{ mg } 100\text{g}^{-1}$) followed by magnesium ($68\text{mg } 100\text{g}^{-1}$) and calcium ($65\text{mg } 100\text{g}^{-1}$) and possesses the potential to be used as vegetable source of omega-3 fatty acid. It is very good source of alpha-linolenic acid (ALA) and gamma-linolenic acid (LNA) (4mg g^{-1} fresh weight) of any green leafy vegetable. It contains alpha-tocopherol and ascorbic acid (26.6 mg and $506 \text{ mg } 100\text{g}^{-1}$ of fresh and dry weight, respectively). The oxalate content of purslane leaves was reported in range of $671\text{--}869\text{mg } 100\text{g}^{-1}$ fresh weight. The antioxidant content and nutritional value of purslane are important for human consumption. It revealed tremendous nutritional potential and has indicated the potential use of this herb for the future (Kamal Uddin *et al.*, 2014). Due to its high nutritive and antioxidant properties purslane has been described as a "power food" (Alam *et al.*, 2014; Simopoulos *et al.*, 1995).

In India even though it is rich source of nutraceuticals, still being treated only as a weed and its cultivation as a

food crop and the effects of cultural conditions on its nutritional value is known very little. Estimation of the phylogenetic relationship and knowing the genetic diversity between genotypes in germplasm of any species is essential as it provides useful traits for further genetic development and increase selection efficiency. Genetic diversity in plant varieties can be estimated by observing the phenotypes of the plants and measuring the morphological characters which in turn lay foundation for breeding programs. Hence the present study on Genotypic and Phenotypic Correlation and Path analysis studies in portulaca (*Portulaca oleracea* L.), accessions collected from different location of Karnataka were undertaken.

MATERIAL AND METHODS

The experiment was conducted at research block of department of Vegetable Science at Kittur Rani Channamma College of Horticulture, Arabhavi, Belagavi district (Karnataka), UHS, Bagalkot during 2018-2019. The details twenty five genotypes mentioned in Table 1.

The experiment was laid out by using Randomized complete block design (RCBD) design with three replications.

Table 1. Details of portulaca genotypes collected from various locations of Karnataka

Sl. No.	Genotypes	Source
1	HUB-1	Mannali
2	HUB-2	Yakrana
3	HUB-3	Gouspur
4	HUB-4	Handikera
5	HUB-5	Halburga
6	HUB-6	Chandanahalli
7	HUB-7	Ghatbora
8	HUB-8	Ghatbora
9	HUB-9	Ghatbora
10	HUB-10	Ghatbora
11	HUB-11	Ghatbora
12	HUB-12	Ghatbora
13	HUB-13	Ghatbora
14	HUB-14	Ghatbora
15	HUB-15	Ghatbora
16	HUB-16	Ghatbora
17	HUB-17	Ghatbora
18	HUB-18	Bidar
19	HUB-19	Bidar
20	HUB-20	Bidar
21	HUB-21	Bidar
22	HUB-22	Bidar
23	HUB-23	Bidar
24	HUB-24	Bidar
25	HUB-25	Bidar

The genotypes were randomly assigned in each replication. During study, observations *viz.*, plant height, number of leaves, leaf area, number of branches, primary branches, secondary branches, plant spread E-W, plant spread N-S, stem girth, number of node, internode distance, number of flowers, days to first flowering, days to 50% flowering, number of inflorescence per plant, fresh weight of plant, dry weight of plant, foliage yield per plant, foliage yield per plot, foliage yield per hectare, 1000 seed weight, Vit-A, Vit-C, protein, calcium, magnesium content, iron content, oxalate, nitrates and chlorophyll were recorded the data was subjected to statistical analysis.

Genotypic (r_g) and phenotypic (r_p) correlation coefficients were estimated as suggested by Al-Jibourie *et al.* (1958).

$$\text{Genotypic correlation} = r_{xy}(g) = \frac{\text{Cov}_{xy}(G)}{\sqrt{V_x(G) \times V_y(G)}}$$

$$\text{Phenotypic correlation} = r_{xy}(p) = \frac{\text{Cov}_{xy}(P)}{\sqrt{V_x(P) \times V_y(P)}}$$

Where,

$\text{Cov}_{xy}(G)$ = Genotypic covariance between x and y

$\text{Cov}_{xy}(P)$ = Phenotypic covariance between x and y

$V_x(G)$ = Genotypic variance of character 'x'

$V_x(P)$ = Phenotypic variance of character 'x'

$V_y(G)$ = Genotypic variance of character 'y'

$V_y(P)$ = Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table r values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$$r_{1y} = a + r_{12}b + r_{13}c + \dots + r_{1li}$$

$$r_{2y} = a + r_{21}a + b + r_{23}c + \dots + r_{2li}$$

$$r_{3y} = r_{31}a + r_{32}b + c + \dots + r_{3li}$$

$$r_{ly} = r_{l1}a + r_{l2}b + r_{l3}c + \dots + I$$

Where,

r_{1y} to r_{ly} = Co-efficient of correlation between causal factors 1 to l with dependent characters y.

r_{12} to r_{li} = Co-efficient of correlation among causal factors

a, b, c, ..., i = Direct effects of characters 'a' to 'i' on the dependent character 'y'

Residual effect (R) was computed as follows.

$$\text{Residual effect (R)} = 1 - \sqrt{a^2 + b^2 + c^2 + \dots + i^2 + 2abr_{12} + 2acr_{13} + \dots}$$

RESULTS AND DISCUSSION

Plant height was found to have a positive and significantly (both at $p = 0.01$ and $p = 0.05$) association with foliage yield per plant ($rP = 0.301$), number of leaves per plant ($rP = 0.304$), number of branches per plant ($rP = 0.613$), number of nodes ($rP = 0.297$), stem girth ($rP = 0.808$), fresh weight of plant ($rP = 0.396$), vitamin-A content ($rP = 0.383$). It was also significantly (at $p = 0.05$) and positively associated with secondary branches ($rP = 0.268$). It was also positively but non significantly correlated with leaf area ($rP = 0.187$), number of flowers ($rP = 0.193$), dry weight of plant ($rP = 0.199$) and also it was negatively and non significant correlated with plant spread E-W ($rP = 0.591$), plant spread

Table 2. Genotypic correlation coefficients among growth, yield and quality parameters in portulaca genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	rG
1	1	0.304**	0.187	0.613**	0.268*	0.297**	-0.136	-0.045	0.808**	0.193	0.396**	0.199	0.383**	-0.052	0.301**
2		1	-0.053	0.510**	0.360**	0.345**	0.456**	0.421**	0.425**	-0.065	0.187	0.057	0.427**	-0.547**	0.606**
3			1	0.204	0.575**	0.569**	0.247*	0.415**	0.417**	0.184	0.470**	0.325**	0.405**	-0.236*	0.154
4				1	0.387**	0.524**	0.353**	0.457**	0.642**	-0.028	0.327**	0.278*	0.499**	-0.129	0.339**
5					1	0.965**	0.557**	0.646**	0.674**	0.133	0.441**	0.256*	0.501**	-0.363**	0.432**
6						1	0.643**	0.723**	0.644**	0.281*	0.424**	0.198	0.486**	-0.189	0.466**
7							1	0.930**	0.095	0.243*	0.135	0.065	0.215	-0.144	0.366**
8								1	0.285*	0.337**	0.384**	0.130	0.374**	-0.143	0.453**
9									1	0.148	0.468**	0.183	0.521**	-0.298**	0.548**
10										1	0.231*	-0.225*	0.065	0.372**	0.271*
11											1	0.513**	0.541**	-0.260*	0.561**
12												1	0.482**	-0.406**	0.230*
13													1	-0.217	0.352**
14														1	-0.355**
15															1

*Significant at 5%

**Significant at 1%

rG- Genotypic correlation with foliage yield per plant

Residual effect = 0.5831

1. Plant height (cm)

2. Number of leaves per plant

3. Leaf area (cm²)

4. Number of branches

5. Secondary branches

6. Number of node

7. Plant spread E-W (cm)

8. Plant spread N-S (cm)

9. Stem girth (mm)

10. Number of flower

11. Fresh weight (g)

12. Dry weight (g)

13. Vitamin-A (mg)

14. Fe (mg)

N-S ($r_P = 0.045$), and Iron ($r_P = 0.052$). Similar observations were made by Sarker *et al.* (2014), Khurana *et al.* (2013), Ahmmed *et al.* (2012) for plant height. Number of leaves per plant had positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlated with foliage yield per plant ($r_P = 0.606$), number of branches ($r_P = 0.510$), secondary branches ($r_P = 0.360$), number of nodes (0.345), plant spread E-W ($r_P = 0.456$), plant spread N-S ($r_P = 0.421$), stem girth ($r_P = 0.425$) and vit-A ($r_P = 0.427$). It was also significant (both at $p = 0.01$ and $p = 0.05$). Similar observations were made by Sarker *et al.* (2014), Khurana *et al.* (2013) for number of leaves per plant. Leaf area had positive and non significantly correlated with foliage yield per plant ($r_P = 0.154$), plant spread E-W ($r_P = 0.247$), plant spread N-S (0.415), stem girth ($r_P = 0.417$), fresh weight of plant ($r_P = 0.470$), dry weight of plant ($r_P = 0.325$), vitamin-A ($r_P = 0.405$). It was also significantly (at $p = 0.05$) but negative associated with Iron ($r_P = 0.236$). Results agree the findings of Khurana *et al.* (2013) for leaf area. Number of branches had positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlated with foliage yield per plant ($r_P = 0.339$), stem girth ($r_P = 0.642$), fresh weight of plant ($r_P = 0.327$) and vitamin-A ($r_P = 0.499$). It was also significantly (at $p = 0.05$) and positively associated with dry weight of plant ($r_P = 0.278$). This results Confirms the findings of Sarker *et al.* (2014).

Fresh weight had Positive and significant (both at $p = 0.01$ and $p = 0.05$) correlation was found for foliage yield per plant ($r_P = 0.561$), dry weight ($r_P = 0.513$), and vit-A ($r_P = 0.541$). It was also significant but negatively correlated with Iron ($r_P = 0.260$). Dry weight had Positive and significant ($p = 0.05$) correlation was found for foliage yield per plant ($r_P = 0.230$) and vit-A ($r_P = 0.482$). It was also significant (both at $p = 0.01$ and $p = 0.05$) but negatively correlated with Iron ($r_P = 0.406$). Vitamin A content had positive and significantly (both at $p = 0.01$ and $p = 0.05$) correlated with foliage yield per plant ($r_P = 0.352$) and found that negatively significant correlated with Iron ($r_P = 0.217$). Iron had significant (both at $p = 0.01$ and $p = 0.05$) but negatively correlated with foliage yield per plant ($r_P = 0.355$). Similar results were also obtained by Kujur (2015) for foliage yield per plot; Similar results were obtained by Singh *et al.* (2015) in fenugreek.

Plant height had positive and significant correlation with foliage yield per plant ($r_g = 0.301$) and it had high positive and direct effect (4.54) on foliage yield per plant, it had high positive indirect effect through secondary branches (2.483), plant spread e-w (1.21), number of leaves (0.442) and number of branches (0.717). These results are in accordance with the findings of Balai *et al.* (2006), Mathur (1996) and Mishra (2016) in fenugreek. Number of leaves per plant had positive and significant correlation with foliage yield per plant ($r_g =$

Table 3. Genotypic path coefficient analysis for yield and its components in portulaca genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	rG
1	4.544	0.442	-0.044	0.717	2.483	-1.736	1.211	-0.406	-5.917	0.148	-0.772	0.030	-0.403	0.005	0.301**
2	1.382	1.452	0.013	0.597	3.340	-2.018	-4.051	3.806	-3.116	-0.050	-0.365	0.008	-0.449	0.057	0.606**
3	0.851	-0.077	-0.236	0.239	5.331	-3.332	-2.191	3.750	-3.053	0.141	-0.916	0.049	-0.426	0.025	0.154
4	2.786	0.741	-0.048	1.169	3.584	-3.065	-3.136	4.135	-4.700	-0.021	-0.637	0.042	-0.525	0.014	0.339**
5	1.217	0.523	-0.135	0.452	9.271	-5.645	-4.945	5.844	-4.940	0.102	-0.860	0.038	-0.527	0.038	0.432**
6	1.348	0.501	-0.134	0.612	8.943	-5.852	-5.704	6.542	-4.718	0.216	-0.827	0.030	-0.511	0.020	0.466**
7	-0.620	0.663	-0.058	0.413	5.166	-3.761	-8.875	8.412	-0.695	0.186	-0.263	0.010	-0.226	0.015	0.366**
8	-0.204	0.611	-0.098	0.535	5.991	-4.233	-8.254	9.044	-2.089	0.258	-0.749	0.019	-0.393	0.015	0.453**
9	3.671	0.617	-0.098	0.750	6.253	-3.769	-0.842	2.579	-7.325	0.113	-0.913	0.027	-0.548	0.031	0.548**
10	0.876	-0.095	-0.043	-0.033	1.231	-1.647	-2.156	3.045	-1.082	0.766	-0.450	-0.034	-0.068	-0.039	0.271*
11	1.798	0.272	-0.111	0.382	4.089	-2.482	-1.197	3.475	-3.428	0.177	-1.950	0.077	-0.569	0.027	0.561**
12	0.903	0.082	-0.076	0.325	2.378	-1.159	-0.574	1.178	-1.340	-0.172	-1.000	0.149	-0.507	0.043	0.230*
13	1.742	0.620	-0.095	0.584	4.648	-2.843	-1.905	3.380	-3.817	0.050	-1.055	0.072	-1.052	0.023	0.352**
14	-0.234	-0.795	0.056	-0.151	-3.363	1.107	1.281	-1.295	2.184	0.285	0.507	-0.061	0.228	-0.105	-0.355**

Diagonal indicates direct effect *Significant at 5% **Significant at 1% rG- Genotypic correlation with foliage yield per plant
Residual effect = 0.5831

- | | |
|-------------------------------|----------------------|
| 1. Plant height | 8. Plant spread N-S |
| 2. Number of leaves per plant | 9. Stem girth |
| 3. Leaf area | 10. Number of flower |
| 4. Number of branches | 11. Fresh weight |
| 5. Secondary branches | 12. Dry weight |
| 6. Number of node | 13. Vitamin-A |
| 7. Plant spread E-W | 14. Fe |

Table 4. Phenotypic path coefficient analysis for yield and its components in portulaca genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	rG
1	-0.2650	0.1054	-0.0298	-0.0753	-0.0420	0.0524	-0.0086	0.0012	0.3482	0.0394	0.1604	0.0228	-0.0331	0.0012	0.277*
2	-0.0635	0.4400	0.0025	-0.0608	-0.0599	0.0608	0.0285	-0.0114	0.1717	-0.0127	0.0759	0.0065	-0.0277	0.0123	0.562**
3	-0.0426	-0.0060	-0.1855	-0.0254	-0.0940	0.1010	0.0141	-0.0114	0.1639	0.0348	0.1808	0.0351	-0.0311	0.0053	0.139
4	-0.1457	0.1955	-0.0345	-0.1370	-0.0635	0.1028	0.0200	-0.0130	0.2710	-0.0045	0.1244	0.0316	-0.0395	0.0030	0.311**
5	-0.0570	0.1350	-0.0893	-0.0445	-0.1954	0.1664	0.0312	-0.0172	0.2597	0.0231	0.1652	0.0282	-0.0373	0.0080	0.376**
6	-0.0706	0.1359	-0.0952	-0.0715	-0.1652	0.1969	0.0380	-0.0211	0.2825	0.0576	0.1630	0.0234	-0.0393	0.0046	0.439**
7	0.0348	0.1925	-0.0402	-0.0420	-0.0935	0.1149	0.0652	-0.0256	0.0403	0.0464	0.0456	0.0074	-0.0151	0.0033	0.334**
8	0.0108	0.1685	-0.0709	-0.0597	-0.1128	0.1394	0.0561	-0.0298	0.1272	0.0696	0.1558	0.0159	-0.0316	0.0035	0.442**
9	-0.1918	0.1570	-0.0632	-0.0771	-0.1055	0.1156	0.0055	-0.0079	0.4811	0.0291	0.1767	0.0211	-0.0407	0.0068	0.507**
10	-0.0500	-0.0267	-0.0309	0.0030	-0.0217	0.0543	0.0145	-0.0099	0.0670	0.2088	0.0946	-0.0269	-0.0051	-0.0091	0.262*
11	-0.1024	0.0804	-0.0808	-0.0410	-0.0778	0.0773	0.0072	-0.0112	0.2048	0.0476	0.4151	0.0619	-0.0451	0.0063	0.542**
12	-0.0488	0.0231	-0.0525	-0.0349	-0.0445	0.0371	0.0039	-0.0038	0.0818	-0.0453	0.2074	0.1239	-0.0394	0.0098	0.218
13	-0.0998	0.1387	-0.0656	-0.0615	-0.0829	0.0879	0.0112	-0.0107	0.2227	0.0121	0.2129	0.0556	-0.0879	0.0052	0.338**
14	0.0131	-0.2204	0.0402	0.0169	0.0633	-0.0366	-0.0087	0.0042	-0.1336	0.0772	-0.1060	-0.0492	0.0184	-0.0246	-0.346**

Diagonal indicates direct effect *Significant at 5% **Significant at 1% rG- Genotypic correlation with foliage yield per plant
Residual effect = 0.5700

- | | |
|-------------------------------|----------------------|
| 1. Plant height | 8. Plant spread N-S |
| 2. Number of leaves per plant | 9. Stem girth |
| 3. Leaf area | 10. Number of flower |
| 4. Number of branches | 11. Fresh weight |
| 5. Secondary branches | 12. Dry weight |
| 6. Number of node | 13. Vitamin-A |
| 7. Plant spread E-W | 14. Fe |

0.606) and it had high positive and direct effect (1.45) on foliage yield per plant, it also had high positive and indirect effect through number of branches per plant (0.523), foliage yield per hectare (0.453), vitamin-C (0.446), plant spread N-

S (0.441), foliage yield per plot (0.418) and plant height (0.394). Similar observations made by Kujur (2015). Leaf area plant had positive and non significant correlation with foliage yield per plant ($r_g=0.154$) and it had high positive and direct

effect (-0.236) on foliage yield per plant, it also had high positive and indirect effect through secondary branches (5.331), plant spread N-S (3.750), plant height (0.851), number of branches per plant (0.239), number of flowers (0.141). Similar observations made by Kujur (2015). Number of branches per plant had positive and significant correlation with foliage yield per plant ($r_g = 0.339$) and it had high positive and direct effect (1.169) on foliage yield per plant, it also had high positive and indirect effect through plant height (2.78), secondary branches (3.584), plant spread N-S (4.135), number of branches (1.169) number of leaves (0.741). Similar observations made by Kole (2004), Singh and Pramila (2009) and Gangopadhyay *et al.* (2009). Dry weight of plant had positive and significant correlation with foliage yield per plant ($r_g = 0.230$) and it had high negative and direct effect (0.149) on foliage yield per plant, it had high positive indirect effect through secondary branches (2.37), plant spread N-S (1.178), plant height (0.903), number of branches per plant (0.325), number of leaves per plant (0.0.082), and iron (0.043). Similar results are reported by Mamatha *et al.* (2017). Vit- A content had positive and significant correlation with foliage yield per plant ($r_g = 0.352$) and it had high negative and direct effect (-1.05) on foliage yield per plant, it had high positive indirect effect through secondary branches (4.64), plant spread N-S (3.38), plant height (1.742), number of leaves per plant (0.620), number of branches per plant (0.584), number of flowers (0.050), dry weight of plant (0.072) and iron (0.023). Iron content had negatively and significant correlation with foliage yield per plant ($r_g = -0.355$) and it had high negative and direct effect (-0.105) on foliage yield per plant, it had high positive indirect effect through leaf area (0.056), number of node (1.107), plant spread E-W (1.28), stem girth (2.18), number of flowers (0.285), fresh weight of plant (0.507) and vit- A (0.228).

CONCLUSION

The experiment conducted with 25 portulaca varieties conclude that the portulaca plant height has significant and positive (both at $p = 0.01$ and $p = 0.05$) correlation with foliage yield, number of leaves and number of branches plant⁻¹ number of shades, stem girth, weight of plant and the vitamin content etc.

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AMMI analysis nested with BLUP for stability analysis of barley genotypes evaluated at Northern Hills Zone of the country

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ABSTRACT

Highly significant effects of environments (E), GxE interaction and genotypes (G) had expressed by AMMI analysis for problem soils under coordinated barley improvement program of the country. Interaction effects GxE accounted for 52.4% & 30.5% and environment effects explained 19.4% & 50.3% during cropping seasons of 2018-19 and 2019-20 respectively. Stability measure WAASB based on all significant interaction principal components ranked suitability of UPB1077, BHS400, HBL851 genotypes. Superiority index while weighting 0.65 and 0.35 for mean yield & stability ranked VLB162, BHS400, HBL113 as of stable performance with high yield barley genotypes. ASTAB measure achieved the desirable lower values for BHS474, HBL113, VLB 162. Composite measure MASV1 found BHS474, HBL113, VLB162 and as per MASV ranks BHS474, HBL113, HBL863 genotypes would be of choice for these locations of the zone. Biplot graphical analysis as per 66.3% of variation of the stability measures exhibited MASV1 clubbed with ASTAB, EV, SIPC, Za, W3, WAASB and MASV measures. Yield based measures clubbed with corresponding SI measures. For the second-year lower value of WAASB measure had observed for BHS481, BHS400, BHS352 whereas large value by HBL867. Ranking of genotypes as per Superiority index found BHS482, HBL113, VLB168 as of stable performance with high yield. Barley genotypes HBL113, VLB168, VLB166 were selected as per values of ASTAB measure accounted the AMMI analysis with BLUP of genotypes yield values. Composite measure MASV1 selected HBL113, VLB168, HBL867 while HBL113, VLB168, HBL867 identified by MASV as genotypes of choice for these locations of the zone. 73.1% of variation of the stability measures in biplot analysis observed MASV1 clubbed with ASTAB, EV, SIPC, Za, W3, WAASB and MASV measures. Average yield measures clubbed with corresponding SI measures.

Keywords: AMMI, MASV, ASTAB, WAASB, SSI

Barley (*Hordeum vulgare* L.) was domesticated about 10,000 years ago and placed at the fourth position in the world agriculture scenario (Kendel et al, 2019). Mainly cultivated not only for food, bio-fuel and animal feed but used as raw material for malt and malt-based products (Kharub et al, 2017). More emphasis given to consume barley and barley-based products by the health-conscious consumers (Karkee et al, 2020). As grains consist of ample quantity of β -glucan, an important constituent to decrease the sugar of diabetic patients, reduce the serum cholesterol of heart patients and decrease the risk of coronary heart disease (Shimizu et al, 2008). GxE interactions under multi location trials had been estimated to select/identify productive and stable genotypes to sustain the production (Agahi et al 2020). Most of the GxE pattern retained by AMMI analysis in the first interaction principal component axes (Gauch 2013). BLUP proved the potential to improve the predictive accuracy of random effects (Piepho et al 2008). BLUP and AMMI, two distinct approaches, utilized to distinguish the pattern from the

random error components in GxE interactions. The benefits of AMMI and BLUP, had incorporated into a measure Superiority Index for the stability and adaptability performance of genotypes (Olivoto et al 2019). The behaviour of Superiority measures had been compared with other AMMI based measures for barley genotypes evaluated under the Northern Hills Zone of the country.

MATERIALS AND METHODS

Northern hills zone encompasses the hilly terrain of Northern region extending from Jammu & Kashmir to North Eastern States. NHZ comprises J&K (except Jammu and Kathua distt.); Himachal Pradesh (except Una and Paonta Valley); Uttarakhand (except Tarai area); Sikkim, hills of West Bengal and North Eastern states. Sixteen advanced genotypes at seven locations and eighteen genotypes at five locations were evaluated under research field trials during 2018-19 and 2019-20 cropping seasons respectively. Field trials were conducted at research centers in randomized

complete block designs with four replications. Recommended agronomic practices were followed to harvest good yield. Details of genotype parentage along with environmental conditions were reflected in tables 1 & 2 for ready reference.

Stability measure as Weighted Average of Absolute Scores calculated as

$$WAASB = \sum_{k=1}^p |IPCA_{ik} \times EP_k| / \sum_{k=1}^p EP_k$$

where $WAASB_i$ was the weighted average of absolute scores of the i th genotype (or environment); $IPCA_{ik}$ the score of the i th genotype (or environment) in the k th IPCA, and EP_k was the amount of the variance explained by the k th IPCA. Superiority index allowed variable weightage between yield and WAASB to select genotypes that combined high performance and stability as

$$SI = \frac{(rG_i \times \theta_Y) + (rW_i \times \theta_S)}{(\theta_Y + \theta_S)};$$

where rG_i and rW_i were the rescaled values for yield and WAASB, respectively, for the i th genotype; G_i and W_i were the yield and WAASB for i th genotype. SI superiority index for the i th genotype weighted between yield and stability, and θ_Y and θ_S were the weights for yield and

stability would be of order 65 and 35 respectively for present study,

AMMI analysis was performed using AMMISOFT version 1.0, available at <https://scs.cals.cornell.edu/people/hugh-gauch/> and SAS software version 9.3.

RESULTS AND DISCUSSION

AMMI analysis of barley genotypes

First year of study 2018-19

AMMI analysis had observed highly significant GxE interaction, environment (E) and genotypes (G) effects. Environment explained about significantly 19.4% of the total sum of squares due to treatments indicating that diverse environments caused most of the variations in genotypes yield (Table 3). Significant proportion of GxE interaction deserves the stability estimation of genotypes over environments (Ajay et al 2020). Genotypes explained only 9.3% of total sum of squares, whereas GxE interaction accounted for 52.4% of treatment variations in yield. More of GxE interaction sum of squares as compared to genotypes indicated the presence of genotypic differences across environments and complex GxE interaction for yield. Partitioning of GxE interaction revealed that the first six multiplicative terms (IPCA1, IPCA2, IPCA3, IPCA4, and IPCA5) of AMMI were highly significant and explained

Zobel	Averages of the squared eigenvector values	$EV = \sum_{n=1}^N \lambda_{in}^2 / n$
Sneller et al	Sums of the absolute value of the IPC scores	$SIPC = \sum_{n=1}^N \lambda_n^{0.5} \gamma_{in}$
Rao and Prabhakaran	AMMI based stability parameter	$ASTAB = \sum_{n=1}^n \lambda_n \gamma_{ni}^2$
Zali et al	Modified AMMI stability Value	$MASV = \sqrt{\sum_{n=1}^{N-1} \frac{SSIPC_n}{SSIPC_{n+1}} (PC_n)^2 + (PC_{n+1})^2}$
Zali et al	Absolute value of the relative contribution of IPCs to the interaction	$Z_a = \sum_{n=1}^N \lambda_n \gamma_{in} $
Ajay et al	MASV1	$MASV1 = \sqrt{\sum_{n=1}^{N-1} \left(\frac{SSIPC_n}{SSIPC_{n+1}} PC_n \right)^2 + (PC_{n+1})^2}$
Olivato	Superiority Index	$SI = \frac{(rG_i \times \theta_Y) + (rW_i \times \theta_S)}{(\theta_Y + \theta_S)}$

Table 1: Parentage details of barley genotypes and environmental conditions (2018-19)

Code	Genotype	Parentage	Code	Location	Latitude	Longitude	Altitude
G1	VLB 161	INBON-54 (2015-16)	E1	Almora	29° 35' N	79° 39'E	1610
G2	UPB 1082	UPB 1008/ RD 2794	E2	Bajaura	31°50'N	77°9'E	1103.85
G3	HBL 863	HBL 276/ Dyar Local	E3	Berthin	31°50'N	77°9'E	1103
G4	HBL 113	SELECTION FROM ZYPHYZE	E4	Kangra	32.10	76.27	672
G5	VLB 163	TR145/195039 H97054003 09/6T0007	E5	Katraain	25.40	76.07	2756
G6	VLB 164	VMORALES P.STO/3/LIBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA_1	E6	Majhera	29° 16' N	80° 5' E	1532
G7	BHS 477	BHS 369 / HBL 113	E7	Malan	32°08' N	76°35'E	846
G8	BHS 475	BHS 385 / HBL 113//BHS 169	E8	Shimla	31°10' N	77°17'E	2276
G9	BHS 474	BLG 132 / BHS 369					
G10	VLB 162	ALELI/ESCOBA/3/ARUPO/K8755//MORA/4/CANELA/5/MSEL					
G11	HBL 845	HBL 113 /HBL 276					
G12	UPB 1077	AHOR1489.58//GLORIA-BAR/COPAL/3/PRO-/4/CAPUL/TOCTE/5/ICARO					
G13	UPB 1078	BLLU/CANICAPA					
G14	HBL 848	IBON-72 (EIBGN 2015-16)					
G15	BHS 472	BHS 365 /BHS 169					
G16	VLB 118	14th EMBSN-9313					
G17	HBL 851	IBON-59 (EIBGN 2015-16)					
G18	HBL 858	HBL 316 /Dolma					
G19	BHS 400	34th IBON-9009					
G20	BHS 352	HBL240/BHS504//VLB129					
G21	BHS 476	BHS 365 /BHS 169					

Table 2: Parentage details of barley genotypes and environmental conditions (2019-20)

Code	Genotype	Parentage	Code	Location	Latitude	Longitude	Altitude
G1	HBL867	WI3167/6/ANCA/2469//TOJI/3/SHYRI/4/ATACO/5/ALELI/7/Arar/Ligne e527//Zy /DL69	E1	Almora	29° 35' N	79° 39'E	1610
G2	BHS478	BHS385/BHS369	E2	Bajaura	31°50'N	77°9'E	1103.85
G3	VLB166	CABUYA/MJA//PETUNIA1/5/PENCO/CHEVRON-BAR/3/ATACO/BERMEJO //HIGO/4/PETUNIA 1	E3	Berthin	31°50'N	77°9'E	1103
G4	HBL868	(CABUYA/MJA//PETUNIA1/5/PENCO/CHEVRON-BAR/3/ATACO/BERMEJO //HIGO/4/PETUNIA1	E4	Kangra	32.10	76.27	672
G5	UPB1085	TOCTE/PETUNIA 2//PETUNIA1	E5	Katraain	25.40	76.07	2756
G6	BHS352	HBL240/BHS504//VLB129	E6	Majhera	29° 16' N	80° 5' E	1532
G7	BHS481	BHS369/HBL113	E7	Malan	32°08' N	76°35'E	846
G8	BHS482	BHS385/BHS369	E8	Rajauri	28.64	77.12	913
G9	VLB169	Barque/Arta	E9	Shimla	31°10' N	77°17'E	2276
G10	HBL866	HBL 276 / HBL 113					
G11	UPB1084	UPB 1021/DWRB 107					
G12	HBL113	SELECTION FROM ZYPHYZE					
G13	HBL865	HBL 113 / HBL 316					
G14	VLB168	CANELA/5/PENCO/CHEVRON-BAR					
G15	UPB1083	RD 2552 / DWRUB 73					
G16	VLB118	14th EMBSN-9313					
G17	BHS479	BBM556/BHS169//BHS369					
G18	VLB167	ALANDA//LIGNEE527/ARAR/3/BF891M-653/4/GIZA130					
G19	HBL864	HBL 113 / Dolma					
G20	BHS480	BLG132/BHS369					
G21	BHS400	34th IBON-9009					
G22	VLB165	TOCTE/PETUNIA 2//PETUNIA 1					

34.7%, 23.5%, 15.1%, 11.6%, 9.7% and 4.1% of interaction sum of squares, respectively. Total of significant components were 98.7% and remaining 1.3% was the residual or noise that discarded (Oyekunle et al 2017).

Second year of study 2019-20

Highly significant effects of environment (E), GxE interaction and genotypes (G) had been achieved by analysis for multi-location evaluation of barley genotypes. Environment explained to the tune of 50.3%; GxE interaction accounted for 30.5% whereas Genotypes contributed only 9.6% of total treatment variations in yield (Table 3). Further analysis of GxE interaction observed seven highly significant multiplicative terms (IPCA1, IPCA2, IPCA3, IPCA4, IPCA5, IPCA6 and IPCA7) contributed about 41.3%, 15.8%, 14.4%, 11.2%, 8.4%, 4.2% and 3.3% of interaction sum of squares, respectively. Total of these components were to the tune of 98.4% and remaining was noise that was discarded.

Ranking of barley genotypes as per AMMI based stability measures

First year of study 2018-19

Least value of absolute IPCA1 expressed by HBL845, HBL858, BHS476 and higher value achieved by UPB1077 (Table 5). Low values of (EV) associated with stable behaviour, the genotypes HBL858 followed by BHS474, HBL845 expressed lower values and maximum value by BHS472 genotype. Measure SIPC identified HBL 858 followed by BHS474, HBL 845 as of stable nature, whereas UPB1077 would be of least stable type. Za measure considered absolute value of the relative contribution of IPCs to the interaction revealed HBL858, BHS 474, and HBL 845 as genotypes with descending order of stability, whereas UPB1077 genotype with the least stability. ASTAB measure

observed genotypes HBL858, BHS 474 and HBL845 as stable and UPB 1077 was least stable in this study (Rao & Prabhakaran 2005). All significant IPCAs had been considered by MASV1 and MASV measures. Values of MASV1 showed that the genotypes, HBL858, BHS474 and HBL845 were most stable and HBL858, BHS 474 & HBL845 would be stable by MASV measure respectively (Ajay et al 2019). Measure W1 favoured UPB1077, BHS477, UPB1082 while as per W2, genotypes identified were VLB161, UPB1077, BHS477 while W3 favoured UPB1077, HBL851, VLB161 whereas values of measure W4 settled for UPB1077, BHS400, VLB161. Genotypes UPB1077, BHS400, BHS472 had pointed out by W5 and W6 settled for UPB1077, BHS 400, HBL851 genotypes. Finally lower values of WAASB associated with stable nature of UPB1077, BHS400, HBL851 genotypes as for considered locations of the zone at the same time maximum deviation from the average performance across environments obtained by HBL 858.

Second year of study 2019-20

Genotypes VLB169, UPB1084, HBL864 expressed least absolute values of IPCA1 measure and higher value achieved by BHS481 (Table 6). Stable behaviour of HBL867, HBL866, HBL864 genotypes anticipated as per minimum values of EV measure and maximum value had by VLB118 genotype. HBL867, HBL866, followed by HBL864 identified for the lower value SIPC measure, whereas BHS481 would be of least stable behaviour. Preference order of genotypes HBL867, HBL864, HBL866 revealed by Za measure in descending order of stability, whereas BHS481 would express the least stability. ASTAB measure observed genotypes HBL867, VLB166, and HBL864 as the stable whereas BHS481 genotype was of least stable performance (Rao & Prabhakaran 2005). HBL867, HBL866, HBL864

Table 3: AMMI analysis and percentage contribution of significant interaction principal components (2018-19)

Source	Degree of freedom	Mean Sum of Squares	Level of significance	Proportional contribution of factors	GxE interaction Sum of Squares (%)	Cumulative Sum of Squares (%) by IPCA's
Treatments	167	108.38	***	87.54		
Genotype (G)	20	163.55	***	15.82		
Environment (E)	7	571.52	***	19.35		
GxE interactions	140	77.35	***	52.37		
IPC1	26	144.65	***		34.73	34.73
IPC2	24	106.07	***		23.51	58.24
IPC3	22	74.12	***		15.06	73.30
IPC4	20	62.56	***		11.55	84.85
IPC5	18	58.36	***		9.70	94.56
IPC6	16	28.02	***		4.14	98.70
Residual	14	10.09	**			
Error	504	5.11				
Total	671	30.82				

Table 4: AMMI measures and Weighted average of absolute scores of Barley genotypes (2018-19)

Genotype	IPCA1	MASV1	MASV	Za	EV	SIPC	ASTAB	W1	W2	W3	W4	W5	WAASB
VLB 161	1.719	3.764	3.205	13.386	0.017	4.176	39.579	1.7188	1.5699	1.3602	1.1747	1.0226	0.9749
UPB 1082	1.895	3.701	3.193	13.447	0.019	4.353	41.518	1.8949	1.4411	1.1413	1.1467	1.0141	0.9659
HBL 863	1.483	3.188	2.674	12.186	0.013	4.144	27.438	1.4835	1.1628	1.0790	0.9512	0.8898	0.8590
HBL 113	0.956	3.753	3.011	11.516	0.015	4.145	24.649	0.9555	0.9571	0.7719	0.7886	0.8213	0.7828
VLB 163	1.202	3.349	2.655	10.451	0.015	3.797	22.967	1.2022	1.0248	0.8024	0.6918	0.7204	0.7212
VLB 164	0.838	4.552	3.899	13.333	0.022	4.640	44.272	0.8376	1.4116	1.1039	1.0280	0.9556	0.9249
BHS 477	1.935	3.856	3.147	13.103	0.018	4.216	40.229	1.9353	1.5452	1.2115	1.0243	0.9781	0.9475
BHS 475	0.588	4.430	3.771	12.640	0.028	5.120	37.050	0.5881	0.7664	0.6002	0.7899	0.8256	0.8150
BHS 474	1.063	2.141	1.866	6.970	0.007	2.320	13.943	1.0634	0.6327	0.6863	0.5883	0.5156	0.4988
VLB 162	0.515	3.771	3.489	11.440	0.027	4.716	34.754	0.5145	0.6208	0.5574	0.7969	0.7364	0.7353
HBL 845	0.052	2.941	2.512	7.933	0.012	3.450	15.994	0.0518	0.2019	0.4126	0.4597	0.4922	0.4899
UPB 1077	2.552	5.290	4.523	19.121	0.039	6.648	78.956	2.5516	1.5536	1.4790	1.4906	1.3933	1.3333
UPB 1078	0.588	4.461	3.639	13.798	0.030	5.733	35.026	0.5883	0.8297	0.8236	0.8102	0.8668	0.8865
HBL 848	1.316	3.218	2.871	12.430	0.026	4.933	31.973	1.3156	0.9595	0.8265	0.8697	0.8007	0.8320
BHS 472	0.288	6.148	5.397	15.648	0.048	5.868	77.488	0.2879	0.8779	1.3265	1.1154	1.0958	1.0351
VLB 118	0.521	4.974	4.343	14.538	0.028	5.218	52.664	0.5208	1.2068	1.2945	1.1202	1.0329	0.9893
HBL 851	1.553	4.064	3.485	15.169	0.024	5.346	43.550	1.5532	1.5082	1.3654	1.1693	1.0697	1.0599
HBL 858	0.110	1.522	1.329	4.790	0.004	2.061	5.023	0.1102	0.2666	0.2507	0.2912	0.2913	0.3025
BHS 400	1.127	5.249	4.299	16.988	0.030	6.202	49.229	1.1267	1.1901	1.2216	1.1855	1.2083	1.1435
BHS 352	0.825	3.340	3.142	11.059	0.040	5.022	36.316	0.8247	0.4894	0.6433	0.6962	0.6217	0.6975
BHS 476	0.229	6.507	4.765	9.866	0.036	4.341	41.167	0.2286	0.2059	0.2299	0.3341	0.6152	0.5947

Table 5: Simultaneous selection indexes of barley genotypes based on AMMI and BLUP (2018-19)

Genotype	IPCA1	EV	SIPC	Za	ASTAB	MASV1	MASV	MEAN	R _k	Siam	R _k	GM	R _k	HM	R _k	Sigm	R _k	Sihm	R _k
VLB 161	39	28	28	35	33	31	32	19.29	21	12.17	21	18.47	21	17.75	21	12.17	21	12.17	21
UPB 1082	37	27	28	33	33	26	28	20.19	18	20.03	19	19.91	18	19.64	17	23.88	19	26.76	18
HBL 863	26	14	15	19	16	14	15	22.49	10	43.12	10	22.10	9	21.72	8	44.91	10	46.15	10
HBL 113	14	9	9	11	8	12	10	24.80	3	65.18	3	24.58	3	24.37	3	67.19	3	68.87	3
VLB 163	26	17	16	17	16	19	16	21.99	12	43.52	9	21.65	11	21.35	11	46.03	9	48.04	9
VLB 164	25	25	26	28	32	31	31	21.24	15	30.27	17	20.43	16	19.62	18	29.44	17	28.04	17
BHS 477	33	21	21	25	26	25	22	21.94	13	35.48	14	21.20	13	20.62	13	34.76	14	34.82	15
BHS 475	12	19	20	16	16	19	20	23.80	5	55.69	6	23.43	5	23.04	5	56.96	6	57.68	6
BHS 474	18	8	8	8	8	8	8	23.36	6	62.67	4	23.04	6	22.79	6	64.61	4	66.50	4
VLB 162	7	15	14	9	10	13	15	26.53	2	81.44	1	26.06	2	25.62	2	80.52	1	79.92	1
HBL 845	18	20	20	20	20	20	20	20.76	17	41.00	11	20.36	17	19.97	16	43.61	11	45.45	12
UPB 1077	35	33	35	35	35	33	33	21.47	14	18.42	20	20.94	14	20.42	14	19.58	20	20.20	20
UPB 1078	15	23	25	23	16	22	21	23.26	7	48.67	8	22.90	7	22.54	7	50.30	8	51.45	8
HBL 848	31	28	29	26	23	21	22	21.12	16	32.42	16	20.69	15	20.24	15	34.64	15	35.89	14
BHS 472	13	30	28	28	29	29	30	22.54	9	37.52	13	22.09	10	21.63	10	38.84	13	39.52	13
VLB 118	10	19	20	21	23	21	22	24.60	4	56.51	5	24.32	4	24.06	4	58.11	5	59.52	5
HBL 851	28	22	28	29	27	24	23	22.15	11	33.44	15	21.57	12	20.98	12	33.84	16	33.77	16
HBL 858	21	20	20	20	20	20	20	19.74	19	38.72	12	19.46	19	19.18	19	42.79	12	45.85	11
BHS 400	14	18	21	21	19	19	18	26.99	1	71.44	2	26.66	1	26.33	1	71.44	2	71.44	2
BHS 352	29	40	34	26	30	26	28	19.37	20	22.25	18	18.82	20	18.24	20	24.30	18	25.31	19
BHS 476	11	26	17	12	22	29	28	22.58	8	52.88	7	22.13	8	21.68	9	54.07	7	54.83	7

genotypes were of choice by of MASV1 and MASV measure pointed for HBL867, HBL866, HBL864 as the stable genotypes while BHS481 would be unstable (Ajay et al 2019). W1 measure selected BHS481, HBL866, BHS479 while measure W2 favoured BHS481, BHS479, BHS352, whereas genotypes BHS481, BHS479, BHS400 selected by W3

measure. Values of W4 favoured BHS481, BHS400, BHS352 while W5 settled for BHS481, BHS400, BHS352 barley genotypes as same set was also mentioned by W6 measure. Lower value of WAASB measure had observed for BHS481, BHS400, BHS352 whereas large value by HBL867.

Table 6: Loadings of measures as per two Principal Components 2018-19

Measure	PC1	PC2
IPCA1	0.1961	0.1751
MASV1	0.2139	-0.1721
MASV	0.2348	-0.1675
Za	0.3128	-0.0562
EV	0.1975	-0.1197
SIPC	0.2737	-0.1144
ASTAB	0.2906	-0.0612
WAASB	0.3146	-0.0202
W1	0.1961	0.1751
W2	0.2482	0.1057
W3	0.2786	0.0605
W4	0.2989	0.0279
W5	0.3123	-0.0305
Almora	0.0409	-0.2842
Bajaura	0.0505	-0.2692
Berthin	0.0716	-0.2685
Kangra	-0.1627	-0.0539
Katrain	0.0699	-0.0509
Majhera	0.1197	-0.0521
Malan	-0.0194	-0.2592
Shimla	0.0346	-0.2354
Mean	0.0311	-0.3578
Siam	-0.1093	-0.3436
Sigm	-0.1208	-0.3398
Sihm	-0.1296	-0.3347
66.29	39.08	27.21

Superiority indexes as per AMMI and BLUP : Barley Genotypes

First year of study 2018-19

Mean yield of genotypes based on BLUP values favoured BHS 400, VLB 162, HBL 113 where BHS400, VLB162, HBL113 selected by Geometric adaptability index

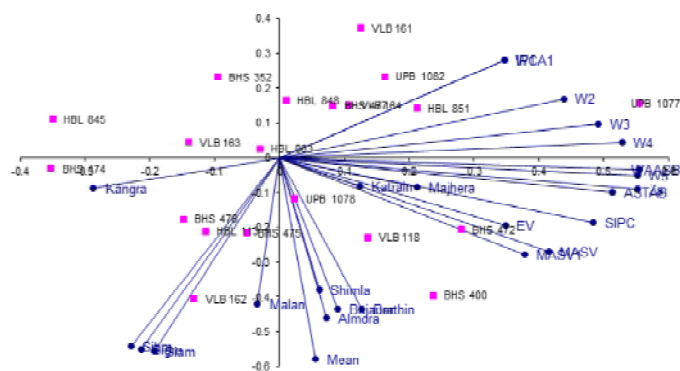


Figure 1: Biplot analysis of superiority index & other measures of barley genotypes 2018-19

while Harmonic mean of genotypic values pointed for BHS400, VLB162, HBL113 as suitable genotypes as far as considered locations are concerned. Superiority index while weighting 0.65 and 0.35 for average yield & stability found VLB162, BHS400, HBL113 as of stable performance with high yield. Least magnitude of SIgm ranked VLB162, BHS400, HBL113 as desirable genotypes while values of SIhm measure favoured VLB162, BHS400, HBL113 barley genotypes.

Stability alone is not a desirable selection criterion as stable genotypes may not be a high yielders, simultaneous use of yield and stability in a single measure is essential (Kang 1993; Farshadfar et al 2008). Simultaneous Selection Index also referred to as genotype stability index (GSI) or yield stability index (YSI) (Farshadfar et al 2011) was computed by adding the ranks of stability measure and mean yield of genotypes. Least ranks for IPCA1 measure exhibited by VLB162, VLB118, BHS476, were considered as stable with high yield, whereas high values suggested as least stable yield for VLB 161 genotype (Table 7). EV measure identified BHS474, HBL113, &HBL863 whereas SPIC favoured BHS474, HBL113 & VLB 162 genotypes. Genotypes BHS474, VLB162& HBL113 possessed lower value of Za measure. ASTAB measure achieved the desirable lower values for BHS474, HBL113, VLB 162. Composite measure MASV1 found BHS474, HBL113, VLB162 and as per MASV ranks BHS474, HBL113, HBL863 genotypes would be of choice for these locations of the zone.

Second year of study 2019-20

Simultaneous ranking of barley genotypes as per IPCA1 measure favoured VLB168, VLB169, UPB1085 as per the least values, whereas large values of BHS352 suggested unstable high yield (Table 8). EV measure ranked for HBL113, VLB168,

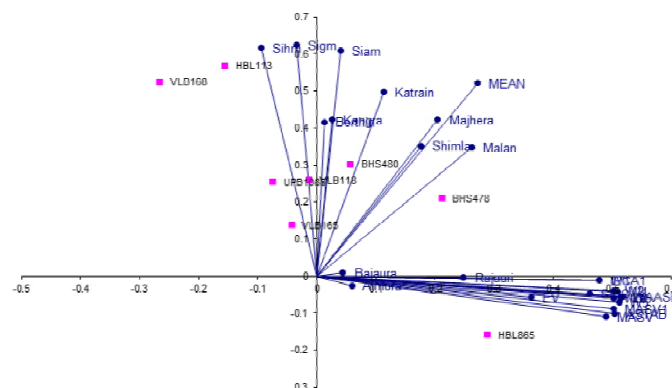


Figure 2: Biplot analysis of stability & adaptability measures of barley genotypes 2019-20

Table 7: AMMI analysis and percentage contribution of significant interaction principal components (2019-20)

Source	Degree of freedom	Mean Sum of Squares	Level of significance	Proportional contribution of factors	GxE interaction Sum of Squares (%)	Cumulative Sum of Squares (%) by IPCA's
Treatments	197	378.13	***	90.40		
Genotype (G)	21	377.68	***	9.63		
Environment (E)	8	5175.62	***	50.25		
GxE interactions	168	149.73	***	30.53		
IPC1	28	371.17	***		41.32	41.32
IPC2	26	152.67	***		15.78	57.10
IPC3	24	151.01	***		14.41	71.50
IPC4	22	127.70	***		11.17	82.67
IPC5	20	104.98	***		8.35	91.02
IPC6	18	58.05	***		4.15	95.17
IPC7	16	51.13	***		3.25	98.42
Residual	14	28.33	***			
Error	594	13.32				
Total	791	104.17				

Table 8 AMMI based measures and Weighted average of absolute scores for barley genotypes (2019-20)

Genotype	IPCA1	EV	SIPC	Za	ASTAB	MASV1	MASV	W1	W2	W3	W4	W5	W6	WAASB
HBL867	0.192	0.004	2.571	4.710	12.930	2.209	1.994	0.1924	0.1597	0.3558	0.4083	0.3885	0.3794	0.3655
BHS478	1.401	0.032	7.170	13.344	75.552	5.888	4.838	1.4015	1.1650	1.3226	1.1382	1.0500	1.1017	1.0895
VLB166	0.554	0.010	4.005	7.303	22.753	3.640	2.905	0.5537	0.5886	0.5575	0.5092	0.5942	0.6059	0.5775
HBL868	1.102	0.024	6.650	13.249	74.960	6.043	4.894	1.1021	1.3344	1.3043	1.0989	1.1786	1.1212	1.0861
UPB1085	0.590	0.030	7.150	12.086	69.093	5.374	4.764	0.5901	0.7408	0.6596	0.9120	0.9074	0.9374	0.9179
BHS352	2.727	0.031	7.526	17.483	126.955	8.432	6.017	2.7274	1.9733	1.7146	1.8253	1.6633	1.6008	1.5395
BHS481	3.315	0.040	9.929	23.078	183.246	10.130	7.135	3.3153	2.9973	2.5440	2.3463	2.2259	2.1147	2.0302
BHS482	2.362	0.024	6.313	14.890	98.600	7.348	5.296	2.3624	1.9419	1.5139	1.6082	1.4279	1.3868	1.3222
VLB169	0.026	0.013	4.619	7.429	30.577	3.802	3.256	0.0255	0.2073	0.3116	0.4718	0.5534	0.5401	0.5352
HBL866	0.460	0.008	3.823	7.298	26.952	3.015	2.731	0.4603	0.7170	0.7947	0.6729	0.6175	0.6014	0.5905
UPB1084	0.091	0.017	4.554	7.520	40.267	4.957	3.992	0.0907	0.1221	0.3278	0.4018	0.5832	0.5641	0.5456
HBL113	1.420	0.011	4.997	10.424	37.688	4.664	3.351	1.4199	1.0787	0.9197	0.9404	0.9251	0.9013	0.8848
HBL865	1.406	0.023	7.002	14.470	79.550	5.940	4.818	1.4060	1.3731	1.5614	1.3516	1.2962	1.2517	1.2097
VLB168	0.485	0.015	5.411	10.031	46.687	3.958	3.639	0.4846	0.8686	0.9548	0.9043	0.8332	0.8215	0.7955
UPB1083	1.149	0.044	9.391	17.077	115.431	6.983	5.880	1.1494	1.5237	1.5116	1.3320	1.3924	1.3454	1.3527
VLB118	1.240	0.051	7.238	11.654	74.687	5.373	4.420	1.2400	0.9046	0.8352	0.7432	0.7709	0.8090	0.9026
BHS479	2.646	0.021	7.035	16.726	99.999	7.619	5.208	2.6456	2.2163	1.9117	1.7887	1.6114	1.5523	1.4913
VLB167	0.465	0.021	5.064	8.114	37.775	3.924	3.547	0.4655	0.3960	0.6178	0.5818	0.5391	0.6085	0.6124
HBL864	0.115	0.009	4.161	7.060	24.557	3.243	2.840	0.1149	0.2414	0.4603	0.5094	0.5497	0.5392	0.5260
BHS480	2.061	0.012	4.621	11.036	54.024	5.785	3.857	2.0615	1.4767	1.3060	1.1691	1.0375	1.0308	0.9985
BHS400	1.916	0.038	9.627	19.323	121.179	7.309	5.845	1.9158	1.8453	1.8799	1.8358	1.6816	1.6297	1.6037
VLB165	0.796	0.022	6.329	11.847	61.173	5.469	4.492	0.7965	1.0106	1.0753	0.9047	1.0009	0.9632	0.9444

& BHS479 barley genotypes. Minimum ranks as per SIPC favoured HBL113, BHS482 & VLB168 genotypes. Lower value of Za ranks possessed by VLB168 HBL113, & HBL867 genotypes for stable higher yield as compared to others genotypes. Barley genotypes HBL113, VLB168, VLB166 were selected as per values of ASTAB measure accounted the AMMI analysis with BLUP of genotypes yield values. Composite measure MASV1 selected HBL113, VLB168, HBL867 while HBL113, VLB168, HBL867 identified by MASV as genotypes of choice for these locations of the zone.

Maximum average yield expressed by BHS400, BHS481, BHS482 genotypes and good variation had been observed from 36.3 to 26.6 q/ha among genotypes. Higher value of Genotypic adaptability index achieved by BHS400, BHS482, BHS481 whereas Harmonic mean of genotypic values ranked BHS400, VLB168, HBL113 barley genotypes. Simultaneous ranking of genotypes by Superiority index measures pointed towards BHS482, HBL113, VLB168 and large value by BHS352. Superiority index while weighting 0.65 and 0.35 for GAI & stability found VLB168, HBL113,

BHS400 as of stable performance with high yield. While considering Harmonic mean and stability corresponding ranks identified VLB168, HBL113, VLB169 genotypes.

Biplot graphical analysis

First year of study 2018-19

Loadings of studied measures as per first two significant principal components were reflected in table 9. Biplot graphical analysis considered these PCAs as accounted for 66.3% of variation of the measures (Bocianowskiet al 2019). Studied measures grouped into three major clusters. MASV1 clubbed with ASTAB, EV, SIPC, Za, W3, WAASB and MASV measures. Yield based measures clubbed with corresponding SI measures. Measure IPCA1 and W2 maintained distance from measures and observed as outliers in different quadrant.

Second year of study 2019-20

Loadings of the measures as per first two significant principal components were reflected in table 12. Biplot graphical analysis considered these PCAs as accounted for 73.1 % of the total variation among the measures. Measures had grouped all together into three clusters. MASV1 clubbed with ASTAB, EV, SIPC, Za, W3, WAASB and MASV measures. Average yield measures clubbed with corresponding SI measures. Others SI measures observed in adjacent quadrant.

Table 10: Loadings of measures as per two Principal Components 2019-20

Measure	PC1	PC2
IPCA1	0.2490	-0.0079
MASV1	0.2621	-0.0557
MASV	0.2554	-0.0696
Za	0.2679	-0.0367
EV	0.1896	-0.0360
SIPC	0.2407	-0.0299
ASTAB	0.2627	-0.0639
WAASB	0.2699	-0.0345
W1	0.2490	-0.0079
W2	0.2621	-0.0248
W3	0.2615	-0.0374
W4	0.2651	-0.0265
W5	0.2667	-0.0448
W6	0.2687	-0.0368
Almora	0.0308	-0.0162
Bajaura	0.0229	0.0057
Berthin	0.0064	0.2638
Kangra	0.0136	0.2680
Katrai	0.0594	0.3148
Majhera	0.1067	0.2675
Malan	0.1365	0.2199
Rajauri	0.1293	-0.0020
Shimla	0.0922	0.2229
MEAN	0.1419	0.3302
Siam	0.0213	0.3856
Sigm	-0.0181	0.3957
Sihm	-0.0488	0.3903
73.09	50.20	22.89

Table 9: Simultaneous selection indexes of barley genotypes based on AMMI and BLUP (2019-20)

Genotype	IPCA1	EV	SIPC	Za	ASTAB	MASV1	MASV	Mean	R _k	Siam	R _k	GM	R _k	Sigm	R _k	HM	R _k	Sihm	R _k
HBL867	20	17	17	17	17	17	17	30.73	16	63.55	12	29.94	16	66.42	9	29.02	14	68.38	6
BHS478	26	30	29	27	27	26	27	32.27	12	58.35	16	31.21	12	59.18	14	30.20	9	60.19	13
VLB166	22	18	17	18	16	18	18	31.65	14	65.12	9	30.93	13	68.22	6	30.08	10	70.24	5
HBL868	33	37	35	36	36	38	38	26.34	22	19.85	21	24.92	22	19.85	21	23.48	21	20.32	21
UPB1085	17	24	24	21	20	19	21	33.73	8	71.49	6	31.97	7	67.55	7	29.87	11	61.84	10
BHS352	41	37	39	40	41	41	41	27.49	20	17.77	22	25.75	20	15.51	22	24.10	20	14.43	22
BHS481	24	22	24	24	24	24	24	36.11	2	63.58	11	33.88	3	56.12	15	31.92	5	50.66	16
BHS482	22	17	14	20	20	22	21	36.09	3	78.39	1	34.05	2	72.09	5	31.86	6	65.17	7
VLB169	14	20	19	18	18	18	18	32.11	13	69.03	8	31.48	11	72.51	4	30.76	7	75.19	3
HBL866	26	23	23	24	25	23	23	26.59	21	31.93	20	25.05	21	31.05	20	23.40	22	30.27	20
UPB1084	20	27	23	24	26	27	28	28.68	18	46.42	17	27.93	18	50.05	17	27.08	17	53.09	15
HBL113	21	10	13	14	11	13	11	34.43	5	76.75	2	33.31	4	76.65	2	32.04	3	75.47	2
HBL865	25	23	24	26	26	25	24	32.96	10	60.36	15	30.89	14	54.65	16	28.71	16	48.84	17
VLB168	13	14	16	14	15	13	14	34.02	6	75.95	3	33.09	6	77.18	1	32.12	2	77.82	1
UPB1083	29	38	37	36	36	34	37	30.73	17	42.80	18	28.46	17	36.38	19	26.14	19	30.51	19
VLB118	22	31	27	20	22	19	20	33.42	9	69.78	7	31.61	10	65.63	10	29.23	13	58.34	14
BHS479	24	15	19	22	22	24	21	34.45	4	64.09	10	33.19	5	63.13	12	31.93	4	62.03	9
VLB167	21	25	24	22	22	21	22	31.37	15	62.57	14	30.18	15	62.75	13	28.78	15	61.80	11
HBL864	22	22	23	21	22	22	22	27.50	19	39.16	19	26.89	19	43.96	18	26.23	18	48.41	18
BHS480	29	17	18	21	21	24	20	32.73	11	63.28	13	31.62	9	63.66	11	30.52	8	64.03	8
BHS400	18	20	22	22	21	19	20	36.33	1	73.97	4	35.29	1	73.97	3	34.33	1	73.97	4
VLB165	17	19	19	19	18	19	19	33.83	7	71.61	5	31.95	8	66.84	8	29.86	12	61.23	12

CONCLUSIONS

Simultaneous utilization of stability and yield of genotypes would be more appropriate to recommend high-yielding stable genotypes. The main advantages of AMMI and BLUP had been combined to increase the reliability of multi-locations trials analysis by Superiority Indexes. An additional advantage was to assign desirable weights to the yield and stability performance based on the goal of crop breeding trials.

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Estimation of genetic variability, heritability and genetic advance in twenty-one released varieties of oat (*Avena sativa* L.) for grain and fodder yield

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ABSTRACT

Present investigation was carried out at Instructional Dairy Farm in G. B. Pant University of Agriculture and Technology, Pantnagar on twenty one released varieties of oat (*Avena sativa* L.) during *rabi* 2010-11 and 2011-12. Heritability estimates varied from 28.79 per cent for crude protein content to 94.30 per cent for plant height. Grain yield per plant showed highest GCV estimates of 43.91 per cent. High to moderately high variability for GCV coupled with high estimates of heritability were observed for all the characters. As per pooled two years analysis results revealed maximum genotypic coefficient of variation for grain yield per plant, harvest index, leaf : stem ratio, dry matter yield, green fodder yield and straw yield per plant. While high heritability and moderate to high genetic advance was observed for plant height, leaf length, leaf : stem ratio, spikelet per panicle, dry matter yield, green fodder yield, straw yield per plant, grain yield per plant and harvest index indicating the preponderance of additive genetic effects for these traits. The genetic advancement as per cent mean was found to be highest for harvest index (66.09) followed by green fodder yield (51.74), dry matter yield (49.07), leaf : stem ratio (47.63), grain yield plant⁻¹ (41.87) and straw yield plant⁻¹ (41.87).

Key words: Oat, genetic variability, heritability, genetic advance, variation

Oat (*Avena sativa* L.), belongs to family Gramineae, is an important forage annual crop of *rabi* season and ranks sixth in production among all cereal crops next to wheat, maize, rice, barley and sorghum in the world scenario. It is rich in nutrients including silicon, manganese, zinc, calcium, phosphorus and vitamins A, B₁, B₂ and E. The genus *Avena* is large and diverse containing both wild and cultivated polyploidy series with a basic chromosome number of n=7. Three naturally occurring ploidy levels are known with the genus, diploids (2n=2x=14), tetraploid (2x=4x=28) and hexaploid (2n=6x=42). Oat (2n=6x=42) is a natural allopolyploid evolved through cycles of inter-specific hybridization and poly-ploidization combining three distinct genomes, *A. sterilis* and *A. fatua* share the same genome as that of *A. sativa*. Availability of the genetic variability for the component characters is a major asset for initiating a fruitful crop improvement program. Arora *et al.* (2008) carried out evaluation and characterization for some morphological traits in 554 germplasm accessions of oats. Moderate amount of genetic variability was recorded for green fodder yield and dry matter yield. Best accessions namely HFO-455, HFO-

18 and HFO-442 can be utilized in oat varietal development programme. Arora *et al.* (2009) collected one hundred and eight germplasm accessions of oats from various sources at CCSHAU, Hisar, where he found moderate to low amount of genetic variation in genetic stock for various traits studied. Singh and Singh (2009) found that the genotypes (G) x environment (E) interaction was significant for both green and dry fodder yield among 36 oat genotypes. Pundhir *et al.* (2008) studied the genotypic and phenotypic coefficients of variation, heritability, expected genetic advance, correlation and path-analyses in 36 genotypes of oats over four environments revealed moderate to high estimates of heritability coupled with high genetic advance for most of the traits. Bahadur *et al.* (2007) studied oat genotypes to determine the extent of variability for various fodder yield and quality traits under normal and late sown conditions where he found considerable variability existed for all the characters. Sharma and Gupta (2007) studied the stability parameters in 33 oat genotypes to obtain the magnitude and nature of genotypes (G) x environment (E) interactions and stability for forage yield. Shekhawat *et al.* (2006, 2007) studied

that range was 4.69 to 26.60 for GCV, 5.42 to 35.32 for PCV, 30.50 to 74.90 per cent for heritability (broad sense) and 8.36 to 46.78 per cent for genetic advance (as % of mean).

Genetic diversity is a prerequisite for an effective plant breeding programme. It is a useful and essential tool for choice of parents in hybridization nursery, to develop potential high yielding cultivars and to meet the diversified goals of plant breeding (Haydar *et al.*, 2007). Hornokova *et al.* (2003) stated that the knowledge of genetic diversity helps in the identification, differentiation and characterization of genotypes or populations. So it becomes important to exploit the germplasm and the material available to develop new varieties for specific needs. Hence, the present investigation was carried out.

MATERIALS AND METHODS

The research work for the experiment was conducted at Instructional Dairy Farm in G.B. Pant University of Agriculture and Technology, Pantnagar. The healthy seeds of twenty-one oat varieties (Table 1) comprising a diverse group of released and notified oat varieties, collected from different SAUs and Research Institutes across the country, were sown during *rabi* 2010-11 and *rabi* 2011-12. The material was evaluated in RBD with twenty-one varieties in three replications with row to row spacing of 40 cm and plant to plant distance of 10 cm. The distance between two plots was 150 cm. Normal package of practices with recommended dose of fertilizers were followed. Observations were recorded

Table 1: List of oat varieties tested

S. No.	List of Oat Varieties
1	JHO-99-1
2	JHO-99-2
3	JHO-2000-4
4	JHO-851
5	JHO-822
6	HFO-114
7	OS-7
8	HJ-8
9	OS-346
10	OL-9
11	OL-125
12	SKO-20
13	SABZAR
14	JO-03-91
15	JO-1
16	NDO-1
17	PLP-1
18	RO-19
19	UPO-94
20	UPO-212
21	KENT

on ten randomly selected representative plants from each plot in replication leaving the border rows. Data on sixteen quantitative characters namely plant height (cm), days to 50 per cent heading, number of tillers per plant, length of leaf (cm), width of leaf (cm), green fodder yield (per meter row length in kg), dry matter yield (per meter row length in kg), leaf : stem ratio, panicle length (cm), spikelet per panicle, days to maturity, grain yield per plant (gm), straw yield per plant (g), 1000 grain weight (g), harvest index (%) and crude protein content (%) were recorded at different stages of plant growth. Phenotypic and genotypic coefficients of variation were obtained as the ratio of respective standard deviation from general mean of characters and expressed in percentage (Burton, 1952). Heritability in broad sense and the expected genetic advance under selection for different characters were calculated using method suggested by Allard (1960).

Heritability is the ratio of genotypic variance to the total variance, *i.e.*, phenotypic variance (genotypic and environmental), and it denotes the proportion of phenotypic variance that is due to genotypes, *i.e.*, heritable and was calculated according to the formula.

$$H (\text{broad sense}) = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2_e} \times 100$$

Where, σ^2_g = genotypic variance and $\sigma^2_g + \sigma^2_e$ = phenotypic variance (genotypic and environmental)

For estimation of variability different parameters such as mean, range coefficient of variation, *etc.* were used to estimate the diversity present among the germplasm lines for different metric traits. Genetic advance was calculated in per cent of mean by the formula given by Johnson *et al.* (1955).

$$GA (\% \text{ of mean}) = \frac{\sigma^2_g \times K}{\sigma^2_p \times \text{mean}} \times 100$$

Where, K is selection differential at 5 per cent selection intensity ($K = 2.06$) σ^2_g = genotypic variance and σ^2_p = phenotypic standard deviation of the character.

RESULTS AND DISCUSSION

Analysis of variance and mean values

Analysis of variance shown in Tables 2, 3 and 4 for all the characters showed highly significant genetic variance among the varieties for all the characters under study during *rabi* 2010-11 and 2011-12, and in pooled analysis, indicating that there was enough variability found for these traits among the varieties. High genetic variance for morphological traits *viz.*, leaf number, green stem weight, panicle length,

dry leaf and dry stem weight studied among the varieties in oat were also reported by Nehvi *et al.* (2007) and Krishna *et al.* (2013).

The comparative mean values of twenty-one oat varieties for sixteen characteristics along with standard error of mean and coefficient of variation are presented in Table 5. Mean performance of genotypes exhibited wide range of

variation during both the season as well as in pooled analysis. As per pooled analysis the wide range of variation for plant height (102.14–153.00 cm), days to 50 per cent heading stage (108.50–142.33 days), green fodder yield (1.23 – 3.81 kg), leaf : stem ratio (0.23 – 0.67), days to maturity (155.00 – 176.00 days), grain yield plant⁻¹ (4.77– 58.52 g), 1000 grain weight (21.62 – 46.76 g), harvest index (7.47 –

Table 2. Analysis of variance for measurable characters at different stages of twenty one oat varieties (2010-2011)

Characters	Source of Variation			SE (Mean) ±	LSD at 1%	CV (%)
	Replication	Treatments	Error			
	Degree of Freedom					
	2	20	40			
Plant height (cm)	0.078	402.356**	1.073	0.504	2.290	0.760
Days to 50% heading	4.825	423.982**	2.175	0.850	3.260	1.280
Number of tillers per plant	0.269	0.330**	0.110	0.190	0.730	2.910
Length of leaf (cm)	0.206	75.172**	0.618	0.450	1.740	1.740
Width of leaf (cm)	0.005	0.263**	0.003	0.030	0.130	2.840
Green fodder yield (per meter row length in kg)	0.003	1.000**	0.002	0.030	0.100	2.190
Dry matter yield (per meter row length in kg)	0.000	0.045**	0.001	0.018	0.072	7.770
Leaf : Stem ratio	0.001	0.043**	0.001	0.020	0.010	7.060
Days to maturity	23.349	99.554**	13.399	6.040	8.080	2.220
Panicle length (cm)	0.227	37.933**	0.592	1.270	1.700	2.060
Spikelet per panicle	0.045	1085.675**	0.324	0.940	1.250	0.630
Grain yield per plant (g)	1.050	366.375**	0.595	1.270	1.700	3.140
Straw yield per plant (g)	0.201	1821.424**	1.621	2.100	2.810	1.230
Harvest index (%)	0.707	175.155**	0.962	1.610	2.150	4.990
1000 grain weight (g)	0.123	107.405**	0.427	1.080	1.440	1.760
Crude protein content (%)	0.073	6.181**	0.083	0.480	0.640	1.850

**Significant at 1% probability level, *Significant of 5% probability level

Table 3. Analysis of variance for measurable characters at different stages of twenty-one oat varieties (2011-2012)

Characters	Source of Variation			SE (Mean) ±	LSD at 1%	CV (%)
	Replication	Treatments	Error			
	Degree of Freedom					
	2	20	40			
Plant height (cm)	0.318	381.113**	1.307	0.660	2.520	0.850
Days to 50% heading	15.571	251.713**	6.355	1.460	5.570	2.140
Number of tillers per plant	0.267	7.037**	0.108	0.190	0.720	2.980
Length of leaf (in cms)	0.295	65.309**	0.798	0.520	1.970	2.030
Width of leaf (in cms)	0.012	0.188**	0.004	0.040	0.140	3.240
Green fodder yield (per meter row length in kg)	0.003	0.936**	0.007	0.050	0.180	4.040
Dry matter yield (per meter row length in kg)	0.053	0.073**	0.070	0.153	0.586	7.720
Leaf : Stem ratio	0.002	0.042**	0.009	0.010	0.060	6.210
Days to maturity	18.396	97.963**	8.764	1.530	6.540	1.790
Panicle length (cm)	0.414	23.378**	0.637	0.110	1.760	2.160
Spikelet per panicle	0.109	1082.725**	0.477	1.760	1.530	0.780
Grain yield per plant (g)	0.781	332.481**	1.025	0.580	2.240	4.160
Straw yield per plant (g)	3.603	1826.899**	3.281	1.050	4.000	1.750
Harvest index (%)	2.594	162.260**	1.404	0.680	2.620	6.030
1000 grain weight (g)	0.048	83.798**	0.353	0.340	1.310	2.370
Crude protein content (%)	0.302	4.781**	0.091	0.170	0.660	1.970

**Significant at 1% probability level, *Significant at 5% probability level.

40.48%) and crude protein content (13.20–17.77%). Moderate to high range of variability for different traits *viz.*, plant height, number of tillers per plant, length of leaf, width of leaf, days to maturity, green fodder yield and grain yield per plant were in accordance with the findings of Gautam *et al.*, (2006) and Sangwan *et al.*, (2012) in oat.

Coefficient of variation

Plant breeding is mainly the exploitation of genetic variation and in view of the possible decline of variation, breeders should always examine means of conserving variability and creating new germplasm. Information on genetic variability of yield and quality components is of paramount importance in crop improvement programme. The extent of genotypic variability indicates the amenability of given character for its improvement (Burton and De Vane, 1953). The simple analysis of variance only signify the differences between treatments/variety means as a whole without giving any idea about different components of this variation. Keeping this fact in view, the variation was partitioned into phenotypic, genotypic and environmental variances by estimating the phenotypic, genotypic and environmental coefficient of variation.

A comparative study of the genotypic, phenotypic and environmental coefficient of variation was measured in twenty-one varieties of oat in first year, second year and in pooled analysis (Table 5), which revealed higher contribution of the genotypic variance in determining the phenotypic variance for most of the characters studied.

Based on the analysis during both the years, high estimates of PCV and GCV were substantial for most of the characters namely grain yield, green fodder yield, dry matter yield, straw yield, leaf : stem ratio, harvest index and spikelet per panicle indicated reasonable higher variability in these traits which can be effectively improved through selection. On the other hand, lower estimates of PCV and GCV for plant height, days to 50 per cent heading, number of tillers per plant, width of leaf and crude protein content showed moderate to low variability for these characteristics for which response to selection may be restricted to certain degrees. The estimates of PCV were slightly higher than GCV for all the traits studied indicating little role of environment in the expression of these characters. Krishna *et al.* (2013) also reported higher value for most of the morphological traits namely plant height, length of leaf, green fodder yield, number of tillers per plant, panicle length and grain yield showed higher value for PCV in oats.

High estimates of GCV and PCV for days to 50 per cent heading, tiller number per plant and dry matter yield have also been reported by Shankar *et al.* (2002), Gautam *et al.* (2006) and Sangwan *et al.* (2012). While the finding of high PCV and GCV values for number of leaves, grain yield per plant, harvest index, straw yield, panicle length and spikelet per panicle were in accordance with reports of Kumar *et al.*, (2004), Shekhawat *et al.* (2006) and Sangwan *et al.* (2012). Appreciably high estimates of PCV and GCV indicated the presence of reasonably higher level of genetic variations suggesting the effectiveness of selection programmes for the improvement of these characters.

Table 4. Analysis of variance for measurable characters at different stages of twenty-one oat varieties (pooled analysis)

Characters	Source of Variation					SE (Mean) ±	LSD at 1%	CV (%)
	Replication	Environment	Interaction	Treatments	Error			
	Degree of Freedom							
	2	1	2	20	100			
Plant height (cm)	0.282	232.397	0.175	781.282**	1.389	0.480	1.790	0.870
Days to 50% heading	12.863	234.794	7.532	470.525**	4.448	0.860	3.20	1.820
Number of tillers per plant	0.531	4.148	0.005	15.313**	0.098	0.130	0.470	2.790
Length of leaf (cm)	0.478	34.718	0.022	139.869**	0.689	0.340	1.20	1.860
Width of leaf (cm)	0.016	0.069	0.000	0.446**	0.004	0.030	0.100	3.160
Green fodder yield (per meter row length in kg)	0.002	0.001	0.004	1.933**	0.004	0.030	0.100	3.170
Dry matter yield (per meter row length in kg)	0.009	0.008	0.000	0.040**	0.006	0.045	0.073	17.877
Leaf : Stem ratio	0.002	0.006	0.000	0.084**	0.001	0.010	0.040	6.450
Days to maturity	1.167	0.127	40.579	193.176**	9.737	1.270	4.730	1.890
Panicle length (cm)	0.159	6.350	0.482	55.046**	1.744	0.540	2.000	3.560
Spikelet per panicle	0.027	63.201	0.127	2167.844**	0.432	0.270	1.000	0.740
Grain yield per plant (g)	0.149	2.119	1.682	698.018**	0.815	0.370	1.370	3.760
Straw yield per plant (g)	1.188	0.221	2.616	3647.372**	2.151	0.600	2.220	1.420
Harvest index (%)	0.297	0.347	3.003	336.308**	1.164	0.440	1.640	5.500
1000 grain weight (g)	0.365	12.565	0.020	206.490**	0.458	0.280	1.030	1.840
Crude protein content (%)	0.327	4.195	0.051	10.743**	0.114	0.140	0.510	2.180

**Significant at 1% probability level, *Significant at 5% probability level.

Table 5. Comparative estimates of different genetic parameters for sixteen characters in twenty-one oat varieties

Characters	Year	Range	Mean $\pm$ SE	CV (%)	Coefficient of Variation		Heritability broad sense %	Genetic advance (% of mean)
					PCV (%)	GCV (%)		
Plant height (cm)	2010-11	103.19 – 154.76	136.47 $\pm$ 1.49	1.93	8.15	7.92	94.37	15.84
	2011-12	102.14 – 153.00	135.12 $\pm$ 1.19	1.59	8.43	8.28	96.44	16.76
	Pooled	102.14 – 153.00	135.12 $\pm$ 1.57	2.05	8.60	8.35	94.30	16.71
Days to 50% heading	2010-11	106.67 – 140.67	114.79 $\pm$ 2.00	3.09	7.92	7.29	84.71	13.82
	2011-12	110.33 – 144.00	117.52 $\pm$ 2.04	3.13	8.27	7.66	85.71	14.61
	Pooled	108.50 – 142.33	116.16 $\pm$ 2.07	3.17	8.13	7.48	84.79	14.19
Number of tillers per plant	2010-11	6.28 – 13.81	11.38 $\pm$ 0.69	10.77	17.15	13.34	60.53	21.38
	2011-12	6.33 – 13.24	11.02 $\pm$ 0.71	11.42	17.15	12.80	55.67	19.67
	Pooled	6.31 – 13.52	11.20 $\pm$ 0.67	10.58	16.95	13.24	61.04	21.31
Length of leaf (cm)	2010-11	35.38 – 52.57	45.15 $\pm$ 0.81	3.16	11.03	10.57	91.81	20.86
	2011-12	34.90 – 50.53	44.10 $\pm$ 0.79	3.17	10.97	10.50	91.66	20.71
	Pooled	35.14 – 51.55	44.63 $\pm$ 0.71	3.03	11.14	10.72	92.59	21.25
Width of leaf (cm)	2010-11	1.50 – 2.79	2.04 $\pm$ 0.07	5.85	15.28	14.11	85.33	26.85
	2011-12	1.63 – 2.65	1.99 $\pm$ 0.07	6.03	13.58	12.16	80.30	22.45
	Pooled	1.56 – 2.72	2.01 $\pm$ 0.06	5.45	14.49	13.42	85.84	25.62
Green fodder yield (per meter row length in kg)	2010-11	1.21 – 3.82	2.04 $\pm$ 0.06	11.63	29.67	27.30	84.65	51.74
	2011-12	1.26 – 3.80	2.04 $\pm$ 0.13	11.74	29.09	26.61	83.71	50.16
	Pooled	1.23 – 3.81	2.04 $\pm$ 0.13	11.43	29.54	27.24	85.02	51.74
Dry matter yield (per meter row length in kg)	2010-11	0.21 – 0.82	0.41 $\pm$ 0.04	15.36	32.63	28.79	77.80	52.34
	2011-12	0.21 – 0.83	0.42 $\pm$ 0.03	12.27	29.66	27.01	82.89	50.65
	pooled	0.30 – 0.83	0.42 $\pm$ 0.03	13.36	29.81	26.65	79.91	49.07
Leaf : Stem ratio	2010-11	0.22 – 0.66	0.39 $\pm$ 0.04	19.00	34.11	28.32	68.96	48.45
	2011-12	0.24 – 0.68	0.40 $\pm$ 0.04	16.86	33.01	28.38	73.92	50.27
	Pooled	0.23 – 0.67	0.39 $\pm$ 0.04	18.09	33.03	27.64	70.01	47.63
Panicle length (cm)	2010-11	36.28 – 56.83	50.73 $\pm$ 0.76	1.46	10.30	9.66	87.98	18.66
	2011-12	39.00 – 55.40	50.79 $\pm$ 0.81	1.54	10.39	9.65	86.37	18.48
	Pooled	37.64 – 54.81	50.76 $\pm$ 0.83	1.56	10.79	9.97	85.29	18.96
Spikelet per panicle	2010-11	49.76 – 118.81	89.66 $\pm$ 5.27	3.57	22.73	20.20	79.02	36.99
	2011-12	47.57 – 116.86	88.24 $\pm$ 5.14	3.83	22.75	20.35	80.02	37.51
	Pooled	48.67 – 117.83	88.95 $\pm$ 5.25	4.14	22.75	20.24	79.15	37.09
Days to maturity	2010-11	155.33 – 177.00	165.06 $\pm$ 1.36	10.41	3.74	3.44	84.80	6.53
	2011-12	154.67 – 175.00	165.13 $\pm$ 1.44	10.17	3.76	3.43	83.16	6.44
	Pooled	155.00 – 176.00	165.10 $\pm$ 1.46	10.39	3.74	3.40	82.49	6.36
Grain yield per plant (g)	2010-11	3.82 – 59.28	24.56 $\pm$ 2.86	20.74	48.42	43.75	81.64	41.90
	2011-12	5.72 – 57.76	24.30 $\pm$ 2.76	20.06	48.37	44.01	82.79	42.45
	Pooled	4.77 – 58.52	24.43 $\pm$ 2.94	21.34	48.82	43.91	80.89	41.87
Straw yield per plant (g)	2010-11	55.99 – 155.29	103.57 $\pm$ 6.86	11.79	25.73	22.86	78.99	41.86
	2011-12	53.99 – 154.71	103.49 $\pm$ 6.38	10.94	25.34	22.86	81.38	42.49
	Pooled	54.99 – 155.00	103.53 $\pm$ 6.81	11.70	25.57	22.74	79.07	41.65
1000 grain weight (g)	2010-11	21.58 – 46.99	37.10 $\pm$ 1.88	9.06	17.48	14.79	72.71	25.98
	2011-12	21.66 – 46.53	36.47 $\pm$ 1.89	9.08	17.48	14.93	73.03	26.29
	Pooled	21.62 – 46.76	36.79 $\pm$ 1.99	9.57	17.78	14.98	71.02	26.01
Harvest index (%)	2010-11	6.61 – 40.80	19.55 $\pm$ 2.18	19.92	42.50	37.42	77.93	68.07
	2011-12	7.49 – 40.17	19.65 $\pm$ 2.21	20.11	42.50	37.44	77.62	67.95
	Pooled	7.47 – 40.48	19.60 $\pm$ 2.23	20.49	42.06	36.74	76.28	66.09
Crude protein content (%)	2010-11	12.87 – 17.99	15.63 $\pm$ 0.76	8.61	12.61	8.10	46.94	11.43
	2011-12	13.21 – 17.56	15.27 $\pm$ 0.91	10.38	12.61	7.17	32.27	8.38
	Pooled	13.20 – 17.77	15.45 $\pm$ 0.98	11.18	13.25	7.11	28.79	7.86

Heritability and genetic advance

Knowledge of both heritability and genetic advance of a trait is necessary for deciding the scope of improvement through selection (Johnson *et al.*, 1955). The success of a breeding program mainly depends on the extent of additive genetic variance present in the breeding material for the concerned characters. Estimation of genetic advance and heritability is of prime importance in any selection programme which solely depends on additive genetic variance. Broad sense heritability estimates provides information on relative magnitude of genetic and environmental variation in germplasm pool.

Results of heritability and genetic advance for *rabi* 2010-11, *rabi* 2011-12 and pooled over the years analysis (Table 5) revealed high to moderate estimates of heritability (h^2_p) for all the characters under study except crude protein content. In both the years, high estimates of heritability were recorded for plant height, leaf length, width of leaf, green fodder yield, panicle length and days to 50 per cent heading. Moderately high heritability were recorded for grain yield per plant, straw yield per plant, 1000 grain weight, spikelet per panicle, harvest index and dry matter yield. While the minimum value was recorded for crude protein content. These results on heritability were in accordance with the findings of Gautam *et al.* (2006), Shekhawat *et al.* (2006), Nehvi *et al.* (2007), Bahadur and Choubey (2008) and Roy *et al.* (2013) in oat. Knowledge of heritability coupled with expected genetic advance of a trait is necessary for assessing the scope of improvement of character through selection. Expected genetic advance indicated the expected genetic progress for a particular trait under a suitable selection system.

Characters exhibited high estimates of heritability coupled with high to moderately high genetic advance were plant height, days to 50 per cent heading, leaf length, width of leaf, green fodder and dry matter yield, leaf : stem ratio, spikelet per panicle, grain yield per plant, straw yield per plant and harvest index. High genetic advance along with high heritability were observed in oat for biological yield by Mall *et al.* (2005), for days to 50 per cent heading and leaf : stem ratio by Shekhawat *et al.* (2006), for green fodder yield, leaf : stem ratio, number of tillers per plant, length of leaf and grain yield per plant by Gautam *et al.* (2006), for plant height, length of leaf, straw yield per plant by Roy *et al.* (2013), and for spikelet per panicles and 1000 grain weight by Shankar *et al.* (2002). Characters with high heritability along with high to moderately high genetic advance are genetically important traits as they can be improved easily through selection due to preponderance of additive genetic variance in the inheritance of these characters.

CONCLUSION

The overall results indicated the presence of adequate genetic variability among the varieties for most of the characters studied. The characters with appreciably high estimates of heritability coupled with moderate to high genetic advance would be important traits in the development of improved oat cultivars through selection.

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Effect of post emergence application of herbicides, sole or in combination, on weed dynamics, growth and yield of pigeonpea under rainfed conditions

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ABSTRACT

Field experiments carried out at JNKVV, Jabalpur during *kharif* season of 2014-15 and 2015-16 to evaluate the bio-efficacy of propaquizafop + imazethapyr ready mixture against weeds and their influence on yield and economics of pigeonpea, in randomized block design with three replications, revealed that post emergence application of propaquizafop alone at lowest doses (50 and 62.5 g ha⁻¹) led to no marked effect against most of the weeds, but its efficacy improved when applied in combination with imazethapyr, being higher under propaquizafop + imazethapyr mixture applied at 62.5+ 75 g ha⁻¹ or 100+100 g ha⁻¹. Yield of pigeonpea was superior under propaquizafop + imazethapyr mixture applied at 100 + 100 g ha⁻¹ followed by 62.5 + 75 g ha⁻¹ which were comparable to hand weeding twice at 20 and 40 DAS. Highest benefit-cost ratio (BCR) was found under propaquizafop + imazethapyr mixture at 62.5+75 g ha⁻¹ followed by propaquizafop + imazethapyr mixture (100+100 g ha⁻¹), imazethapyr (100 g ha⁻¹), propaquizafop (125 g ha⁻¹), propaquizafop (100 g ha⁻¹), Fenoxaprop-p-ethyl (100 g ha⁻¹) propaquizafop (62.5 g ha⁻¹) and propaquizafop (50 g ha⁻¹). Weed control efficiency (WCE), Weed index (WI), Weed management index (WMI) and Harvest index (HI) were highest under propaquizafop + imazethapyr mixture applied at 62.5+75 g ha⁻¹ followed by propaquizafop + imazethapyr mixture applied at 100+100 g ha⁻¹ and hand weeding twice at 20 and 40 DAS.

Key words: Efficacy, pigeonpea, weed control, yield, economics, herbicide

Pigeonpea [*Cajanus cajan* (L.) Millsp.] commonly known as red gram, *tur* or *arhar* is the fifth prominent legume crop in the world. India, Myanmar, Malawi, Kenya, Uganda and Tanzania are the major pigeonpea producing countries. Pigeonpea having diversified uses as food, feed, fodder and fuel, is second most important pulse crop of India next to chickpea producing 3.29 million tons annually from 3.88 million ha (Anon, 2014). The Indian sub continent alone contributes nearly 92 per cent of the total pigeonpea production in the world. Although India leads the world both in area and production of pigeonpea, its productivity is lower (697 kg ha⁻¹) than the world average (775 kg ha⁻¹) (FAO, 2013).

In India, pigeonpea is grown in *kharif* season when severe infestation of weeds occur resulting in low grain yield. Crop yield losses due to weeds have been estimated in the range of 55 to 60 per cent (Kandasamy, 1999). However, due to frequent rains it becomes difficult to remove weeds by hand at proper time. Furthermore, non availability of labour for hand weeding is another problem. Therefore, it is

necessary to find out effective weed control techniques using herbicides. The predominant method of weed control by mechanical hoeing and manual weeding may not be possible due to heavy and continuous rainfall in *kharif* season. In pigeonpea, initial six-seven weeks period (42-49 days) is the critical period of crop-weed competition. Therefore, weeds must be controlled during this period for realising higher grain yields. Sometimes, farmers miss the application of pre-emergence herbicide and later on find it very difficult to control weeds manually during critical crop weed competition. Under such situations, post-emergence application of herbicides may help in alleviating weed problem. Presently, propaquizafop (50 g ha⁻¹) is a very effective post emergence herbicide for controlling grassy weeds in soybean (Tiwari and Mathew 2002). On the other hand, Misra *et al.* (2001) found that imazethapyr (75 g ha⁻¹) gave an effective control of grassy as well as broad leaved weeds in soybean. Therefore, the present investigation was undertaken to evaluate the efficacy of post emergence herbicides alone or in combination to control weeds for higher seed yield of pigeonpea.

MATERIALS AND METHODS

A field experiment was conducted at JNKVV, Jabalpur during *khari*f season of 2014-15 and 2015-16. The experiment was laid out in randomized block design with three replications. The soil of the experimental site was sandy in texture (51.64% sand, 19.12% silt and 29.18% clay) with pH 7.2, having 365 kg N, 16.34 P₂O₅ and 327.16 K₂O per hectare. This area received a total annual rainfall of 899.8 mm in 52 rainy days (Average of both year).

There were ten treatments comprising of two doses of ready mixture of propaquizafop + imazethapyr (62.5+75 and 100+100 g ha⁻¹), four doses of sole application of propaquizafop (50, 62.5, 100 and 125 g ha⁻¹), fenoxaprop-p-ethyl (100 g ha⁻¹), imazethapyr (100 g ha⁻¹) applied as a post emergence, hand weeding (twice at 20 and 40 days after sowing) and the weedy check (control). The herbicides were sprayed using knapsack sprayers and the spray volume was 500 L ha⁻¹. The pigeon pea genotype ICPL 87119 was sown by giving a spacing of 60 x 30 cm. A fertilizer dose of 20:60:20 NPK kg ha⁻¹ was applied at sowing. The gross plot and net plot sizes were 5.0 x 3.6 m and 4.4 x 2.4 m, respectively.

The data on weed population and dry weight was recorded at 15 days after spraying post emergent herbicides with quadrat measuring 50 x 50 cm² and expressed in m². Weeds were counted and clipped above the ground surface, dried in an oven at 70°C for 48 h and dry weight recorded. This data was computed by using the formulae of Misra and Misra (1997) and Devasenapathy *et al.* (2008) as under

Weed control efficiency

$$WCE (\%) = \frac{WDc - WDt}{WDc} \times 100$$

Where, WCE - Weed control efficiency (per cent), WDc - Weed density (m²) in control plot and WDt - Weed density (m²) in treated plot.

Weed index (WI)

Weed index represents the reduction in yield due to weeds in comparison with the weed-free plots. It can be calculated by the following equation

$$WI (\%) = \frac{X - Y}{X} \times 100$$

Where, X = weight of seed yield (kg ha⁻¹) in treatment which has highest yield and Y = weight of seed yield (kg ha⁻¹) in treatment for which weed index is to be calculated.

Weed control index

$$WCI (\%) = \frac{WBc - WBt}{XWBc} \times 100$$

Where, WCE - Weed control efficiency (per cent), WBc - Weed biomass (g.m-2) in control plot and WBt - Weed biomass (g.m-2) in treated plot.

Yield Increase

$$\text{Yield increase over control } (\%) = \frac{T - C}{C} \times 100$$

Where, T = yield of respective treatment (kg/ha) and C = yield of control (kg/ha)

Weed management index (WMI)

This index is the ratio of yield increase over the control because of weed management and percent control of weeds by the respective treatment, computed using the formula:

$$WMI = \frac{\text{Per cent yield increase over control}}{\text{Per cent control of weeds}}$$

Number of pods/plant, number of seeds/plant and 1000 seed weight were recorded at harvest. Seed yield was recorded in each plot after harvest. The economics of treatment was computed with minimum support price or prevailing market rate of products. The data was subjected to $\sqrt{X + 0.5}$ transformation and statistically analyzed as suggested by Panse and Sukhatme (1967), weed control efficiency by Mani *et al.* (1976) and weed index by Gill and Kumar (1969).

RESULTS AND DISCUSSION

Major weed species in pigeonpea field were *Echinochloa colona* and *Dinebra ratroflexa* as they contributed 26.05 and 23.21 per cent of the relative density of weeds. However, the other monocot weeds *Cyperus rotundus* (18.78%) and dicotweeds namely *Alternanthera philoxeroides* (12.23%), *Eclipta alba* (11.22%) and *Phyllanthus niruri* (8.51%) were noticed in the pigeonpea field during both the years. It was observed that the maximum weed intensity and weed dry weight in weedy check were significantly more as compared to rest of the treatments in both the years of investigation. The lowest weed counts/intensity and weed dry weights were observed in weed free treatment (Table 1). The dry matter of weeds in weedy check was maximum because of higher weed intensity and its dominance in utilizing the sunlight, nutrients, moisture, CO₂, *etc.* These results are in close conformity with those of Dhonde *et al.* (2009).

Table 1. Weed density, weed biomass at 30 days after spraying and agronomic indices as influenced by different treatments (Mean data of 2015 and 2016)

Treatment	Weed density (m ²)			Weed biomass (g/m ²)	WEC (%)	WI (%)	WCI (%)	WMI	Yield increase (%)
	Grassy	Sedges	Broad leaved						
Propaquizafop (50 g ha ⁻¹)	7.04 (49.00)	4.56 (20.33)	5.56 (30.44)	18.81 (353.37)	26.47	34.80	13.09	0.61	16.19
Propaquizafop (62.5 g ha ⁻¹)	6.90 (47.17)	4.49 (19.67)	5.50 (29.78)	18.36 (336.57)	30.03	34.00	17.61	0.60	17.85
Propaquizafop (100 g ha ⁻¹)	6.10 (36.65)	3.76 (13.67)	4.73 (21.89)	15.43 (237.53)	50.48	26.93	42.03	0.60	30.47
Propaquizafop (125 g ha ⁻¹)	5.74 (32.50)	3.67 (13.00)	4.61 (20.78)	14.78 (218.07)	54.54	24.93	47.07	0.62	34.05
Fenoxaprop-p-ethyl (100 g ha ⁻¹)	6.27 (38.83)	3.85 (14.33)	5.44 (29.11)	15.94 (253.73)	47.11	28.67	38.01	0.58	27.38
Imazethapyr (100 g ha ⁻¹)	6.52 (42.00)	3.34 (10.07)	3.92 (14.89)	14.85 (220.10)	54.12	23.97	46.51	0.81	44.04
Propaquizafop + Imazethapyr (62.5+75 g ha ⁻¹)	5.31 (27.67)	2.97 (8.33)	3.79 (13.89)	11.63 (134.83)	71.89	8.70	67.23	0.89	64.28
Propaquizafop+ Imazethapyr (100+100 g ha ⁻¹)	4.76 (22.17)	2.40 (5.33)	3.39 (11.00)	9.53 (90.26)	81.29	5.33	78.62	0.85	69.05
Hand weeding (20 and 40 DAS)	2.12 (4.00)	1.68 (2.33)	1.68 (2.33)	4.36 (18.50)	96.14	00	95.84	0.82	78.56
Weedy check	8.77 (76.50)	5.31 (27.67)	5.72 (32.22)	18.81 (353.37)	0.00	44.00	0.00	0.00	0.00
Sem±	0.08	0.07	0.10	0.09	-	-	-	-	-
CD at 5%	0.24	0.21	0.31	0.27	-	-	-	-	-

Values given in the parentheses are the original means; Data subjected to square root transformation

The combined application of propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ as post emergence caused more reduction in density and dry weight of broad leaved and grassy weeds over rest of the treatments, followed by combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹. Sole application of propaquizafop at 100 and 125 g ha⁻¹ as post emergence caused significant reduction in the density and dry weight of grassy weeds in comparison to its lower doses at 50 and 62.5 g ha⁻¹. This was due to the characteristics of the herbicide that it inhibits the activity of AC case enzyme which play important role in biosynthesis of fatty acids (Billore *et al.*, 2001, Meena *et al.*, 2011).

Sole application of propaquizafop at the lower doses (50 and 62.5 g ha⁻¹) showed lower value of weed control efficiency (26.47 and 30.03%) because of poor control of weeds. While the increased doses of propaquizafop 100 and 125 g ha⁻¹ had increased WCE (50.48 and 54.54%). Marked increase in weed control efficiency was noticed with propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ applied together (71.89%) or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ (81.29%). This was because of better control of monocot and dicot weeds. The maximum weed control efficiency (96.14%) was noticed under hand weeding twice

due to complete check on weeds. Similar results were reported by Mallareddy *et al.* (2008) and Gupta *et al.* (2013).

Weed index (WI) denotes reduction in the yield due to presence of weeds in comparison to weed free (hand weeded plots). Maximum reduction in yield (44.00%) was noticed in weedy check plots due to presence of weeds throughout the crop season (Table 1 and Fig. 1). The reduction in yield was checked to the tune of 8.70 and 5.33 per cent under the combined application of Propaquizafop 62.5 g ha⁻¹ +

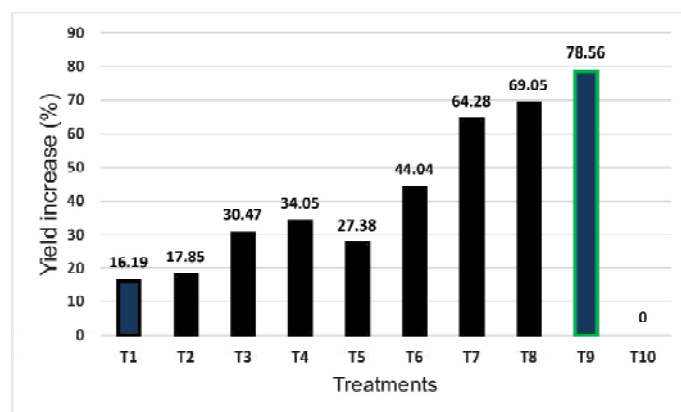


Fig. 1. Effect of different treatments on yield increase (%)

Table 2. Grain yield of pigeon pea and its attributes as influenced by different treatments (Mean data of 2015 and 2016)

Treatment	No. of pods plant ⁻¹	No. of seeds pod ⁻¹	Seed index (g)	Seed yield (t ha ⁻¹)	Harvest Index (%)	NMR (Rs ha ⁻¹)	B:C ratio
Propaquizafop (50 g ha ⁻¹)	97.30	3.04	9.07	1.54	18.84	76870	4.39
Propaquizafop (62.5 g ha ⁻¹)	99.65	3.09	9.08	1.56	19.00	78064	4.43
Propaquizafop (100 g ha ⁻¹)	106.01	3.11	9.12	1.72	20.00	87669	4.81
Propaquizafop (125 g ha ⁻¹)	107.33	3.40	9.13	1.77	20.36	9P196	4.88
Fenoxaprop-p-ethyl (100 g ha ⁻¹)	102.99	3.11	9.10	1.68	19.74	84166	4.49
Imazethapyr (100 g ha ⁻¹)	111.10	3.60	9.18	1.90	21.27	97098	5.05
Propaquizafop+ Imazethapyr (62.5+75 g ha ⁻¹)	115.37	3.60	9.23	2.17	23.08	112458	5.68
Propaquizafop+ Imazethapyr (100+100 g ha ⁻¹)	115.87	3.76	9.24	2.24	23.36	115470	5.67
Hand weeding (20 and 40 DAS)	119.63	3.93	9.25	2.36	24.00	111581	4.10
Weedy check	92.37	3.02	9.04	1.32	17.07	65133	3.96
Semt	0.85	0.25	0.07	0.039	-	-	-
CD at 5%	2.52	NS	NS	0.120	-	-	-

NMR= Net monetary return, B:C Ratio = Benefit cost ratio

imazethapyr 75 g ha⁻¹ or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹. This was because of minimal weed stress due to effective control of weed menace under these treatments during critical period of crop growth and consequently less reduction in seed yield due to presence of weeds.

A treatment having high values of agronomic indices such as WMI and yield increase should be considered a good treatment with high weed control efficiency (Suria *et al.*, 2011). Also, an ideal treatment should have low values of WI (Ramamurthy, 1999). Among the herbicidal treatments propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ resulted in higher values of WCE and WCI followed by propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ treatment. However, none of the herbicidal treatments surpassed hand weeding twice, which recorded the highest WCE (96.14%) and WCI (95.84%) due to elimination of all sorts of weeds during the course of weeding. Regarding WMI, highest value was obtained under propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ followed by propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ mixture and hand weeding twice at 20 and 40 DAS (Table 1).

Among all the treatments, minimum pods/plant and seed index were noticed under weedy plots (92.37 and 9.04 g). Thin and lanky crop plants under severe weed competition, could not assimilate and partitioned enough photosynthates for formation of pods and seed development in crop plants hence led to minimum pods/plant and seed index in weedy check plots. The pods/plant and seed index were significantly higher in plots receiving combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ (Table 2). Shete *et al.* (2009) have also reported similar results.

The seed yield was lowest (1.32 t ha⁻¹) in the plots receiving no weed control measures (weedy check) due to severe competition right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally minimum seed yield. Combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ registered higher seed yield (2.17 and 2.24 t ha⁻¹, respectively) than other treatments. While hand weeding twice resulted in maximum seed yield (2.36 t ha⁻¹) and proved its superiority over all the herbicidal treatments as also was observed by Vivek *et al.* (2003).

Harvest index, the ratio of economic yield to the biological yield, was minimum under weedy check plots. Combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ and hand weeding twice registered higher values of harvest index (23.08, 23.36 and 24.00%, respectively).

The benefit – cost ratio represents the profitability of a treatment with each rupee of investment. It was remarkable to note that the combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ or propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ as post emergence were more cost effective (5.68 and 5.67, respectively) than other herbicidal treatments and hand weeding (Table 2). The combined treatment of propaquizafop and imazethapyr at both the levels for weed control provided maximum remuneration.

CONCLUSION

It can be concluded from the study that the weed control is a limiting factor for realizing higher grain yields in pigeonpea. Apart from the weed free treatment, weeds can

effectively and efficiently be controlled with propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ ready mixture as post emergence as it provided higher growth and better seed yield. However, hand weeding twice (20 and 40 DAS) was most suitable. Combined application of propaquizafop 62.5 g ha⁻¹ + imazethapyr 75 g ha⁻¹ as post emergence was found more remunerative (₹ 112458 ha⁻¹), which was at par with propaquizafop 100 g ha⁻¹ + imazethapyr 100 g ha⁻¹ (₹ 115740 ha⁻¹).

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Physiological changes associated with hydropriming in maize hybrids

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ABSTRACT

A study was undertaken in the laboratory of National Seed Project Shalimar and in the laboratory of Department of Genetics and Plant Breeding, Faculty of Agriculture, Wadura during 2019-2021. The objective of the present study was to standardize the hydro-priming technique in two maize hybrids SMH-3 and SMH-5 and to know the physiological changes associated with the priming in maize seeds. Different combinations of temperature and duration of soaking were tested and the most efficient priming temperature was $25\pm1^{\circ}\text{C}$ and the ideal duration of soaking was 24 h. All the physiological attributes like first count, final count of germination, T_{50} , BRI, MSL, MSDW, SVI-I, SVI-II were significantly higher in both hybrids and their parental lines than the non-primed maize seeds.

Keywords: Germination, hybrids, maize, priming, temperature

Good seedling establishment is an important prerequisite for successful crop production and this is particularly true for crops, such as maize (*Zea mays* L.) which do not have the capacity to adjust to sub-optimal stand by tillering (Finch Savage *et al.*, 2004). Maize is the leading crop of the world and is widely cultivated as cereal crop. Globally, maize is known as queen of cereals because of its highest genetic yield potential and it has many types like normal yellow/white grain, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, etc. Apart from this, maize is an important industrial raw material and provides large opportunity for value addition. Germination and seedling establishment are critical stages in the plant life cycle. The three early phases of germination are: (i) imbibition, (ii) lag phase and (iii) protrusion of the radicle through the testa (Simon, 1984). While seed germination is impaired by certain conditions (soil contamination, extreme temperatures, pathogens), several types of simple procedures known as priming can be used to enhance it (Forti *et al.*, 2020). Seed priming is defined as the process of regulating seed germination by managing parameters like temperature or seed moisture content during the initial stages of germination (ISTA, 2018). By doing so, the priming techniques bring the seed closer to the point of germination. During priming, seeds are advanced to an equal stage of the germination process to enable fast and uniform emergence when planted. Depending on plant species, seed

morphology and physiology, different priming treatments can be applied, triggering the so-called “pre-germinative metabolism” (Paparella *et al.*, 2015). This is characterized by rapid water uptake, which in turn activates a series of dynamic biochemical events such as the use of reserve storage compounds (lipids, carbohydrates, proteins), production of reactive oxygen species (ROS) and subsequent activation of antioxidant enzymes, DNA damage sensing and repair (Macovei *et al.*, 2107). Indeed, intense DNA repair, essential for de novo DNA synthesis in embryo cells (Ashraf *et al.*, 1993) and enhanced antioxidant functions are the prerequisites of a successful germination process and can be used as molecular markers of seed vigor. Earlier works showed that the success of seed priming is influenced by the complex interaction of factors including plant species, water potentiality of the priming agent, duration of priming, temperature, seed vigor, seed dehydration and storage conditions of the primed seed (Parera and Cantliffe, 1994). Although, the previous studies have indicated that some benefits are associated with pre-sowing treatments for seed vigour enhancement but there is dearth of information about the germination performance of primed seeds of maize. The present study was undertaken to standardize the hydro-priming technique in two maize hybrids SMH-3 and SMH-5 and to know the physiological changes associated with the priming in maize seeds.

MATERIAL AND METHODS

Seeds of maize hybrids were hydro-primed according to Basu *et al.* (1975). They were soaked in water in a 1:2 (W/V) ratio at three temperatures and for three lengths of time. The hydroprimed seeds were employed in the experiment after being dried to their original moisture content at room temperature. The non-primed seeds were used as control. The standard germination test, as prescribed by ISTA (2007), was carried out in the laboratory. Three replications of 100 seeds were planted equidistantly on damp germination paper. The rolled towels were incubated in a germination chamber at a temperature of $25 \pm 1^\circ\text{C}$ and a relative humidity of 90 per cent. On fourth and seventh days of the germination test, the initial and final counts were taken. The germination percentage was calculated using normal seedlings. After seven days, their performance was evaluated for first and

final counts of germination, time to 50 per cent germination, mean seedling length, mean seedling dry weight, speed of germination and seedling vigour.

RESULTS AND DISCUSSION

In the present study it was found that hydro-priming influenced the maize hybrids significantly at maximum temperature (25°C) and at maximum duration of 24 h. The parameters like first count, final count, BRI (speed of germination) were also found to be significantly higher at T_2 (25°C) and for D_2 (24 h) (Table 1). These findings are in agreement with Sowmya *et al.* (2012) who revealed higher first count, final count, BRI and SVI at 25°C and lower at 10°C . The average T_{50} value among the two hybrids SMH-3 and SMH-5 were 4.85 days and 4.59 days, respectively. Among temperatures, the lower T_{50} value (3.72 days) was at T_2 and it was higher (6.5 days) at T_0 . Among durations, lower T_{50} value was observed for D_2 (3.77 days) and it was higher (6.5 days) for D_0 . Among interactions it was higher (6.5 days) at D_0T_0 and lower (2.1 days) at D_2T_2 (Table 1). These findings are in agreement with (Dezfuli *et al.*, 2008). The first count of hybrids it was increased from (30 to 36 percent) in SMH-3 and (23 to 30%) in SMH-5 (Table 1). The final count was increased from (50 to 65%) in SMH-3 and (54 to 65%) in SMH-5 and the speed of germination (BRI) of hybrids was

Treatment details

Treatments	
Duration of soaking (h) (D)	Temperature ($^\circ\text{C}$) (T)
D_0 : Control (no soaking)	T_0 : Control (no soaking)
D_1 : 18 h	T_1 : $10 \pm 1^\circ\text{C}$
D_2 : 24 h	T_2 : $25 \pm 1^\circ\text{C}$

Table 1: T_{50} values (days) and first count germination (per cent) as influenced by hydro-priming in maize hybrids

		T_{50} Values of SMH-3 and SMH-5			Mean	First count of SMH-3 and SMH-5			Mean
		T_0	T_1	T_2		T_0	T_1	T_2	
SMH-3	D_0	6.66	6.66	6.66	6.66	30.00	30.00	30.00	30.00
	D_1	6.66	2.66	2.66	4.00	30.00	42.00	46.66	39.55
	D_2	6.66	2.66	2.33	3.88	30.00	40.00	47.66	39.22
Sub Mean		6.66	4.00	3.88	4.85 ^a	30.00	37.33	41.44	36.25 ^a
SMH-5	D_0	6.33	6.33	6.33	6.33	23.00	23.00	23.00	23.00
	D_1	6.33	2.66	2.33	3.77	23.00	35.66	40.00	32.88
	D_2	6.33	2.66	2.00	3.66	23.00	37.66	48.33	36.33
Sub Mean		6.33	3.88	3.55	4.59 ^a	23.00	32.11	37.11	30.74 ^b
Factor Mean	Temperature	6.50 ^b	3.94 ^a	3.72 ^a		26.50 ^c	34.72 ^b	39.27 ^a	
	Duration	6.50 ^b	3.88 ^a	3.77 ^a		26.50 ^c	36.22 ^b	37.77 ^a	
		$D \times T$				$D \times T$			
		D_0	6.50	6.50		26.50	26.50	26.50	
		D_1	6.50	2.66		26.50	38.83	43.33	
		D_2	6.50	2.66		26.50	38.83	48.00	
		SE (d)				SE (d)			
		0.152				0.515			
		0.187				0.631			
		0.187				0.631			
		0.264				0.893			
		0.264				0.893			
		0.323				1.094			
		0.458				1.547			
		CD (5%)				CD (5%)			
		0.307				1.040			
		0.377				1.274			
		0.377				1.274			
		0.533				1.803			
		0.533				1.803			
		0.652				2.209			
		0.925				3.124			

Note: a, b and c indicates the level of significance, a being the highest followed by b and c.

increased from (0.219 to 0.228) for SMH-3 and (0.239 to 0.245) for SMH-5 (Table 2). These findings were found to be in conformation with the findings of Damalas *et al.* (2019) who

confirmed that hydro-priming accelerated the Faba bean germination, seedling vigour index and field emergence for Faba bean. Similar results were observed by Umair *et al.* (2010)

Table 2: Final count germination (per cent) and speed of germination (BRI) as influenced by hydro-priming in maize hybrids

		Final count of SMH-3 and SMH-5				BRI of SMH-3 and SMH-5			
		T ₀	T ₁	T ₂	Mean	T ₀	T ₁	T ₂	Mean
SMH-3	D ₀	50.00	50.00	50.00	50.00	0.219	0.219	0.219	0.219
	D ₁	50.00	86.00	85.00	73.66	0.219	0.228	0.236	0.228
	D ₂	50.00	82.33	85.66	72.66	0.219	0.241	0.251	0.237
Sub Mean		50.00	72.77	73.55	65.44 ^a	0.219	0.229	0.235	0.228 ^b
SMH-5	D ₀	54.00	54.00	54.00	54.00	0.239	0.239	0.239	0.239
	D ₁	54.00	78.00	77.00	69.66	0.239	0.247	0.257	0.248
	D ₂	54.00	80.33	84.66	73.00	0.239	0.249	0.255	0.248
Sub Mean		54.00	70.77	71.88	65.55 ^a	0.239	0.245	0.250	0.245 ^a
Factor Mean	Temperature	52.00 ^b	71.77 ^a	72.72 ^a		0.229 ^c	0.237 ^b	0.243 ^a	
	Duration	52.00 ^b	71.66 ^a	72.83 ^a		0.229 ^c	0.238 ^b	0.243 ^a	
		D × T				D × T			
	D ₀	52.00	52.00	52.00		0.229	0.229	0.229	
	D ₁	52.00	82.00	81.00		0.229	0.238	0.246	
	D ₂	52.00	81.33	85.16		0.229	0.245	0.253	
		SE (d)		CD (5%)		SE (d)		CD (5%)	
H		1.187		2.397		0.0011		0.0022	
T		1.454		2.937		0.0014		0.0028	
D		1.454		2.937		0.0014		0.0028	
H×T		2.056		4.153		0.0020		0.0040	
H×D		2.056		4.153		0.0020		0.0040	
T×D		2.518		5.086		0.0024		0.0048	
H×T×D		3.561		7.193		0.0034		0.0068	

Table 3: Mean seedling length (cm) and mean seedling dry weight (g) as influenced by hydro-priming in maize hybrids

		MSL of SMH-3 and SMH-5				MSDW of SMH-3 and SMH-5			
		T ₀	T ₁	T ₂	Mean	T ₀	T ₁	T ₂	Mean
SMH-3	D ₀	13.83	13.83	13.83	13.83	0.008	0.008	0.008	0.008
	D ₁	13.83	23.30	29.50	22.21	0.008	0.022	0.044	0.025
	D ₂	13.83	24.50	34.83	24.38	0.008	0.029	0.064	0.034
Sub Mean		13.83	20.54	26.05	20.14 ^a	0.008	0.019	0.039	0.022 ^a
SMH-5	D ₀	13.33	13.33	13.33	13.33	0.011	0.011	0.011	0.011
	D ₁	13.33	19.26	20.83	17.81	0.011	0.024	0.030	0.022
	D ₂	13.33	22.83	23.50	19.88	0.011	0.029	0.036	0.025
Sub Mean		13.33	18.47	19.22	17.01 ^b	0.011	0.021	0.025	0.019 ^a
Factor Mean	Temperature	13.58 ^c	19.51 ^b	22.63 ^a		0.009 ^c	0.020 ^b	0.032 ^a	
	Duration	13.58 ^c	20.01 ^b	22.13 ^a		0.009 ^c	0.023 ^b	0.029 ^a	
		D × T				D × T			
	D ₀	13.58	13.58	13.58		0.009	0.009	0.009	
	D ₁	13.58	21.28	25.16		0.009	0.023	0.037	
	D ₂	13.58	23.66	29.16		0.009	0.029	0.050	
		SE (d)		CD (5%)		SE (d)		CD (5%)	
H		0.4478		0.904		0.0015		0.003	
T		0.5484		1.107		0.0018		0.003	
D		0.5484		1.107		0.0018		0.003	
H×T		0.7755		1.566		0.0026		0.005	
H×D		0.7755		1.566		0.0026		0.005	
T×D		0.9498		1.918		0.0032		0.006	

Table 4: Seedling vigour index-I and seedling vigour index-II as influenced by hydro-priming in maize hybrids

		SVI-I of SMH-3 and SMH-5			Mean	SVI-II of SMH-3 and SMH-5			Mean
		T ₀	T ₁	T ₂		T ₀	T ₁	T ₂	
SMH-3	D ₀	748	748	748	748	0.629	0.629	0.629	0.629
	D ₁	748	1805	2424	1659	0.629	1.663	3.338	1.876
	D ₂	748	1954	2915	1872	0.629	2.118	5.342	2.696
Sub Mean		748	1502	2029	1426 ^a	0.629	1.470	3.103	1.734 ^a
SMH-5	D ₀	697	697	697	697	0.596	0.596	0.596	0.596
	D ₁	697	1340	1765	1267	0.596	1.483	2.572	1.551
	D ₂	697	1675	2238	1536	0.596	2.185	2.858	1.880
Sub Mean		697	1237	1566	1167 ^b	0.596	1.421	2.009	1.342 ^b
Factor Mean	Temperature	722 ^c	1370 ^b	1798 ^a		0.612 ^c	1.445 ^b	2.556 ^a	
	Duration	722 ^c	1463 ^b	1704 ^a		0.612 ^c	1.713 ^b	2.288 ^a	
		D × T				D × T			
	D ₀	722	722	722		0.612	0.612	0.612	
	D ₁	722	1572	2094		0.612	1.573	2.955	
	D ₂	722	1814	2576		0.612	2.151	4.100	
		SE (d)				SE (d)			
	H	52.38				0.106			
	T	64.15				0.129			
	D	64.15				0.129			
	H×T	90.73				0.183			
	H×D	90.73				0.183			
	T×D	111.12				0.224			
	H×T×D	157.14				0.318			
		CD (5%)				CD (5%)			
	H	52.38				0.106			
	T	64.15				0.129			
	D	64.15				0.129			
	H×T	90.73				0.183			
	H×D	90.73				0.183			
	T×D	111.12				0.224			
	H×T×D	157.14				0.318			

which confirmed that hydro-priming significantly affected the germination percentage, root and shoot length, seedling dry weight and seedling vigour index in mung bean. The parameters like MSL, MSDW, SVI-I and SVI-II showed higher values at maximum temperature of 25°C and at maximum duration of soaking of 24 h. The mean seedling length (MSL) of hybrids was increased from (13 to 22 cm) at T₀ and T₂ and same for D₀ and D₂. Among interactions it was increased from (13 cm to 29 cm) in D₀T₀ and D₂T₂ and the mean seedling dry weight (MSDW) was increased from (0.009 to 0.032 g) at T₀ and T₂ and (0.009 to 0.029 g) for D₀ and D₂. Among interactions it was increased from (0.009 g to 0.050 g) at D₀T₀ and D₂T₂ (Table 3). The seedling vigour index-I (SVI-I) was increased from (722 to 1798) at T₀ and T₂ and (722 to 1704) for D₀ and D₂. Among interactions it was increased from (722 to 2576) at D₀T₀ and D₂T₂ and seedling vigour index-II (SVI-II) was increased from (0.612 to 2.55) at T₀ and T₂ and (0.612 to 2.28) for D₀ and D₂. Among interactions it was increased from (0.612 to 4.1) at D₀T₀ and D₂T₂ (Table 4). Qadir (2021) found similar results in two bread wheat genotypes and declared that hydro-priming enhanced the germination percentage, seedling vigour, radicle length and were confirmed by Mahmoodi *et al.* (2011).

CONCLUSION

All the attributes mentioned above were significantly

improved upon hydropriming and their results were efficiently higher than non-primed seeds therefore, hydro-priming for 24 h at 25°C was the best treatment for improving germination rate, seedling vigor, speed of germination of maize. These effects can improve seedling establishment and field performance of this important cereal.

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Performance of brinjal to water quality under drip irrigation system

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ABSTRACT

An experiment was conducted to study the performance of brinjal under surface and sub-surface drip irrigation using saline and good quality water at the Precision Farming Development Centre, ARS, Swami Keshwanand Rajasthan Agricultural University, Bikaner during 2015-2018 on loamy sand soil. The experiment comprised of two levels of irrigation water salinity viz., 0.25(BAW) and 2.76 dS/m, two drip system (surface and sub-surface) or two mulch pattern (without mulch and with mulch) under Factorial Randomized Block Design (RBD) with three replications. Based on three seasons pooled data it was revealed that brinjal cv. Navkiran gave maximum fruits per plant (17.53) and yield (507.50 q ha⁻¹) in best available water, which was 6.33 per cent higher as compared to saline water. Whereas in the sub-surface drip irrigation system, maximum number of fruits per plant (18.28) and yield (512.70 q ha⁻¹), out of both the treatment, were recorded, which was significantly higher over surface drip. Further, significantly higher number of fruits per plant (17.3) and yield (523.33 q ha⁻¹) were found with mulching.

Key words: Irrigation water quality, saline water, brinjal, surface and sub surface drip, mulch

Brinjal (*Solanum melongena* L.) is a popular vegetable crop grown throughout India. Because of its versatility and low price, it is popular among small-scale farmers and low-income consumers, and is often referred to as the poor man's vegetable. After China, India is the world's second-largest producer of brinjal, with 13.0 million tonnes produced from 0.74 million hectares (NHB, 2019-20). Brinjal is a tropical vegetable crop believed to be a native of India. It can be grown on different kinds of soil but does best in well-drained silt loams or clay loams with a pH of 5.5-6.5. When these crops are grown as irrigated crops, farmers generally use surface methods of irrigation. Drip irrigation along with plastic mulching is effective in increasing the yield when compared with surface irrigation (Sunilkumar and Jaikumaran, 2002 and Tiwari *et al.*, 2003).

Saline water has been used successfully for irrigation. Crop yield is the most important consideration in the utilization of saline water (Malash *et al.*, 2005). Sub-surface drip irrigation systems may increase water use efficiency (WUE) due to reduced soil and plant surface evaporation because only the root zone or the partial root zone is irrigated

as opposed to sprinkler irrigation where the entire area is wetted. Under combined deficit and salt water irrigation, crop growth characteristics and yield were different from those under solo deficit and saline irrigation. According to Ayers *et al.* (1993), the combination of drought and salinity reduced crop water availability at a faster pace than either salinity or drought alone. According to Hachicha *et al.* (2006), salt accumulates on the soil surface before it migrates and reaches the root zone when drip irrigation is used.

Ground water quality of Bikaner district is not good and has the problem of salinity. Drip irrigation is the right option in this situation, which not only enhances WUE but poor quality water can also be used safely with minimum hazard on soil and plant. The most suited technology for judicious leaching fraction is the use of a drip irrigation system for saline water. Drip irrigation (Banyopadhyay *et al.*, 2005) is a traditional and successful method of distributing water directly to the soil and closer to the plant without significant water loss, resulting in increased water productivity.

Mulching is a technique for covering the soil surface around plants in order to provide a favourable environment for their growth. Polyethylene mulches are widely used in the cultivation of vegetables. Weed control, temperature moderation, salinity reduction, etc., are the desirable effects of plastic mulching. It also exerts decisive effect on earliness, yield and quality of the crop (Raina *et al.*, 1999).

Several studies have been done all over the world to analyze the effect of drip irrigation, irrigation water and plastic mulching on vegetables. Here, an attempt was made to summaries the available literature giving emphasis on brinjal. The various aspects of drip, irrigation water and mulching are brought under different heads.

MATERIALS AND METHODS

The field experiment was conducted at Precision Farming Development Centre, Agricultural Research station, Swami Keshwanand Rajasthan Agricultural University, Bikaner (28°01'N latitude and 73°22'E longitude at an altitude of 234.70 meters above mean sea level) during *rabi* seasons of 2015-16, 2016-17 and 2017-18. The soil of experimental field was loamy-sand, alkaline in reaction (pH 8.2) having 120 kg ha⁻¹ available N (Alkaline permanganate method) low level of available phosphorus (15.1 kg ha⁻¹, Olsen's method) and medium in available potassium (173.7 kg ha⁻¹, Flame photometric method) in 0-15 cm soil depth at the start of the experiment.

The experiment was planned to study the performance of vegetables under surface and sub-surface drip irrigation using saline and good quality water. The treatments comprised of two levels of irrigation water (BAW and saline water) and two drip systems (surface and sub-surface) at 80 per cent to level or two mulch pattern (without mulch and with mulch 25 μ) under Factorial Randomized Block Design (RBD) with three replications. Brinjal cv. Navkiran was

grown as per standard horticultural practices. Irrigation was applied through in-line drip with discharge rate of 4 liters per hour per emitter. Irrigations were scheduled on alternate day basis and recommended fertilizers were applied through drip. The yield attributes and yields were collected, and the data was statistically analysed for variance estimates using the approach recommended by (Panse and Sukhatme, 1985). To clarify the important effects of different saline waters and irrigation systems, the critical differences between the measured values under different treatment combinations were also evaluated.

RESULTS AND DISCUSSION

Effect of irrigation system

Results revealed that drip irrigation system significantly influenced yield attributes and yield of brinjal. The number of fruits plant⁻¹ and yield (q ha⁻¹) exhibited the superiority with the use of sub surface irrigation system over surface drip irrigation system (Table 1). Sub surface drip irrigation system produced significantly higher number of fruits plant⁻¹ (17.59) and yield (512.70 q ha⁻¹) which might be due to less salt accumulation in rhizosphere under sub surface drip irrigation than surface drip irrigation system.

Effect of irrigation water quality

Results based on pooled data revealed that quality of irrigation water had profound effect on number of fruits plant⁻¹ and yield (q ha⁻¹) (Table 1). The significantly higher value of number of fruits plant⁻¹ (17.53) and yield (507.50 q ha⁻¹) were obtained with the use of BAW over saline water with the tune of 17.17 and 477.26 q ha⁻¹, respectively. The reduction in yield parameters might be due to harmful effect of salts in physiological processes. Decrease in photosynthesis, nutrient absorption and uptake and increase in photorespiration resulted in lower photosynthates

Table 1. Response of quality of water, irrigation mode and mulch on yield attributes of brinjal

Treatments	No. of fruits plant ⁻¹				Yield (q ha ⁻¹)			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
BAW	17.33	17.0	18.23	17.53	473.81	506.5	542.17	507.50
Saline water	16.98	16.7	17.84	17.17	445.38	476.8	509.53	477.26
S.Em.±	0.20	0.20	0.20	0.20	5.31	20.95	5.31	5.31
C.D. (5%)	0.61	0.63	0.61	0.61	16.23	64.00	16.23	16.23
Surface drip	16.93	16.6	17.78	17.12	440.50	471.8	503.93	472.06
Sub surface drip	17.37	17.1	18.28	17.59	478.69	511.6	547.78	512.70
S.Em.±	0.20	0.20	0.20	0.20	5.31	20.95	5.31	5.31
C.D. (5%)	0.61	0.63	0.61	0.61	16.23	64.00	16.23	16.23
Without mulch	16.75	16.5	17.58	16.93	430.31	461.1	492.23	461.22
With mulch	17.55	17.3	18.48	17.77	488.88	522.2	559.47	523.53
S.Em.±	0.001	0.16	0.001	0.001	0.09	4.23	0.09	0.09
C.D. (5%)	0.004	0.49	0.004	0.004	0.29	12.92	0.29	0.29

assimilation and ultimately led to poor yields. Unlike flood irrigation, drip irrigation removes salt from the rhizosphere and maintains a low soil moisture tension (Pasternak, 1987). According to Kang (2004), drip irrigation system with low rate and frequent irrigation applications can maintain high soil matrix potential in the root zone over a long period of time, compensating for the decrease in osmotic potential caused by saline water irrigation, and a constant high water potential can be maintained for crop growth.

Effect of mulching

A critical examination of data showed that use of mulch had a significant effect on the growth, yield attributes and yield of brinjal (Table 1). The highest number of fruits plant⁻¹ (17.17) and yield (523.53 q ha⁻¹) were recorded with the use of plastic mulch with an increment of 4.96 and 13.39 per cent, respectively, over no use of mulch. This increase in yield parameters might be due to plastic mulch as it was most effective in conservation of soil moisture, weed control and slight increase or maintenance in temperature. These results were in close conformity of the results obtained by Hatami *et al.* (2012) who demonstrated that polyethylene mulch had a significant effect on weed density. Mulch material minimize soil erosion, weed problems and nutrient loss (Clough *et al.*, 1990). Beneficial effects of mulching like earliness in yield (Decoteau *et al.*, 1989) and reduction in insect and disease problems (Greenough *et al.*, 1990) were also reported.

CONCLUSION

The present study indicated that drip irrigation at 80 per cent ET₀ level, 100 per cent RDF with 25µ plastic mulch condition resulted in higher yield. Combination of drip irrigation with plastic mulch enhanced the soil moisture availability, by preventing water loss through evaporation. The fertilizer use efficiency also increased considerably under drip fertigation than direct application. Hence, drip fertigation with mulch was appropriate and efficient method for brinjal cultivation than conventional.

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Impact of hydrogel on wheat (*Triticum aestivum* L.) in sandy soils under limited irrigation conditions

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ABSTRACT

An experiment on impact of hydrogel on wheat (*Triticum aestivum* L.) in sandy soils under limited irrigation conditions was conducted through on farm trials on farmers field in Bhiwani district of Haryana during 2013-14 and 2014-15. In Bhiwani, wheat was grown on an area of about one lakh ha during *rabi* season. Sixty per cent soils of the district are sandy in texture with poor water retention capacity. The trial consisted of three treatments *viz.*, normal irrigation (six irrigations), limited irrigations (four) and hydrogel application with limited irrigations (four). Pusa hydrogel @ 2.5 kg ha⁻¹ was applied during the experiment. Hydrogel with limited irrigations (four) fetched higher average grain yield (4980 kg ha⁻¹) and net returns (Rs. 39995 ha⁻¹) than normal irrigations (4730 kg ha⁻¹ and Rs. 36680 ha⁻¹) and was followed by limited irrigations (4530 kg ha⁻¹ and Rs. 32600 ha⁻¹). The use of hydrogel resulted into saving of two irrigations as compared to normal irrigations under sandy soil conditions.

Key words: Wheat, hydrogel, limited irrigation, yield, water saving

Wheat (*Triticum aestivum* L.) ranks first among cereal crops in the world and second among food grains in India. Therefore, increasing grain yield production is considered as one of the most important national goals to meet the demand for food grains of ever increasing human population. Water is the most important natural resource for any crop. After introduction of green revolution, there has been over exploitation of water for agricultural purposes resulting into undesirable rise and depletion of water table in different areas. In Bhiwani district of Haryana, wheat is grown in an area of about one lakh ha of the total cultivable area during *rabi* season. Sixty per cent soils of the district are sandy in texture with poor water retention capacity. The water table in this region is 300-350 feet and goes down by 3-5 feet every year. The underground water quality of the region is also not good and 45 per cent water is brackish in nature which is not suitable for irrigation purpose. Water scarcity is a major constraint for crop production in these areas. Therefore, it is very important to increase irrigation efficiency, water productivity of crop by reducing the losses of water and also ensuring better conditions for crop growth. Hydrogel, a synthetic polymer used as soil amendment is insoluble, hydrophilic in nature and can absorb large quantities of water (Schacht, 2004). Hydrogels have great potential in areas where opportunity for irrigation is limited and can

increase the water availability during crop establishment. The capacity of the hydrogel to absorb and retain water is as much as 80-180 times its original volume, while on weight basis it can absorb as high as 400 times its original weight (Kalhapure *et al.*, 2016). Hydrogel (Super absorbent polymer) is a water retaining, cross-linked hydrophilic, biodegradable amorphous polymer which can absorb and retain water at least 400 times of its original and make at least 95 per cent of stored water available for crop absorption. The hydrogel particles may be taken as "miniature water reservoir" in the soil and water will be removed from these reservoirs upon the root demand through osmotic pressure difference. Use of hydrogels increases the amount of available moisture in root zone, thus implying longer intervals between irrigations (Johnson, 1984). The volume of hydrogel reduces with release of water, which in turn increases soil porosity, aeration, water infiltration, better root growth and helps in achieving higher yield levels.

The irrigation requirement of wheat is very high (6 irrigations), which increases cost of production. Its cultivation may be made more profitable by decreasing the demand of water and the frequency of irrigation. Major research question in rainfed and supplemental irrigation production systems revolve around how best we can utilize available rain or limited irrigation water. Considering the

advantages of hydrogel, the on farm trials were conducted with the objectives of studying the effect of hydrogel on growth, yield attributing characters and yield of wheat, to work out the economics of different treatments and to study the effect of hydrogel on number of irrigations.

MATERIALS AND METHODS

On farm trials were conducted for two consecutive years during *rabi* 2013-14 and 2014-15 at farmers' fields of villages Gignau, Karimodh and Haripur of Bhiwani district (Haryana) located between 28.19° and 29.05° north latitudes and 75.26° and 76.28° east longitudes. The district has a semi-arid climate with hot and dry winds in summer, severe cold in winter and humid warm weather during monsoon. The maximum temperature sometimes exceeds 47°C in summer, while temperature below freezing accompanied by frost in winter. The average annual rainfall is 300-400 mm. About 80-90 per cent of total rainfall is received from south-west monsoon in the months, of July to September, while remaining 10-20 per cent rainfall is received from north-east monsoon in the winter season. The trial was conducted on 0.4 ha dividing it into three equal parts. Each trial consisted of three treatments *viz.*, normal irrigation (six irrigations), limited irrigations (four) and hydrogel application with limited irrigations (four). The sowing was done in first fortnight of November. Hydrogel @ 2.5 kg ha⁻¹ was drilled at seeding depth along with di ammonium phosphate (DAP) before sowing. Other package of practices were same in all the treatments. The yield data were recorded by harvesting and threshing crop in ten square meter area at each location and converted into per ha. Gap analysis of ten farmers was also done to evaluate whether use of hydrogel have impact on yield increase, economical and saves water.

RESULTS AND DISCUSSION

The experimental soil was of sandy to sandy loam and characterized by high infiltration rate and low water holding capacity. The available nitrogen and phosphorus were was

low and available potash was medium to high. Pooled data presented in Table 1 revealed that application of hydrogel with limited irrigations (four) fetched higher average grain yield (4980 kg ha⁻¹) and net returns (Rs. 39995 ha⁻¹) than normal irrigations (4730 kg ha⁻¹ and Rs. 36680 ha⁻¹) followed by limited irrigations (4530 kg ha⁻¹ and Rs. 32600 ha⁻¹), respectively. Yield showed a significant difference under use of hydrogel than normal irrigation practices. Yield attributing characters, *i.e.*, grains per spike and 1000 grain weight were also higher under hydrogel treatment than normal and restricted irrigation treatments. There was a significant difference in yield attributing characters under use of hydrogel than normal irrigations practices. On an average 10 per cent yield increase was observed under hydrogel application with limited irrigations (four) than other treatments, *i.e.*, normal irrigation and limited irrigations. The use of hydrogel resulted into saving of two irrigations as compared to normal irrigations under sandy soil conditions. Gap analysis of ten farmers was also carried out (Table 2). Most of the farmers (79.8%) accepted that the grain yield would increase with the use of hydrogel in their fields. Apart from this, there was acceptance that this technology would save water (83.9%) as well as its economical (84.9%).

Table 2. Gap analysis of technology intervention

Assessed Parameters	Without intervention	With technology intervention	Per cent increase
Knowledge score of yield increase	9.40 ± 1.6	11.10 ± 2.3	79.8
Knowledge score of water saving	6.10 ± 1.4	16.20 ± 2.5	83.9
Knowledge score of technology economics	9.20 ± 2.5	15.12 ± 2.6	84.9

Table 1. Impact of hydrogel on plant height, yield attributing characters, grain yield and economics of wheat (Pooled mean of 2013-14 and 2014-15).

Treatments	Plant height (cm)	Number of grains spike ⁻¹	1000 grain weight (g)	Average production (kg ha ⁻¹)	Net return (Rs. ha ⁻¹)	B:C ratio	Net saving (No. of irrigations)
Normal irrigation (six)	100	47.50	39.40	4730	36680	1.60	-
Limited irrigation (four)	97	45.00	36.90	4530	32600	1.54	-
Hydrogel application with limited irrigation (four)	100	50.00	40.00	4980	39995	1.61	Two
CD (0.05%)	5.4	4.2	3.2	223	-	-	-

CONCLUSION

Use of hydrogel @ 2.5 kg ha⁻¹ in wheat crop that resulted into higher grain yield and net returns with less number of irrigations under sandy soils can be a real advantage in terms of water saving during *rabi* season. Gap analysis also showed the acceptance of the technology. Almost 80 per cent farmers accepted that their yield would increase, 84 per cent farmers accepted that this technology saves water and 85 per cent farmers accepted that the technology is economical. It could be concluded that the technology is helpful in solving water problem of the farming community in water scarce area and is economical along with higher yield.

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Eco-friendly management of insect pests infesting cucumber (*Cucumis sativus* L.)

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ABSTRACT

The present research work was carried out at Agronomy Farm, College of Agriculture, Dapoli during *Khari*, 2016 on seven flowering plants (cosmos, cowpea, marigold, mustard, niger, sesamum and zinnia) on the borders of cucumber plots for conservation of natural enemies. The flowering plants niger, sesamum, mustard, cowpea and marigold on cucumber bunds proved to be best for reducing the red pumpkin beetle incidence. Niger, mustard, marigold and cowpea proved best for reducing flea beetle incidence. Niger, marigold, cowpea, mustard and sesamum proved best for reducing serpentine leaf miner incidence. Niger, cosmos, cowpea, sesamum and zinnia were found best for reducing the fruit fly infestation. The results of the present study will be helpful in the eco-friendly management of pests of cucurbits.

Keywords: Pest management, cucurbits, natural enemies, flowering plants, border crops

Cucurbits constitute the largest group of green summer vegetables grown all over the world. Cucumber is the popular crop of the Cucurbitaceae family grown throughout India. Fruits of this crop are rich in iron, vitamins (A, B, C), protein, minerals and have medicinal properties. India is the second largest producer of vegetables in the world, next to China, producing around 191 million tonnes of vegetables annually from an area of around 10.3 million hectares (Anonymous, 2019). The annual production of vegetables in Maharashtra is 123.06 lakh tonnes from an area of 7.26 lakh ha (Anonymous, 2018). Even though unavailability of authentic data on area and production of cucumber, it has been reported as a commercial cash crop in tropical and sub-tropical parts of the world. The area under cultivation in Konkan region is about 460 ha with the annual production of 5,163 tonnes (Anonymous, 2009).

Cucumber is attacked by more than a dozen of insect pests. The important ones are red pumpkin beetle, *R. foveicollis* (Coleoptera: Chrysomelidae), fruit fly, *B. cucurbitae* (Diptera: Tephritidae), white fly, *B. tabaci* (Hemiptera: Aleyrodidae), aphid, *A. gossypii* (Hemiptera: Aphididae), leaf eating caterpillar, *D. indica* (Lepidoptera: Pyralidae), serpentine leaf miner, *L. trifolii* (Diptera: Agromyzidae) and red spider mite; *T. urticae* Koch (Acarina: Tetranychidae).

Conservation of the natural enemy fauna *in situ* for

suppressing the pest population seems to be a very good alternative. Farmers continue to resort on insecticidal use for checking pest incidence in their fields without being aware of either the natural biological suppression taking place or impact of the insecticides on the natural bio agents. It is, therefore, essential to convince the farmers of its importance. Odum (1962) was among the first to use the term 'Ecological engineering' which was reviewed as environmental manipulation by man using small amounts of supplementary energy to control systems in which the main energy drives are still coming from natural sources.

Cucumber fields are naturally and richly endowed with predator and parasitoid biodiversity that can be enhanced by planting flowering plants nearby. But, the challenge is to motivate millions of farmers to adopt this concept, stop their routine spraying, and enrich cucumber field bunds with flowers. Parasitization is not an easy concept for farmers to grasp and parasitoids are too tiny to be observed. Farmers can be motivated to observe and conserve "bees and their relatives" and refrain from spraying insecticides, harmful to them. Keeping in view the huge losses caused by cucumber pests, reduce pesticide load and to maintain ecological balance in cucurbit eco-system, it is pertinent to undertake the studies on management of these pests by habitat manipulation.

MATERIAL AND METHODS

The present investigation was conducted at Agronomy Farm, College of Agriculture, Dapoli during *kharif* 2016. The experimental plot was divided into three replications. Whereas, each replication was divided into eight subplots of size 3.0×1.6 m. The raised beds were prepared and used for cultivation of cucumber. While the other crops, mustard, sesamum, cosmos, niger, marigold, cowpea and zinnia, were sown on bunds of size 9.0×0.5 m. The distance between two flowering plants was 0.5 m and 0.25 m between two rows, whereas distance between two plots was 1.0 m. The seeds were sown on June 18, 2016 and crops were harvested on September 18, 2016. The required quantity of FYM was mixed at the time of field preparation and fertilizers were applied at the time of sowing.

The healthy seeds of cucumber cv. Sheetal and cowpea were procured from Vegetable Improvement Scheme, Wakawali. Local varieties of mustard, sesamum and niger were obtained from the Department of Agronomy, College of Agriculture, Dapoli. Healthy seeds of cosmos, zinnia and marigold were obtained from the Department of Horticulture, College of Agriculture, Dapoli. The seeds of cucumber were sown during *kharif*, 2016 with three replications and eight treatments in Randomized Block Design (Table 1). The border crops were sown as per recommended seed rate. Farm yard manure as organic manure was applied at the rate of 5 t ha⁻¹ in the soil before last harrowing so as to mix it well in the soil. Nitrogen and phosphorus were applied in the form of straight fertilizers through urea (46% N) and single super phosphate (16% P₂O₅) to mustard, sesamum and marigold seedlings according to recommendation. The recommended dose for cucumber 100:75:50kg NPK ha⁻¹ was applied at the time of sowing. Application of urea was given through spot near the roots zone of flowering plants on cucumber bunds.

Four plants per plot were selected randomly to record the observations on the incidence of cucumber pests and for recording the natural enemies in cucumber ecosystem. Same cucumber plants were used for recording the presence of different natural enemies. Similarly, five flowering plants

on bunds were randomly selected for recording the natural enemies. The total of eight treatments having seven flowering plants on bunds and one control (no flowering plants, *i.e.*, open bund) were used around the plot of cucumber.

The shot holes made by flea beetle were counted from top, middle and bottom leaf of vine. The scrapped galleries were counted from top, middle and bottom leaf of vine for red pumpkin beetle damage. The damaged and healthy fruits were recorded at each picking for recording fruit infestation by fruit fly. The number of leaf mines were counted from top, middle and bottom leaf for recording damage by leaf miner. The observations were recorded at weekly intervals until harvest of the main crop.

$$\text{Per cent infestation} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

The natural enemies were recorded by naked eyes and by collecting with the help of insect collection net. The recorded natural enemies were counted plot wise. The unidentified natural enemies were got identified from the Department of Agricultural Entomology, College of Agriculture, Dapoli.

Data on pest incidence recorded in different treatments was used to calculate percent reduction in infestation of different cucumber pest over control to find out the impact of conserved natural enemies in cucumber by using following formula.

$$\text{Per cent reduction in pest infestation} = \frac{100}{\% \text{ pest infestation in control}} \times \% \text{ infestation in treatment} - 100$$

RESULTS AND DISCUSSION

Incidence of cucumber pests

The incidence of cucumber pests *viz.*, red pumpkin beetle, flea beetle, serpentine leaf miner and fruit fly were recorded and presented. The red pumpkin beetle appeared from 4th week of July to 2nd week of September in the field and the incidence varied throughout the season. The data for mean number of scrapped galleries per leaf (MNSGs) by red pumpkin beetle was recorded (Table 2). The MNSGs by red pumpkin beetle varied from 0.00 (cow pea and mustard) to 1.0 (control) in week 1 (4th week of July) and result was non-significant. In week 2 (1st week of August), the MNSGs were in the range of 0.00 (cowpea and mustard) to 1.42 (control). There were no scrapped galleries observed in the treatments cowpea and mustard as flowering plants on bunds and these treatments were found to be significantly superior over rest of the treatments and at par with treatments *viz.*, niger (0.58), cosmos (0.75) and zinnia (0.75). The MNSGs by red pumpkin

Table 1. Treatment details

Tr. no.	Name of the plant	Botanical name	Family
T ₁	Cosmos	<i>Cosmos bipinnatus</i> Cav.	Asteraceae
T ₂	Cowpea	<i>Vigna unguiculata</i> L.	Fabaceae
T ₃	Marigold	<i>Tagetes erecta</i> L.	Asteraceae
T ₄	Mustard	<i>Brassica rapa</i> L.	Brassicaceae
T ₅	Niger	<i>Guizotia abyssinica</i> L.	Asteraceae
T ₆	Sesamum	<i>Sesamum indicum</i> L.	Pedaliaceae
T ₇	Zinnia	<i>Zinnia grandiflora</i> Nutta.	Asteraceae
T ₈	Control	-	-

Table 2. Number of scrapped galleries per leaf by red pumpkin beetle

Treatments	Number of scrapped galleries leaf ⁻¹								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.50 (0.98)*	0.75 (1.07)	7.92 (2.89)	7.50 (2.81)	4.25 (2.16)	1.67 (1.47)	3.08 (1.89)	1.67 (1.47)	3.42 (1.84)
T ₂ Cowpea	0.00 (0.71)	0.00 (0.71)	4.33 (2.19)	4.83 (2.31)	3.42 (1.97)	1.33 (1.34)	3.92 (2.10)	2.25 (1.66)	2.51 (1.62)
T ₃ Marigold	0.58 (1.03)	0.83 (1.14)	6.33 (2.61)	5.58 (2.43)	3.58 (2.01)	1.08 (1.23)	3.17 (1.91)	1.33 (1.35)	2.81 (1.71)
T ₄ Mustard	0.00 (0.71)	0.00 (0.71)	6.25 (2.59)	5.58 (2.46)	2.08 (1.57)	1.67 (1.47)	2.92 (1.75)	1.42 (1.37)	2.49 (1.58)
T ₅ Niger	0.25 (0.86)	0.58 (1.03)	4.92 (2.09)	3.92 (2.09)	2.33 (1.65)	1.50 (1.41)	2.83 (1.80)	1.33 (1.35)	2.21 (1.54)
T ₆ Sesamum	0.58 (1.01)	1.17 (1.27)	3.08 (1.82)	3.33 (1.91)	4.67 (2.27)	1.67 (1.46)	2.75 (1.80)	1.33 (1.33)	2.32 (1.61)
T ₇ Zinnia	0.58 (1.00)	0.75 (1.11)	7.25 (2.74)	7.17 (2.76)	3.33 (1.92)	0.83 (1.15)	2.50 (1.72)	1.42 (1.38)	2.98 (1.72)
T ₈ Control	1.00 (1.21)	1.42 (1.36)	5.25 (2.39)	6.75 (2.65)	6.00 (2.54)	2.33 (1.68)	6.33 (2.61)	3.58 (2.01)	4.08 (2.06)
S.E ±	0.14	0.13	0.30	0.21	0.19	0.10	0.16	0.10	0.17
C.D at 5%	NS	0.4	NS	NS	0.57	0.29	0.48	0.31	0.41

*Figures in parentheses are square root transformed values.

beetle varied from 3.08 (sesamum) to 7.92 (cosmos) and 3.33 (sesamum) to 7.50 (cosmos) in week 3 (2nd week of August) and week 4 (3rd week of August), respectively, and data was non-significant. In 5th week (4th week of August), the MNSGs were in the range of 2.08 (mustard) to 6.00 (control). The former was at par with the treatments *viz.*, niger (2.33), zinnia (3.33), cowpea (3.42), marigold (3.58), cosmos (4.25) and sesamum (4.67). The MNSGs in week 6 (5th week of August) were in the range of 0.83 (zinnia) to 2.33 (control). The former was at par with treatments *viz.*, marigold (1.08), cowpea (1.33) and niger (1.50). The MNSGs in week 7 (1st week of September) were in the range of 2.50 (zinnia) to 6.33 (control). The former was at par with treatments *viz.*, mustard (2.92), sesamum (2.75), niger (2.83), cosmos (3.08), marigold (3.17) and cowpea (3.92). The MNSGs in week 8 (2nd week of September) were in the range of 1.33 (sesamum, niger and marigold) to 3.58 (control). The former were at par with treatments *viz.*, mustard (1.42), zinnia (1.42) and cosmos (1.67). The overall MNSGs in eight weeks were in the range of 2.21 (niger) to 4.08 (control). The former was at par with treatments *viz.*, mustard (2.49), sesamum (2.32), cowpea (2.51) marigold (2.81), zinnia (2.98) and cosmos (3.42).

The mean number of shot holes per leaf (MNSHs) due to flea beetle was maximum in 2nd week of August, which decreased gradually from week 2 (1st week of August) to week 5 (4th week of August) and then pest was observed increasing

gradually in week 6 (5th week of September) to week 8 (2nd week of September). Incidence of flea beetle in week 1 (4th week of July) showed that the MNSHs by flea beetle were in the range of 0.25 (cowpea) to 2.42 (cosmos). The results were non-significant (Table 3). The MNSHs by flea beetle in week 2 (1st week of August) were in the range of 3.25 (niger) to 11.75 (control). The former was at par with the treatments *viz.*, zinnia (3.67), cowpea (5.08), mustard (5.17) and sesamum (6.17). The incidence of flea beetle in terms of MNSHs was in the range of 4.50 (niger) to 14.92 (control) in week 3 (August 2nd week). The former was at par with the treatments *viz.*, marigold (4.50), zinnia (5.17), mustard (7.00), cowpea (7.33) and sesamum (7.92). The MNSHs by flea beetle in week 4 (3rd week of August) were in the range of 4.08 (niger) to 11.42 (control). The former was at par with the treatments *viz.*, cowpea (4.92), mustard (5.00), sesamum (5.42), marigold (5.42) and zinnia (5.67). The MNSHs by flea beetle were in the range of 3.08 (niger) to 8.58 (control) in week 5 (4th week of August). The former was at par with the treatments *viz.*, mustard (3.83), cowpea (4.08) and marigold (4.33). The MNSHs in week 6 (5th week of August) were in the range of 2.50 (marigold) to 5.92 (control). The former was at par with the treatments *viz.*, sesamum (2.67), mustard (2.92), zinnia (3.00), cowpea (3.08), cosmos (3.58) and niger (3.58). The MNSHs in week 7 (1st week of September) were in the range of 1.17 (mustard) to 4.25 (control). The former was

Table 3. Mean number of shot holes per leaf by flea beetle

Treatments	Number of shot holes per leaf by Flea beetle								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	2.42 (1.58)*	9.25 (3.10)	11.33 (3.42)	6.67 (2.66)	5.08 (2.35)	3.58 (1.98)	2.58 (1.73)	2.17 (1.62)	5.39 (2.30)
T ₂ Cowpea	0.25 (0.84)	5.08 (2.33)	7.33 (2.78)	4.92 (2.33)	4.08 (2.14)	3.08 (1.89)	2.67 (1.78)	1.92 (1.54)	3.67 (1.95)
T ₃ Marigold	1.33 (1.25)	3.08 (1.85)	4.50 (2.20)	5.42 (2.42)	4.33 (2.19)	2.50 (1.72)	2.58 (1.75)	1.58 (1.43)	3.17 (1.85)
T ₄ Mustard	0.33 (0.88)	5.17 (2.36)	7.00 (2.72)	5.00 (2.34)	3.83 (2.06)	2.92 (1.81)	1.17 (1.28)	0.92 (1.18)	3.29 (1.83)
T ₅ Niger	0.75 (1.08)	3.25 (1.83)	4.50 (2.14)	4.08 (2.14)	3.08 (1.87)	3.58 (2.02)	2.33 (1.67)	1.67 (1.45)	2.91 (1.78)
T ₆ Sesamum	1.00 (1.16)	6.17 (2.56)	7.92 (2.89)	5.42 (2.42)	5.42 (2.43)	2.67 (1.76)	2.67 (1.77)	2.17 (1.62)	4.18 (2.08)
T ₇ Zinnia	1.50 (1.32)	3.67 (2.04)	5.17 (2.38)	5.67 (2.48)	5.83 (2.51)	3.00 (1.87)	2.33 (1.67)	1.67 (1.45)	3.60 (1.96)
T ₈ Control	2.25 (1.65)	11.75 (3.42)	14.92 (3.85)	11.42 (3.45)	8.58 (3.01)	5.92 (2.53)	4.25 (2.18)	3.92 (2.10)	7.88 (2.77)
S.E $\pm$	0.27	0.31	0.30	0.13	0.14	0.14	0.15	0.15	0.20
C.D at 5%	NS	0.93	0.91	0.41	0.41	0.43	0.44	0.46	0.57

*Figures in parentheses are square root transformed values.

at par with the treatments *viz.*, niger (2.33) and sesamum (2.33). The MNSHs in week 8 (2nd week of September) were in the range of 0.92 (mustard) to 3.92 (control). The former was at par with the treatments *viz.*, marigold (1.58), zinnia (1.67), niger (1.67), cowpea (1.92), cosmos (2.17) and sesamum (2.17). The overall MNSHs by flea beetle in eight weeks were in the range of 2.91 (niger) to 7.88 (control). The former was at par with the treatments *viz.*, mustard (3.29), marigold (3.17), cowpea (3.67), zinnia (3.60), sesamum (4.18) and cosmos (5.39).

The mean number of mines per leaf (MNM) by serpentine leaf miner were in the range of 0.00 (cosmos and cowpea) to 0.58 (control) in week 3 (2nd week of August). There was no incidence of serpentine leaf miner observed in treatments cosmos and cowpea (Table 4). The treatment marigold (0.08) and niger (0.08) were at par with the treatments mustard (0.17) and sesamum (0.17). The MNMs by serpentine leaf miner were in the range of 0.00 (marigold) to 2.00 (control) in week 4 (3rd week of August). The treatment sesamum (0.17) and niger (0.17) were at par with the treatments *viz.*, mustard (0.25), cosmos (0.33), zinnia (0.42) and cowpea (0.67). The MNMs by serpentine leaf miner in week 5 (4th week of August) were in the range of 0.00 (cosmos and marigold) to 1.33 (control). No incidence of serpentine leaf miner was observed in the treatments cosmos and marigold. The treatment mustard (0.08) was at par with the treatments cowpea (0.17), niger (0.17), sesamum (0.17) and

zinnia (0.33). The MNMs by serpentine leaf miner in week 6 (5th week of August) were in the range 0.17 (cowpea) to 1.83 (control). The former was at par with the treatments *viz.*, marigold (0.25), mustard (0.33), niger (0.33), zinnia (0.33), cosmos (0.42) and sesamum (0.50). The MNMs by serpentine leaf miner were in the range of 0.33 (mustard) to 1.92 (control) in week 7 (1st week of September). The former was at par with the treatments *viz.*, niger (0.50), sesamum (0.58), marigold (0.58) and zinnia (0.92). The MNMs by serpentine leaf miner in week 8 (1st week of September) were in the range of 0.00 (cowpea) to 2.00 (control). The treatment niger (0.17) was at par with the treatments *viz.*, sesamum (0.42), zinnia (0.58) and marigold (0.67). The overall MNMs by serpentine leaf miner in six weeks were in the range of 0.24 (niger) to 1.61 (control). The former was at par with the treatments *viz.*, marigold (0.26), cowpea (0.36), mustard (0.35), sesamum (0.34), cosmos (0.50) and zinnia (0.51).

The appearance of cucumber fruit fly started from week 6 (5th week of August) and noticed up to week 8 (2nd week of September). The incidence of fruit fly in week 6 (5th week of August) varied from 11.11 per cent (cowpea) to 36.80 per cent (control) and results were non-significant (Table 5). The per cent infestation of cucumber fruit fly was in the range of 4.00 per cent (niger) to 23.41 (control) in week 7 (1st week of September). The former was followed by cosmos (10.00) and both the treatments were significantly superior over rest of the treatments. The next best treatments were zinnia (11.67%),

Table 4. Mean number of mines per leaf by serpentine leaf miner

Treatments	Number of mines per leaf by serpentine leaf miner						
	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Overall mean
	August 2 nd wk	August 3 rd wk	August 4 th wk	August 5 th wk	Sept. 1 st wk	Sept. 2 nd wk	
T ₁ Cosmos	0.00 (0.71)*	0.33 (0.88)	0.00 (0.71)	0.42 (0.94)	1.08 (1.25)	1.17 (1.27)	0.50 (0.96)
T ₂ Cowpea	0.00 (0.71)	0.67 (1.00)	0.17 (0.80)	0.17 (0.80)	1.17 (1.27)	0.00 (0.71)	0.36 (0.88)
T ₃ Marigold	0.08 (0.76)	0.00 (0.71)	0.00 (0.71)	0.25 (0.84)	0.58 (1.04)	0.67 (1.07)	0.26 (0.86)
T ₄ Mustard	0.17 (0.80)	0.25 (0.84)	0.08 (0.76)	0.33 (0.90)	0.33 (0.88)	0.92 (1.14)	0.35 (0.89)
T ₅ Niger	0.08 (0.76)	0.17 (0.80)	0.17 (0.81)	0.33 (0.90)	0.50 (0.98)	0.17 (0.80)	0.24 (0.84)
T ₆ Sesamum	0.17 (0.80)	0.17 (0.80)	0.17 (0.81)	0.50 (0.98)	0.58 (1.00)	0.42 (0.94)	0.33 (0.89)
T ₇ Zinnia	0.50 (1.00)	0.42 (0.94)	0.33 (0.90)	0.33 (0.90)	0.92 (1.19)	0.58 (1.04)	0.51 (0.99)
T ₈ Control	0.58 (1.04)	2.00 (1.56)	1.33 (1.34)	1.83 (1.53)	1.92 (1.55)	2.00 (1.58)	1.61 (1.43)
S.E ±	0.06	0.15	0.07	0.12	0.12	0.13	0.11
C.D at 5%	0.18	0.46	0.20	0.37	0.35	0.40	0.33

*Figures in parentheses are square root transformed values.

Table 5. Percent infestation of fruit fly, *Bactrocera cucurbitae* (Coquillett)

Treatments	Percent infestation of fruit fly			
	Week 6	Week 7	Week 8	Overall mean
	August 5 th wk	Sept. 1 st wk	Sept. 2 nd wk	
T ₁ Cosmos	13.89 (18.03)*	10.00 (18.05)	13.54 (21.49)	12.48 (19.19)
T ₂ Cowpea	11.11 (16.06)	16.33 (23.74)	13.49 (21.18)	13.65 (20.33)
T ₃ Marigold	24.76 (29.33)	17.07 (24.12)	20.03 (26.47)	20.62 (26.64)
T ₄ Mustard	22.05 (27.90)	23.97 (28.67)	9.16 (17.43)	18.39 (24.67)
T ₅ Niger	25.00 (29.79)	4.00 (9.48)	5.71 (11.37)	11.57 (16.88)
T ₆ Sesamum	15.48 (19.19)	13.89 (21.19)	12.29 (20.30)	13.88 (20.23)
T ₇ Zinnia	32.78 (33.59)	11.67 (19.31)	8.41 (16.27)	17.62 (23.05)
T ₈ Control	36.80 (36.82)	23.41 (28.80)	20.34 (26.76)	26.85 (30.79)
SE ±	7.23	3.50	3.09	4.61
C.D. at 5%	NS	10.62	9.36	9.99

*Figures in parentheses are arc sine transformed values.

sesamum (13.89%), cowpea (16.33%) and marigold (17.07%). The per cent infestation by cucumber fruit fly in week 8 (2nd week of September) was in the range of 5.71 per cent (niger) to 20.34 per cent (control). The former was followed by zinnia

(8.41), mustard (9.16) and sesamum (12.29) and all these treatments were at par with each other. The overall percent infestation of cucumber fruit fly in three weeks was in the range of 11.57 percent (niger) to 26.85 (control). The former was at par with cosmos (12.42%), cowpea (13.65%), sesamum (13.88%), zinnia (17.62%), mustard (18.39%) and marigold (20.62%).

The present findings are corroborative with Gavigowda (1976). He collected three species of fruit flies viz., *B. cucurbitae*, *B. diversa*, and *Dacus* sp. on different cucurbits in Bangaluru and observed that *B. cucurbitae* damaged snake gourd to the extent of 34-82 per cent. Mann and Sohi (1983) confirmed that the genus *Aulacophora* includes *A. foveicollis* (L.), are important pest of cucurbits in India. Butani and Jatwani (1984) reported fruit flies and three species of beetles viz., red pumpkin beetle, *A. foveicollis* (Lucas); blue pumpkin beetles, *A. lewisii* and gray beetle, *A. cincta* as the pests of major significance on cucurbits. Deshmukh and Patil (1996) stated that *B. dorsalis* along with *B. cucurbitae* were the serious pests of ridge gourd in Konkan region of Maharashtra. Morde (2003) reported relative preference of *B. cucurbitae* and *B. tau* infesting little gourd, cucumber, bottle gourd and wild cucurbits. However, *B. cucurbitae* observed to be predominant in bottle gourd, bitter gourd and sponge gourd in Panvel area of Maharashtra to the extent of 100 per cent on sponge gourd and ridge gourd from Wakawali area in Maharashtra. Both the species were found infesting ridge gourd, snake gourd, cucumber and wild cucurbits in Dapoli area of Maharashtra. Sawai (2013) reported twelve different species

of fruit flies belonging to family Tephritidae in the Konkan region of Maharashtra. The data on species composition of fruit fly revealed that the species *Bactrocera tau* was observed to be predominant and almost contributed 65.23 per cent flies followed by *B. cucurbitae* with 21.87 per cent of the population. The minor infestation of *B. dorsalis* and *B. caudata* were also observed to the extent of 0.33 and 0.86 per cent, respectively.

Natural enemies in cucumber ecosystem

The mean number of black ants (MNBA) on cucumber plant were recorded from week 1 (4th week of July) to week 8 (2nd week of September). In week 1 (4th week of July) the MNBAs observed were in the range of 0.00 to 0.92 (Table 6). The niger was the best treatment which recorded maximum of 0.92 MNBAs. In week 2 (1st week of August) the MNBAs observed were in the range of 0.00 to 3.83. The niger was again the best treatment which recorded maximum of 3.83 black ants. In week 3 (2nd week of August) the MNBAs observed were in the range of 0.00 to 2.83. The niger was the best treatment which recorded maximum of 2.83 black ants. The MNBAs in week 4 (3rd week of August) were in the range of 0.00 to 1.75. The maximum numbers of black ants (1.75)

were recorded in the treatment niger as flowering plant. The MNBAs were in the range of 0.00 to 1.83 in week 5 (4th week of August) and the treatment niger recorded 1.83 black ants in week 5. In the week 6 (5th week of August) the MNBAs observed were in the range of 0.00 to 2.33. The cowpea was the best treatment which recorded maximum of 2.33 black ants. In week 7 (1st week of September) the MNBAs observed were in the range of 0.00 to 1.00. The cosmos and marigold were the best treatments which recorded maximum (1.00) black ants. The maximum (1.49) black ants were recorded in the treatments niger as flowering plant, followed by cowpea (0.81).

The MNBAs on different flowering plants on bunds were recorded from week 1 (4th week of July) to week 8 (2nd week of September) and were in the range of 0.00 to 1.67 (Table 7). The maximum MNBAs were observed in Niger as flowering plant in week 1 (4th week of July), week 2 (1st week of August) and week 3 (2nd week of August) with a record of 1.67, 1.58 and 1.33 MNBAs, respectively. The maximum (0.50) MNBAs were recorded in cowpea and cosmos as flowering plant in week 4 (3rd week of August). The cosmos (0.92) was the best treatment followed by cowpea (0.75) in week 5 (4th

Table 6. Effect of flowering plants on bunds on number of black ants recorded on cucumber

Treatments	Number of black ants on cucumber plant								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.00	0.00	0.25	2.08	1.00	0.83	0.52
T ₂ Cowpea	0.00	1.00	0.08	0.00	1.75	2.33	0.50	0.83	0.81
T ₃ Marigold	0.00	0.08	0.00	0.00	0.00	1.92	1.00	0.75	0.47
T ₄ Mustard	0.00	0.17	0.00	0.00	0.00	0.00	0.42	0.58	0.15
T ₅ Niger	0.92	3.83	2.83	1.75	1.83	0.00	0.75	0.00	1.49
T ₆ Sesamum	0.00	0.50	0.42	0.58	0.00	0.00	0.25	0.17	0.24
T ₇ Zinnia	0.00	0.00	2.58	1.67	0.00	0.00	0.00	0.17	0.55
T ₈ Control	0.00	0.00	0.00	0.00	0.17	0.75	0.33	0.17	0.18
SD ±	0.32	1.31	1.23	0.77	0.80	1.05	0.36	0.35	0.44

Table 7. Effect of flowering plants on bunds on mean number of black ants on flowering plants

Treatments	Number of black ants on flowering plants								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.00	0.50	0.92	0.92	1.17	1.08	0.57
T ₂ Cowpea	0.33	0.58	0.67	0.50	0.75	0.83	0.92	0.58	0.65
T ₃ Marigold	0.00	0.00	0.00	0.00	0.00	0.08	0.42	0.58	0.14
T ₄ Mustard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01
T ₅ Niger	1.67	1.58	1.33	0.25	0.42	0.92	0.75	0.92	0.98
T ₆ Sesamum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₇ Zinnia	0.00	0.00	0.08	0.00	0.08	0.00	0.00	0.00	0.02
T ₈ Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD ±	0.58	0.57	0.49	0.23	0.38	0.45	0.48	0.44	0.38

week of August). The cosmos (0.92) and niger (0.92) were the best treatments followed by cowpea (0.83) in week 6 (5th week of August). In week 7 (1st week of September) and week 8 (2nd week of September) the MNBAs observed were in the range of 0.00 to 1.17. The treatment cosmos recorded 1.17 MNBAs in week 7 (1st week of September) and 1.08 MNBAs as flowering plant in week 8 (2nd week of September). The MNBAs recorded in different treatments were in the range of 0.00 to 0.98. The maximum (0.98) MNBAs were recorded in niger as flowering plant followed by cowpea (0.65) and cosmos (0.57), whereas no black ants were recorded in sesamum and control.

The syrphid flies were observed on cucumber plants from week 5 (4th week of August) to week 8 (2nd week of September) (Table 8). The mean numbers of syrphid flies were in the range of 0.00 to 0.08 in week 5 (4th week of August). The maximum (0.08) syrphid flies were recorded in cucumber plants with cosmos, cowpea, mustard and control plants bounds. In week 6 (5th week of August) the mean number of syrphid flies were in the range of 0.00 to 0.42. The cosmos (0.42) as flowering plants on bunds was best treatment for syrphid flies. In week 7 (1st week of September) the mean number of syrphid flies were in the range of 0.00 to 0.08. The maximum (0.08) syrphid flies were recorded with the cosmos, cowpea, marigold, niger and control plants. In week 8 (2nd week of September) the mean number of syrphid flies were in the range of 0 to 0.17. The treatment control (0.17) was the best treatment. The overall mean numbers of syrphid flies in different treatments were in the range of 0.04 to 0.17. The maximum (0.17) syrphid flies on cucumber were observed in the treatment cosmos as flowering plant on bund.

The mean numbers of syrphid flies on different flowering plants on bunds were recorded from week 5 (4th week of August) to week 8 (2nd week of September) and were in the range of 0.00 to 0.83 (Table 9). The maximum (0.25)

Table 8. Effect of flowering plants on bunds on number of syrphid flies recorded on cucumber plants

Treatments	Number of syrphid flies on cucumber plants				
	Week 5	Week 6	Week 7	Week 8	Overall mean
	August 4 th wk	August 5 th wk	Sept. 1 st wk	Sept. 2 nd wk	
T ₁ Cosmos	0.08	0.42	0.08	0.08	0.17
T ₂ Cowpea	0.08	0.17	0.08	0.08	0.10
T ₃ Marigold	0.00	0.17	0.08	0.00	0.06
T ₄ Mustard	0.08	0.33	0.00	0.00	0.10
T ₅ Niger	0.00	0.17	0.08	0.08	0.08
T ₆ Sesamum	0.00	0.17	0.00	0.00	0.04
T ₇ Zinnia	0.00	0.08	0.00	0.08	0.04
T ₈ Control	0.08	0.17	0.08	0.17	0.13
SD ±	0.04	0.11	0.04	0.06	0.04

numbers of syrphid flies were observed in sesamum as in week 5 (4th week of August). The niger and mustard were found to be the best treatments which recorded 0.17 syrphid flies in week 6 (5th week of August) whereas no syrphid flies were observed in cosmos, mustard and zinnia. The maximum (0.83) numbers of syrphid flies were observed in cosmos as flowering plants in week 7 (1st week of September). The cosmos were also found to be the best treatment by recording 0.75 syrphid flies in week 8 (2nd week of September), whereas no syrphid flies were observed in niger and control. The maximum (0.42) syrphid flies were recorded in the treatment cosmos as flowering plant on bund followed by sesamum (0.25) and cowpea, marigold, mustard and zinnia (0.17). No syrphid flies were observed in control.

Table 9. Effect of flowering plants on bunds on mean number of syrphid flies on flowering plants

Treatments	Number of syrphid flies on flowering plants				
	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	Overall mean
T ₁ Cosmos	0.08	0.00	0.83	0.75	0.42
T ₂ Cowpea	0.00	0.08	0.25	0.33	0.17
T ₃ Marigold	0.08	0.00	0.42	0.17	0.17
T ₄ Mustard	0.00	0.17	0.33	0.17	0.17
T ₅ Niger	0.08	0.00	0.17	0.00	0.06
T ₆ Sesamum	0.25	0.17	0.42	0.17	0.25
T ₇ Zinnia	0.00	0.00	0.25	0.42	0.17
T ₈ Control	0.00	0.00	0.00	0.00	0.00
SD ±	0.09	0.08	0.24	0.25	0.12

The different spider species viz., *Argiope aemula* (Araneidae), *Oxyopes* sp. (Oxyopidae) and *Perenethis* sp. (Pisauridae) were observed during the course of investigation. The spiders were recorded on cucumber plants from week 2 (1st week of August) to week 8 (2nd week of September). The mean number of spiders in week 2 (2nd week of August) were in the range of 0.00 to 0.08 (Table 10). The maximum (0.08) mean number of spiders were recorded in the treatments niger and zinnia as flowering plants on bunds. In week 3 (2nd week of August) the mean number of spiders were in the range of 0.00 to 0.25. The maximum (0.25) mean number of spiders was recorded in mustard as flowering plant on bund followed by cowpea and sesamum which recorded 0.17 mean number of spiders. The mean numbers of spiders recorded in week 4 (3rd week of August) were in the range of 0.00 to 0.75. The mustard recorded the maximum (0.75) mean number of spiders. The mean number of spiders recorded in week 5 (4th week of August) were in the range of 0.00 to 1.25. The treatment niger (1.25) was found to be the best treatment. The mean numbers of spiders were in the range of 0.00 to

1.00 in week 6 (5th week of August). The treatment cosmos recorded 1.00 spiders, whereas no spiders were observed in mustard, zinnia and control. In week 7 (1st week of September) and week 8 (2nd week of September) the mean number of spiders observed were in the range of 0.00 to 0.42. The treatment cosmos as flowering plant on bunds was the best treatment which recorded 0.33 mean numbers of spiders. The maximum (0.42) mean numbers of spiders were recorded in the marigold and control on cucumber plants in week 8 (2nd week of September). The mean numbers of spiders were in the range of 0.05 to 0.37. The maximum (0.37) mean number of spiders was recorded in the treatment mustard as flowering plant on bund followed by the treatments cosmos (0.31), niger (0.29) and cowpea (0.18).

The mean number of spiders on different flowering plants on bunds were recorded from week 1 (4th week of July) to week 8 (2nd week of September) and they were in the range of 0.00 to 1.33 (Table 11). The maximum mean number of spiders was observed in mustard as flowering plants throughout the period of investigation and varied from 0.83 to 1.33. The mean numbers of spiders of all eight weeks were in the range of 0.00 to 0.92 and maximum (0.92) were recorded

in the treatment mustard followed by cosmos (0.36) and niger (0.32), whereas no spiders were observed in control treatments.

Other natural enemies

The other natural enemies *viz.*, praying mantid, lady beetle, damselflies and tachinid flies were also observed during the course of investigation. The mean number of other natural enemies on cucumber plants were recorded from week 1 (5th week of July) to week 8 (2nd week of September). The number of other natural enemies in week 1 (5th week of July) and week 2 (1st week of August) were in the range of 0.00 to 0.08 (Table 12). The maximum (0.08) was recorded in marigold and control in week 1 (5th week of July), whereas no other natural enemies were observed in rest of the treatments. While the highest (0.08) mean number of other natural enemies were observed in treatments marigold and niger as flowering plant on bund in week 2 (1st week of August), but no other natural enemies were recorded in rest of the treatments. The mean number of other natural enemies recorded in week 3 (2nd week of August) were in the range of 0.00 to 0.17. The control showed 0.17 mean number of other natural enemies. In week 4 (3rd week of August) and week 5

Table 10. Effect of flowering plants on bunds on number of spiders on cucumber plants

Treatments	Number of spiders on cucumber plants							Overall mean
	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.33	0.25	1.00	0.33	0.25	0.31
T ₂ Cowpea	0.00	0.17	0.08	0.00	0.67	0.17	0.17	0.18
T ₃ Marigold	0.00	0.00	0.00	0.00	0.00	0.08	0.42	0.07
T ₄ Mustard	0.00	0.25	0.75	1.00	0.33	0.25	0.00	0.37
T ₅ Niger	0.08	0.00	0.00	1.25	0.58	0.00	0.08	0.29
T ₆ Sesamum	0.00	0.00	0.00	0.00	0.50	0.08	0.17	0.11
T ₇ Zinnia	0.08	0.17	0.00	0.00	0.00	0.08	0.00	0.05
T ₈ Control	0.00	0.00	0.00	0.17	0.00	0.17	0.42	0.11
SD ±	0.04	0.10	0.27	0.50	0.37	0.11	0.17	0.12

Table 11. Effect of flowering plants on bunds on mean number of spiders on flowering plants

Treatments	Number of spiders on flowering plants								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.42	0.25	0.50	0.75	0.33	0.67	0.36
T ₂ Cowpea	0.00	0.00	0.08	0.08	0.33	0.33	0.17	0.17	0.15
T ₃ Marigold	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.01
T ₄ Mustard	0.83	1.25	0.67	0.58	0.92	0.92	0.83	1.33	0.92
T ₅ Niger	0.00	0.08	0.00	0.08	0.83	0.75	0.42	0.42	0.32
T ₆ Sesamum	0.00	0.00	0.08	0.00	0.00	0.00	0.33	0.75	0.15
T ₇ Zinnia	0.00	0.00	0.08	0.00	0.00	0.00	0.33	1.08	0.19
T ₈ Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD ±	0.29	0.44	0.24	0.20	0.39	0.40	0.27	0.50	0.29

(4th week of August), the mean number of other natural enemies observed were in the range of 0.00 to 0.17. The cosmos, zinnia and control were the best treatments in week 4 (3rd week of August) while only cosmos in week 5 (4th week of August) which recorded 0.17 mean number of other natural enemies. The mean numbers of other natural enemies were in the range of 0.00 to 0.25 in week 6 (5th week of August). The maximum mean number (0.25) of other natural enemies was observed in the treatment zinnia as flowering plant. In week 7 (1st week of September) and week 8 (2nd week of September) the mean numbers of other natural enemies observed were in the range of 0.00 to 0.08. The zinnia was the best treatment in week 7 (1st week of September), while mustard in week 8 (2nd week of September) which recorded 0.08 mean number, whereas no other natural enemies were observed in rest of the treatments. The overall mean numbers of other natural enemies were in the range of 0.00 to 0.08. The maximum mean number (0.08) of other natural enemies was recorded from the treatment zinnia as flowering plant followed by control (0.06), mustard (0.05) and marigold (0.05).

The mean numbers of other natural enemies on different flowering plants on bunds were recorded from week 1 (4th

week of July) to week 8 (2nd week of September) and were in the range of 0.00 to 0.25 (Table 13). The maximum (0.25) mean number of other natural enemies was observed in zinnia as flowering plants in week 1 (4th week of July). In week 2 (1st week of August) and week 3 (2nd week of August) the number of other natural enemies were in the range of 0.00 to 0.17 and the treatments marigold, mustard, sesamum and zinnia recorded highest (0.17) mean number of other natural enemies. In week 4 (3rd week of August), week 5 (4th week of August) and week 6 (5th week of August) the mean numbers of other natural enemies observed were in the range of 0.00 to 0.17. The mustard was the best treatment in week 4 (3rd week of August) and cowpea in week 5 (4th week of August), whereas in week 6 (5th week of August) the maximum (0.08) mean number of other natural enemies was recorded in treatments cosmos, marigold and mustard. In week 7 (1st week of September) and week 8 (2nd week of September) the mean numbers of other natural enemies observed were in the range of 0.00 to 0.17. The sesamum was the best treatment in week 7 (1st week of September), while cowpea in week 8 (2nd week of September) which recorded 0.17 mean number of other natural enemies. The overall mean

Table 12. Effect of flowering plants on bunds on mean number of other natural enemies on cucumber plants

Treatments	Number of other natural enemies on cucumber plants								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.00	0.00	0.17	0.08	0.00	0.00	0.03
T ₂ Cowpea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₃ Marigold	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.05
T ₄ Mustard	0.00	0.00	0.00	0.17	0.00	0.17	0.00	0.08	0.05
T ₅ Niger	0.00	0.08	0.00	0.00	0.08	0.08	0.00	0.00	0.03
T ₆ Sesamum	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.02
T ₇ Zinnia	0.00	0.00	0.08	0.17	0.08	0.25	0.08	0.00	0.08
T ₈ Control	0.08	0.00	0.17	0.17	0.08	0.00	0.00	0.00	0.06
SD ±	0.04	0.04	0.06	0.08	0.06	0.09	0.03	0.03	0.03

Table 13. Number of other natural enemies recorded on flowering plants

Treatments	Number of other natural enemies on cucumber plants								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.06
T ₂ Cowpea	0.08	0.08	0.08	0.08	0.17	0.00	0.00	0.17	0.08
T ₃ Marigold	0.00	0.17	0.08	0.08	0.00	0.08	0.00	0.08	0.06
T ₄ Mustard	0.00	0.17	0.00	0.17	0.00	0.08	0.08	0.08	0.07
T ₅ Niger	0.17	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.04
T ₆ Sesamum	0.00	0.17	0.00	0.00	0.08	0.00	0.17	0.08	0.06
T ₇ Zinnia	0.25	0.00	0.17	0.08	0.08	0.00	0.08	0.00	0.08
T ₈ Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SD ±	0.10	0.08	0.06	0.05	0.06	0.04	0.06	0.06	0.03

numbers of other natural enemies were in the range of 0.00 to 0.08, maximum (0.08) being recorded in treatment cowpea and zinnia followed by mustard (0.07), cosmos, marigold and sesamum (0.06 each).

Bijaya *et al.* (1996) observed occurrence of seven species of syrphids viz., *Episyrphus balteatus* De Geer, *Metasyrphus confrater* Wiedmann, *Betasyrphus serrarius* Wiedmann, *Ischiodon scutellaris* Fabricius, *Paragus serratus* Fabricius, *Sphaerophoria Indiana* Bigot and *Sphaerophoria* sp. Variations were observed in the density and diversity of syrphid fauna on the crops. Syrphid flies are very important group of insects in ecosystem from viewpoint of pollination and biological control. Their adults are pollinators of many crops and their larvae are important natural enemies of herbivorous arthropods. The hymenopteran natural enemies like black ants and pollinators like honey bee were observed in the experimental plot. The hymenopteran natural enemies and pollinators were recorded from 1st week of September to 2nd week of October. The maximum numbers of hymenopteran natural enemies were recorded in 3rd week of September and were in the range of 0 to 27. The number of spiders recorded in 1st week of September to 2nd week of October were in the range of 1 to 5. The maximum number of spiders were recorded in 1st week of October and 2nd week of October up to 5 spiders in the treatments aster and sesamum, respectively.

Chavan (2015) reported that maximum (11 ± 3.45) black ants were recorded on mustard as nectar rich plant. The total number of spiders recorded on rice plants during all nine weeks were maximum (10 ± 3.50) on gomphrina followed by 9 ± 3.50 in niger. The number of syrphid flies recorded from week 3 to 7 and maximum 9 ± 2.75 syrphid flies were recorded on niger as nectar rich plant on bund followed by *cock's comb* and calendula which recorded 3 ± 2.75 and 1 ± 2.75 syrphid flies, respectively. The maximum of 9 ± 3.10 other natural enemies were recorded in treatment

cock's comb followed by gomphrina (7 ± 3.10), *ekdandi* (5 ± 3.10), marigold (3 ± 3.10), mustard (3 ± 3.10), cosmos (2 ± 3.10) and sunflower (1 ± 3.10).

Impact of conserved natural enemies on cucumber pests

The data on impact of different treatments on the MNSGs by red pumpkin beetle revealed that in week 1 (4th week of July) the per cent reduction in MNSGs was in the range of 41.67 per cent (marigold) to 100.00 per cent (cowpea and mustard) and 17.84 per cent (sesamum) to 100.00 per cent (cowpea and mustard) in week 2. The treatments cowpea and mustard were found to be the best treatments by attracting the natural enemies to the plots (Table 14). The MNSGs by red pumpkin beetle in week 3 (2nd week of August) was reduced to the range of -50.79 per cent (cosmos) to 41.27 per cent (sesamum). The latter was followed by cowpea (17.46%) and niger (6.35%). The per cent reduction in MNSGs by red pumpkin beetle in the week 4 (3rd week of August) was in the range of -11.11 per cent (cosmos) to 50.62 per cent (sesamum). The latter was followed by niger (41.98%), cowpea (28.40%), marigold and mustard (17.28%). In week 5 (4th week of August) the MNSGs by red pumpkin beetle was reduced to the range of 22.22 per cent (sesamum) and 65.28 per cent (mustard). The per cent reduction in MNSGs by red pumpkin beetle in week 6 (5th week of August) was in the range of 28.47 per cent (cosmos, mustard and sesamum) to 64.23 per cent (zinnia). The latter was followed by marigold (53.51%), cowpea (42.78%) and niger (35.62%). The per cent reduction in MNSGs by red pumpkin beetle in week 7 (1st week of September) was in the range of 38.13 per cent (cowpea) to 60.51 per cent (zinnia). The percent reduction in MNSGs by red pumpkin beetle in week 8 (2nd week of September) was in the range of 37.15 per cent (cowpea) to 62.76 per cent (marigold, niger and sesamum). The overall per cent reduction was in the range of 16.26 per cent (cosmos) to 45.87 per cent (Niger).

Table 14. Per cent reduction in number of scraped galleries per leaf by red pumpkin beetle over control

Treatments	Per cent reduction in number of scraped galleries per leaf by red pumpkin beetle over control								Overall mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	50.00	47.18	-50.79	-11.11	29.17	28.47	51.29	53.45	16.26
T ₂ Cowpea	100.00	100.00	17.46	28.40	43.06	42.78	38.13	37.15	38.47
T ₃ Marigold	41.67	41.31	-20.63	17.28	40.28	53.51	49.97	62.76	31.07
T ₄ Mustard	100.00	100.00	-19.05	17.28	65.28	28.47	53.92	60.43	38.98
T ₅ Niger	75.00	58.92	6.35	41.98	61.11	35.62	55.24	62.76	45.87
T ₆ Sesamum	41.67	17.84	41.27	50.62	22.22	28.47	56.56	62.76	43.07
T ₇ Zinnia	41.67	47.18	-38.10	-6.17	44.44	64.23	60.51	60.43	26.98
T ₈ Control	-	-	-	-	-	-	-	-	-

The data on impact of different treatments on flea beetle (Table 15) revealed that in week 1 (4th week of July) the per cent reduction in the MNSHs by flea beetle was in the range of -7.41 per cent (cosmos) to 88.89 percent (cowpea). The treatment cowpea (88.89%) was found to be the best treatment by attracting the number of natural enemies and was followed by mustard (85.19%), niger (66.67%), sesamum (55.56%), marigold (40.74%) and zinnia (33.33%). The per cent reduction in MNSHs by flea beetle in week 2 (1st week of August) was in the range of 21.28 per cent (cosmos) to 73.76 per cent (marigold). The MNSHs by flea beetle in week 3 (2nd week of August) was reduced in the range of 24.04 per cent (cosmos) to 69.84 per cent (marigold and niger). The per cent reduction in MNSHs by flea beetle in week 4 (3rd week of August) was in the range of 41.62 per cent (cosmos) to 64.24 per cent (niger). The per cent reduction in MNSHs by flea beetle in week 5 (4th week of August) was -4.54 per cent (zinnia) to 44.74 per cent (niger). The per cent reduction in MNSHs by flea beetle in week 6 (5th week of August) was 39.47 per cent (niger) to 57.77 (marigold) and in week 7 (1st week of September) was 37.25 per cent (cowpea) to 72.55 per cent (mustard). The per cent reduction in week 8 (2nd week of September) was 44.73 per cent (sesamum) to 76.62 per cent (mustard). The overall mean of per cent reduction in all eight weeks was in the range of 31.66 per cent (cosmos) to 63.12 per cent (niger).

The data on impact of different treatments on serpentine leaf miner in terms of the MNMs revealed that in the week 3 (2nd week of August) the per cent reduction was in the range of 13.79 per cent (zinnia) to 100.00 per cent (cowpea and cosmos). The treatments cosmos and cowpea (100.00%) were found to be the best treatments in reducing the number of mines per leaf by serpentine leaf miner (Table 16). The per cent reduction in MNMs by serpentine leaf miner in week 4 (3rd week of August) was in the range of 66.67 per cent (cowpea) to 100.00 per cent (marigold). The MNMs by

serpentine leaf miner in week 5 (4th week of August) was in the range of 74.94 per cent (zinnia) to 100.00 per cent (marigold and cosmos). The per cent reduction in week 6 (5th week of August) was in the range of 72.68 per cent (sesamum) to 90.89 per cent (cowpea). The percent reduction in MNMs by serpentine leaf miner in week 7 (1st week of September) was in the range of 39.24 percent (cowpea) to 82.64 per cent (mustard). The per cent reduction in MNMs in week 8 (2nd week of September) was in the range of 41.67 per cent (cosmos) to 100.00 per cent (cowpea). The overall mean of per cent reduction was in the range of -0.07 per cent (zinnia) to 85.33 per cent (mustard).

The data on impact of different treatments on cucumber fruit fly infestation revealed that in week 6 (5th week of August) the per cent reduction was in the range of 10.93 per cent (zinnia) to 69.81 per cent (cowpea) (Table 17). The per cent reduction in infestation of cucumber fruit fly in week 7 (1st week of September) was in the range of -2.38 per cent (mustard) to 82.91 per cent (niger). The per cent reduction in infestation in week 8 (2nd week of September) was in the range of 1.54 per cent (marigold) to 71.90 percent (niger). The overall mean of percent reduction was in the range of 23.20 per cent (marigold) to 56.90 per cent (niger). The latter was followed by cosmos (53.54%), cowpea (49.18%), sesamum (48.29%) and zinnia (34.39%).

The results of present findings are corroborative with the results of Kumar *et al.* (2013). They reviewed habitat manipulation, which is also referred to as "Ecological Engineering", focuses on reducing mortality of natural enemies, providing the supplementary resources and manipulating host plant attributes for the benefit of natural bio-agents. This can be achieved by enhancing the plant diversity and by providing adequate refugia in the agro-ecosystem. Strips harvesting in Lucerne was found to enhance predator or parasitoid population. Strips with taller growth had greater natural enemy's population than in more

Table 15. Per cent reduction in number of shot holes per leaf by flea beetle

Treatments	Per cent reduction in number of shot holes per leaf by flea beetle								Pooled mean
	Week 1 July 4 th wk	Week 2 August 1 st wk	Week 3 August 2 nd wk	Week 4 August 3 rd wk	Week 5 August 4 th wk	Week 6 August 5 th wk	Week 7 Sept. 1 st wk	Week 8 Sept. 2 nd wk	
T ₁ Cosmos	-7.41	21.28	24.04	41.62	40.75	39.47	39.22	44.73	31.66
T ₂ Cowpea	88.89	56.74	50.85	56.95	26.82	47.92	37.25	51.11	53.47
T ₃ Marigold	40.74	73.76	69.84	52.57	22.34	57.77	39.22	59.61	59.81
T ₄ Mustard	85.19	56.03	53.08	56.22	31.30	50.73	72.55	76.62	58.23
T ₅ Niger	66.67	72.34	69.84	64.24	44.74	39.47	45.10	57.48	63.12
T ₆ Sesamum	55.56	47.52	46.94	52.57	2.93	54.95	37.25	44.73	46.99
T ₇ Zinnia	33.33	68.79	65.37	50.38	-4.54	49.32	45.10	57.48	54.26
T ₈ Control	-	-	-	-	-	-	-	-	-

Table 16. Per cent reduction in mean numbers of mines per leaf by serpentine leaf miner over control

Treatments	Per cent reduction in number of mines per leaf by Serpentine leaf miner over control						Pooled mean of all 6 weeks
	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	
	August 2 nd wk	August 3 rd wk	August 4 th wk	August 5 th wk	Sept. 1 st wk	Sept. 2 nd wk	
T ₁ Cosmos	100.00	83.33	100.00	77.23	43.58	41.67	77.57
T ₂ Cowpea	100.00	66.67	87.47	90.89	39.24	100.00	83.61
T ₃ Marigold	85.63	100.00	100.00	86.34	69.62	66.67	78.43
T ₄ Mustard	71.26	87.50	93.73	81.79	82.64	54.17	85.33
T ₅ Niger	85.63	91.67	87.47	81.79	73.96	91.67	79.30
T ₆ Sesamum	71.26	91.67	87.47	72.68	69.62	79.17	68.08
T ₇ Zinnia	13.79	79.17	74.94	81.79	52.26	70.83	-0.07
T ₈ Control	-	-	-	-	-	-	-

recently harvested strips. Creating a raised “Beetle Bank” with perennial grasses within the field provided suitable over wintering habitat for several natural enemies. Habitat manipulation is an emerging technology in biological control programme, which encourages biodiversity and leads to stability and sustainability of agro ecosystem. Wagh (2014) reported that the nectar rich plants aster, cufia, petunia and niger were found better for reducing the leaf folder infestation in rice ecosystem. The crops petunia, sunflower, aster, sesamum and marigold were found better for reducing blue beetle infestation. Sesamum, niger, petunia, sunflower and marigold were better for reducing rice earhead bug infestation, whereas sesamum, sunflower and marigold proved better for reducing army worm infestation.

In a separate study, Chavan (2015) reported that the nectar rich plants cosmos, gomphrina, marigold, sesamum and niger were found better for reducing the stem borer infestation in rice ecosystem. The nectar rich plants sunflower *ekdandi*, mustard, sesamum and marigold were found better for reducing infestation of leaf folder. *Ekdandi*, niger, sesamum, mustard, marigold and cosmos were found better for reducing blue beetle infestation. Sesamum, niger, marigold and cosmos were better for reducing rice earhead bug

infestation, whereas sesamum, sunflower, niger, gomphrina, marigold, mustard and *cock's comb* proved better for reducing rice skipper infestation.

CONCLUSION

The study concludes that the flowering plants niger, sesamum, mustard, cowpea and marigold on cucumber bunds are proved effective in reducing the red pumpkin beetle incidence. Niger, mustard, marigold and cowpea proved best for reducing flea beetle incidence. Niger, marigold, cowpea, mustard and sesamum were best for reducing serpentine leaf miner incidence. Niger, cosmos, cowpea, sesamum and zinnia were found best for reducing the fruit fly infestation. It could be suggested that the flowering plants niger, sesamum, mustard and cowpea could be cultivated on bunds of cucumber field for eco-friendly management of cucumber pests. The present study was based on one season and one location, therefore, further studies should be undertaken to provide concrete recommendations.

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Table 17. Per cent reduction in infestation of fruit fly

Treatments	Per cent reduction in infestation of fruit fly over control			Pooled mean of all 3 weeks
	Week 6	Week 7	Week 8	
	August 5 th wk	Sept. 1 st wk	Sept. 2 nd wk	
T ₁ Cosmos	62.26	57.28	33.44	53.54
T ₂ Cowpea	69.81	30.23	33.66	49.18
T ₃ Marigold	32.71	27.07	1.54	23.20
T ₄ Mustard	40.07	-2.38	54.98	31.50
T ₅ Niger	32.07	82.91	71.90	56.90
T ₆ Sesamum	57.95	40.67	39.60	48.29
T ₇ Zinnia	10.93	50.16	58.67	34.39
T ₈ Control	-	-	-	-

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Evaluation of varieties and spacing against chiku moth *Nephopteryx eugraphella* (Ragonot) in sapota and their eco-friendly management

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ABSTRACT

The study on assessment of varieties and spacing against chiku moth, *Nephopteryx eugraphella* (Ragonot) along with safer management tactics in sapota was carried out at Fruit Research Station, NAU, Gandevi during 2019-20. The average infestation in winter due to chiku moth under normal and high density plantations showed significantly higher damage in Kalipatti (13.25%) followed by Cricket ball (9.00%). However, the damage was comparatively low in PKM-3 (4.57%) and PKM-1 (4.74%). During summer significantly highest incidence was noted in Kalipatti (14.31%) followed by Cricket ball (11.39%) and DHS-1 (11.21%), while the lower infestation was noted in PKM-1 (6.46%) and PKM-3 (6.99%). The average infestation was found to be higher in high density plantation (7.93 and 10.46%) than normal spacing (6.51 and 8.72%) during winter and summer seasons, respectively. Higher damage was noticed in summer than winter among all the varieties. Among evaluation trial of different biopesticides and botanicals after tourk spray, azadirachtin 10000 ppm @ 2 ml L⁻¹ and Bt @ 2 g L⁻¹ showed lower bud and flower damage 6.88 and 7.36 per cent and estimated reduction of 63.53 and 60.93 per cent, respectively over control followed by azadirachtin @ 1 ml L⁻¹ (8.58%) and *B. bassiana* @ 4 g L⁻¹ (8.76%) in damage and reduction up to 54.47 and 53.53 per cent, respectively over control.

Keywords: Varieties, spacing, chiku moth, *Nephopteryx eugraphella* (Ragonot), sapota.

Sapota has attained the status of major fruit crop in Gujarat and flowers can be seen almost throughout the year making fruit harvesting practicable throughout the year particularly between October to June. The conception of high density plantation is becoming trendy among farmers to get higher productivity. But the pest management is one of the major issues for higher productivity due to a big span of 10-11 months between flowering and fruit maturity. The insect and mite pests infesting sapota are 33 in numbers in India and out of that 23 are enlisted in Gujarat (Bisane *et al.*, 2018). Among bud boring complex, chiku moth, *Nephopteryx eugraphella* (Ragonot) (Lepidoptera: Pyralidae), is a most important pest of sapota throughout the country. A recent study showed about 25-27 per cent yield loss jointly due to chiku moth and bud borer, *Anarsia achrasella* Bradley, in sapota under south Gujarat condition (Bisane, 2018).

Regarding succession of chiku moth, Bisane (2018 and 2019) observed the pest infestation on bud and flower throughout the year with two phases of crest damage during May-June at peak flowering stage and during November-

December at new foliage and fruiting initiation stage in sapota cv. Kalipatti under normal spacing. In Gujarat, Kalipatti is a commercial variety with highest area along with other few varieties planted sporadically. Recently, new varieties/hybrids released from southern part of India are under evaluation under normal and high density planting in South Gujarat to validate their suitability in the region. However, comparable losses due to pests under different planting spacings with new varieties/hybrids have not been studied.

Now a days, farmers are asking about the use of safer and eco-friendly pesticides due to rising issues of food poisoning, chemical residues, effect on natural enemies, resurgence and resistance in pest, *etc.* In view of the above aspects, investigation was laid out to evaluate the peak activity period of chiku moth, *Nephopteryx eugraphella* (Ragonot), in different varieties of sapota under normal and high density plantation along with bio-efficacy of different bio-pesticides and botanicals.

MATERIALS AND METHODS

The study on the extent of fruit damage due to chiku moth, *Nephopteryx eugraphella* (Rogouat) under normal and high density planting (HDP) was carried out at the farm of ICAR-AICRP (Fruits), Fruit Research Station, Navsari Agricultural University, Gandevi, Gujarat (20.807545° N, 73.022260° E) during the year 2019-20. The investigation was designed and statistically analyzed in Factorial Randomized Block Design with three replications (one tree considered as one replication) on eight varieties/hybrids viz., PKM-1, PKM-3, PKM-4, DHS-1, DHS-2, Kalipatti (Local check), Cricket ball and CO-3 under two spacings of 10 × 10 m (normal spacing) and 5 × 5 m (HDP). The fruit trees were also kept free from any insecticidal spray during the investigation.

For recording the infestation of chiku moth, randomly selected 10 twigs per tree of each variety was observed around all sides of the tree canopy at fortnightly intervals. Total number of buds and flowers as well as damaged buds and flowers due to chiku moth were counted on each twig and per cent damage was calculated. The observations were recorded between October to January (winter) and February to May (summer) during 2019-20. The damage difference reaction of different varieties/hybrids over local check (Kalipatti) was calculated with the following formula to check the susceptibility/ tolerance level.

$$\% \text{ Variation} = \frac{\% \text{ Damage in variety} - \% \text{ Damage in local check}}{\% \text{ Damage in local check}} \times 100$$

In management trial, eight treatments viz., Bt (*Bacillus thuringiensis* var. *Kurstaki*) 1×10^{11} CFU g⁻¹ @ 2 g L⁻¹ (T₁), *Beauveria bassiana* (1×10^8 CFU g⁻¹) @ 4 g L⁻¹ (T₂), *Metarrhizium anisopliae* (1×10^8 CFU g⁻¹) @ 4 g L⁻¹ (T₃), azadirachtin (10000

ppm) @ 2 ml L⁻¹ (T₄), azadirachtin (10000 ppm) @ 1 ml L⁻¹ (T₅), *Karanj* oil @ 1 ml L⁻¹ (T₆), profenophos 40% + cypermethrin 4% (Ready-mix) (Standard check) 44 EC 0.044% @ 1 ml L⁻¹ (T₇) and control (T₈) were tested in randomized block design with three replications (2 trees/replication). The application of treatments was commenced from first fortnight of March at 15 days interval and total 4 sprays were given. In *Karanj* oil treatment, detergent powder @ 0.5 g L⁻¹ of water was added as sticker.

For recording the damage intensity of chiku moth, randomly selected 10 twigs tree⁻¹ of each treatment was observed around all sides of tree canopy at 1st, 3rd, 5th, 7th, 10th and 14th day after application. Similar methodology of screening was followed to record per cent bud and flower damage. The damage reduction difference due to different treatments over control was calculated using the following formula.

$$\% \text{ Damage reduction} = \frac{\% \text{ Damage in treatment} - \% \text{ Damage in control}}{\% \text{ Damage in control}} \times 100$$

The fruit yield (kg tree⁻¹) was noted at each harvesting from October onwards and total yield of each tree was calculated at the end of season (April-May, 2020). The yield per tree was converted into per ha basis for analysis of ICBR and incremental yield over control.

RESULTS AND DISCUSSION

Varietal screening

Winter

Varieties: The significantly maximum mean damage of 13.25 per cent due to moth was reported in local check Kalipatti followed by 9.00% in Cricket ball (Table 1). However, the

Table 1. Average damage of chiku moth (*N. eugraphella*) in different varieties and spacing of sapota in winter

Tr. No.	Bud and flower damage (%)* (Avg. of 8 fortnightly observations from October to January)			Variation over Kalipatti %
	S ₁ (10 × 10m)	S ₂ (5 × 5m)	Mean (V)	
V ₁ : PKM-1	3.99 (11.34)	5.50 (13.37)	4.74 (12.35)	-64.23
V ₂ : PKM-3	4.11 (11.54)	5.02 (12.75)	4.57 (12.15)	-65.51
V ₃ : PKM-4	5.48 (13.35)	6.58 (14.71)	6.03 (14.03)	-54.49
V ₄ : DHS-1	6.56 (14.65)	8.07 (16.25)	7.31 (15.45)	-44.83
V ₅ : DHS-2	6.06 (14.12)	8.43 (16.66)	7.25 (15.39)	-45.28
V ₆ : Kalipatti	12.63 (20.70)	13.86 (21.69)	13.25 (21.20)	
V ₇ : Cricket ball	8.21 (16.55)	9.79 (18.08)	9.00 (17.32)	-32.08
V ₈ : CO-3	5.06 (12.68)	6.18 (14.21)	5.62 (13.44)	-57.58
Mean (S)	6.51 (14.37)	7.93 (15.96)		-64.23
% Variation over normal spacing	--	21.81	--	--
	V	S	Interaction (V × S)	V
CD at 5%	0.97	0.49	1.37	--
CV %		15.92		--

*Figures in parentheses are arc sin transformed value. V= Variety, S= Spacing.

damage was comparatively less in PKM-3 (4.57%), PKM-1 (4.74%) and CO-3 (5.62%).

Spacing: The significant damage was higher (7.93%) in high density plantation as compared to normal spacing (6.51%). There were significant interaction differences among varieties and spacing during winter. Kalipatti (13.86%), Cricket ball (9.79%) and DHS-2 (8.43%) under high density plantation as well as Kalipatti (12.63%) and Cricket ball (8.21%) under normal spacing were found more susceptible. Whereas, PKM-1 (3.99%) and PKM-3 (4.11%) showed tolerance towards chiku moth under normal spacing.

The three varieties *viz.*, Cricket ball, DHS-1 and DHS-2 had comparable susceptibility reaction with 32.08, 44.83 and 45.28 per cent less damage, respectively than Kalipatti (Table 1). However, PKM-4, CO-3, PKM-1 and PKM-3 had less vulnerability response of 54.49, 57.58, 64.23 and 65.51 per cent, respectively than Kalipatti. High density plantation had 21.81 per cent more vulnerability over normal spacing.

Summer

Varieties: The significantly highest mean damage of 14.31 per cent due to chiku moth was noticed in Kalipatti followed by Cricket ball (11.39%) and DHS-1 (11.21%) (Table 2). The damage was less in PKM-1 (6.46%) and PKM-4 (6.99%).

Spacing: The bud and flower damage was higher (10.46%) in high density plantation than normal spacing plantation (8.72%). There were significant interaction differences among varieties and spacing during summer. As a result, Kalipatti (15.23%), DHS-1 (12.25%) and Cricket ball (12.07%) under

high density plantation as well as Kalipatti (13.38%) under normal spacing were found more susceptible. Whereas, PKM-1 (5.47%), PKM-3 (5.73%) and PKM-4 (6.62%) under normal spacing showed tolerance towards chiku moth.

The three varieties *viz.*, Cricket ball, DHS-1 and DHS-2 having 20.41, 21.66 and 24.53 per cent damage, respectively had comparable susceptibility response with Kalipatti. However, PKM-4, CO-3, PKM-3 and PKM-1 had less vulnerability and noted lesser damage of 44.44, 46.75, 51.15 and 54.86 per cent, respectively than Kalipatti. In spacing, high density plantation had 19.95 per cent more vulnerability over normal spacing. The data revealed 8.00 and 26.56 per cent increased damage in summer than winter under Kalipatti and Cricket ball, respectively indicating consistent infestation by chiku moth in both seasons. The varieties PKM-4, CO-3, PKM-1, DHS-2, PKM-3 and DHS-1 showed slightly increased damage of 31.84 to 53.35 per cent in summer than winter indicating higher susceptibility during summer.

Earlier works have reported highest infestation on buds due to chiku moth in Kalipatti, while bud damage was lowest in PKM-1 under normal spacing (Anon., 1998 and 2001), which was also noted in present investigation. In recent past studies of varietal evaluation, Kalipatti, DHS-1 and Cricket ball were reported to be more susceptible to chiku moth with higher bud and flower damage as compared to tolerancy reaction in DHS-2, PKM-4 and PKM-1 under normal spacing. The maximum damage was observed during May-June as well as during November-December (Anon., 2019a and 2020, Bisane and Naik, 2016 and Bisane, 2021).

Table 2. Average damage of chiku moth (*N. eugraphella*) in different varieties and spacing of sapota in summer

Tr. No.	Bud and flower damage (%) (Avg. of fortnightly 8 observations from February to June)			Variation over Kalipatti %	Variation over winter %
	S ₁ (10 x 10m)	S ₂ (5 x 5m)	Mean (V)		
V ₁ : PKM-1	5.47 (13.31)	7.44 (15.65)	6.46 (14.48)	-54.86	36.29
V ₂ : PKM-3	5.73 (13.51)	8.25 (16.44)	6.99 (14.98)	-51.15	52.95
V ₃ : PKM-4	6.62 (14.58)	9.27 (17.51)	7.95 (16.04)	-44.44	31.84
V ₄ : DHS-1	10.18 (18.48)	12.25 (20.29)	11.21 (19.39)	-21.66	53.35
V ₅ : DHS-2	10.47 (18.68)	11.13 (19.34)	10.80 (19.01)	-24.53	48.97
V ₆ : Kalipatti	13.38 (21.31)	15.23 (22.83)	14.31 (22.07)		8.00
V ₇ : Cricket ball	10.71 (18.91)	12.07 (20.13)	11.39 (19.52)	-20.41	26.56
V ₈ : CO-3	7.20 (15.38)	8.03 (16.20)	7.62 (15.79)	-46.75	35.59
Mean (S)	8.72 (16.77)	10.46 (18.55)		--	--
% Variation over normal spacing	--	19.95	--	--	--
	V	S	Interaction (V x S)	--	--
CD at 5%	1.09	0.55	1.54	--	--
CV %		15.38		--	--

*Figures in parentheses are arc sin transformed value. V= Variety, S= Spacing.

Under high density plantation, Khambhu and Bisane (2017) found lowest average seasonal occurrence in DHS-2, Kalipatti, PKM-3 and Cricket ball, whereas, PKM-4 and PKM-1 had medium damage and CO-3 was least susceptible to chiku moth. Maximum infestation was observed during October to December. All these findings reported from south agro-ecological circumstances match with present research results, however, slight variation might be due to ecological changes and flowering time. Vaja *et al.* (2018) reported that Kalipatti was most susceptible and PKM-1 showed the least susceptibility under normal spacing in other sapota growing regions.

Bio-efficacy of different biopesticides and botanicals

First spray: The significantly minimum bud and flower damage of 9.44 per cent due to chiku moth was observed in profenophos 40% + cypermethrin 4% (T_7) (Table 3). Among biopesticides and botanicals, the application of azadirachtin (2 ml L^{-1}) (T_4) and Bt (T_1) with infestation of 11.54 and 11.95 per cent, respectively performed better over other treatments. After first spray, azadirachtin (2 ml L^{-1}) (T_4), Bt (T_1) and azadirachtin (1 ml L^{-1}) (T_5) showed damage reduction to the extent of 12.31, 9.19 and 7.22 per cent, respectively over control (T_8).

Second spray: The significantly minimum bud and flower damage up to 7.50 per cent was recorded in profenophos 40% + cypermethrin 4% (T_7) (Table 3). Among biopesticide

and botanicals, azadirachtin (2 ml L^{-1}) (T_4), Bt (T_1), *B. bassiana* (T_2) and azadirachtin (1 ml L^{-1}) (T_5) showed 10.13, 10.40, 11.40 and 11.45 per cent damage, respectively, which had descending trend of reduction of 31.67, 29.80, 23.10 and 22.72 per cent over control (T_8).

Third spray: The significantly lowest bud and flower damage of 5.03 per cent was noted in profenophos 40% + cypermethrin 4% (T_7) (Table 3). While among biopesticide and botanicals, azadirachtin (2 ml L^{-1}) (T_4) and Bt (T_1) were found effective and reported lower infestation up to 7.46 and 8.32 per cent with reduction up to 54.65 and 49.41 per cent over control (T_8) after third spray.

Fourth spray: The treatment of profenophos 40% + cypermethrin 4% (T_7) significantly reduced the bud and flower damage of chiku moth up to 3.32 per cent after fourth spray (Table 3). After that, azadirachtin (2 ml L^{-1}) (T_4) and Bt (T_1) were also reported lower 6.88 and 7.36 per cent damage, respectively. However, the maximum infestation reached up to 18.85 per cent in control (T_8) during April-May.

After fourth spray, per cent reduction of bud and flower damage was 82.41, 63.53 and 60.93 per cent in profenophos 40% + cypermethrin 4% (T_7), azadirachtin (2 ml L^{-1}) (T_4) and Bt (T_1), respectively over control (T_8). However, azadirachtin (1 ml L^{-1}) (T_5), *B. bassiana* (T_2), *M. anisopliae* (T_3) and Karanj oil (T_6) showed reduction up to 54.47, 53.53, 43.96 and 40.25 per cent, respectively over control (T_8).

Table 3. Efficacy of different treatments on average bud and flower damage against chiku moth (*N. eugraphella*) in sapota

Tr. No.	I spray		II spray		III spray		IV spray	
	Avg. damage (%) [*]	Reduction over control %	Avg. damage (%) [*]	Reduction over control %	Avg. damage (%) [*]	Reduction over control %	Avg. damage (%) [*]	Reduction over control %
T_1	11.95 (20.11)	9.19	10.40 (18.62)	29.80	8.32 (16.62)	49.41	7.36 (15.55)	60.93
T_2	12.31 (20.40)	6.47	11.40 (19.6)	23.10	9.10 (17.41)	44.64	8.76 (17.14)	53.53
T_3	12.93 (20.95)	1.78	12.75 (20.84)	13.97	10.43 (18.70)	36.59	10.56 (18.89)	43.96
T_4	11.54 (19.76)	12.31	10.13 (18.39)	31.67	7.46 (15.66)	54.65	6.88 (15.09)	63.53
T_5	12.21 (20.09)	7.22	11.45 (19.69)	22.72	9.20 (17.52)	44.06	8.58 (16.91)	54.47
T_6	12.79 (20.89)	2.83	13.31 (21.31)	10.21	11.51 (19.67)	30.03	11.26 (19.48)	40.25
T_7	9.44 (17.76)	28.30	7.50 (15.74)	49.37	5.03 (12.8)	69.44	3.32 (10.26)	82.41
T_8	13.16 (21.11)	--	14.82 (22.58)	--	16.45 (23.81)	--	18.85 (25.71)	--
CD at 5% (T)	2.00	--	1.78	--	1.80	--	1.60	--
CD at 5% (D)	NS	--	NS	--	1.56	--	NS	--
CD at 5% (TxD)	NS	--	NS	--	NS	--	NS	--
CV %	14.99	--	13.73	--	15.32	--	13.88	--

*Figures in parentheses are arc sin transformed value. DAT= Day after treatment, T= Treatment, S= Spray.

Table 4. Efficacy of different treatments on average bud and flower damage against chiku moth (*N. eugraphella*) in sapota (Pool of 4 sprays)

Tr. No.	Avg. bud and flower damage (%)* (Pool of 4 sprays)							Reduction over control (%)	Fruit yield (t ha ⁻¹)	ICBR
	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	Avg.			
T ₁	10.48 (18.63)	10.12 (18.42)	9.36 (17.63)	9.16 (17.40)	8.84 (16.98)	9.11 (17.27)	9.51 (17.72)	39.88	15.53	1.10
T ₂	11.16 (19.34)	10.75 (18.86)	10.52 (18.87)	9.85 (18.09)	9.78 (18.08)	10.29 (18.61)	10.39 (18.64)	34.30	13.37	1.07
T ₃	12.23 (20.36)	11.82 (19.97)	11.54 (19.76)	11.29 (19.48)	11.27 (19.46)	11.86 (20.03)	11.67 (19.85)	26.25	13.35	1.04
T ₄	10.17 (18.33)	9.19 (17.41)	8.39 (16.61)	8.36 (16.54)	8.66 (16.94)	9.22 (17.53)	9.00 (17.23)	43.10	15.82	1.30
T ₅	11.30 (19.46)	10.45 (18.71)	10.33 (18.45)	9.75 (18.02)	9.99 (18.15)	10.35 (18.51)	10.36 (18.55)	34.50	14.20	1.21
T ₆	12.78 (20.87)	12.46 (20.45)	11.67 (19.93)	11.65 (19.86)	11.97 (20.10)	12.79 (20.83)	12.22 (20.34)	22.78	13.03	1.07
T ₇	7.96 (16.10)	6.64 (14.45)	5.71 (13.51)	5.40 (13.08)	5.76 (13.38)	6.46 (14.31)	6.32 (14.14)	60.04	16.87	9.95
T ₈	14.95 (22.62)	15.40 (23.03)	15.65 (23.18)	15.92 (23.34)	16.23 (23.62)	16.78 (24.02)	15.82 (23.03)	--	12.47	--
CD at 5% (T)	2.28	2.34	2.04	2.25	2.21	2.23	0.90	--	2.58	--
CD at 5% (S)	1.61	1.66	1.44	1.59	1.56	1.58	0.64	--	--	--
CD at 5% (TxS)	NS	NS	NS	NS	NS	NS	1.80	--	--	--
CV %	14.37	15.17	13.54	15.13	14.74	14.49	14.73	--	10.26	--

*Figures in parentheses are arc sin transformed value. DAT= Days after treatment, T= Treatment, D= Days, S= Spray.

Average damage (Pool of 4 sprays): The significantly lowest bud and flower damage of 6.32 per cent due to chiku moth was noted in profenophos 40% + cypermethrin 4% (T₇). Among biopesticide and botanical treatments, azadiractin (2 ml L⁻¹) (T₄) and Bt (T₁) also observed lower infestation up to 9.00 and 9.51 per cent followed by azadiractin (1 ml L⁻¹) (T₅) and *B. bassiana* (T₂) (10.36 and 10.39%) damage, respectively. The other treatments viz., *M. anisopliae* (T₃) and *Karanj* oil (T₆) recorded slightly higher infestation of 11.67 and 12.22 per cent damage. The highest bud and flower damage of 15.82 per cent was observed in control (T₈). There was reduction of damage up to 60.04, 43.10 and 39.88 per cent in profenophos 40% + cypermethrin 4% (T₇), azadiractin (2 ml L⁻¹) (T₄) and Bt (T₁), respectively over control (T₈).

The biopesticides and botanicals showed higher efficacy at 5th and 7th day after application of third and fourth spray. Therefore, it is advised to apply 3 to 4 sprays of effective biopesticides and botanicals from the end of February or starting of March to combat chiku moth infestation.

Ghirlahre *et al.* (2016) reported that spinosad 45 SC (0.0169%), *B. thuringiensis* 5 WP (0.0075%) and profenophos + cypermethrin 44 EC (0.044%) were effective against chiku moth, while *Karanj* oil (0.03%) was found least effective among other treatments. In another study, profenophos

(0.075%), chlorpyrifos (0.05%) and Bt @ 2 g L⁻¹ were found effective in reducing the damage of chiku moth as compared to control (Anon., 2019b).

Highest yield of 16.87 t ha⁻¹ was obtained due to application of profenophos 40 per cent + cypermethrin 4 per cent (T₇) followed by azadiractin (2 ml L⁻¹) (T₄) and Bt (T₁) (15.82 and 15.53 t ha⁻¹), respectively. The lowest fruit yield of 12.47 t ha⁻¹ was observed in control (T₈). In ICBR, the higher ratio of 9.95 was estimated in profenophos 40% + cypermethrin 4% (T₇) followed by azadiractin (2 ml L⁻¹) (T₄), azadiractin (1 ml L⁻¹) (T₅) and Bt (T₁) with 1.30, 1.21 and 1.10 ICBR, respectively over control.

CONCLUSION

The studies showed that among different sapota varieties grown at Gandevi, Gujarat, the PKM-1 and CO-3 in winter and PKM-1 and PKM-4 in summer were comparatively less susceptible to chiku moth with 4.74, 5.62, 6.46 and 6.99 per cent incidence, respectively than 13.25 and 14.3 per cent in local kalipatti. High density sapota crop during winter and summer registered higher chiku moth damage of 7.93 and 10.46 per cent than that grown at normal spacing (6.51% and 8.72%), respectively. Application of profenophos (40%) + cypermethrin (4%) registering highest reduction per cent in chiku moth infestation (60.04%) over

the control, 9 maximum fruit yield ($16.87 + \text{ha}^{-1}$) and ICBR (9.95) could be recommended for effective management of chiku moth, *N. eugraphella* in sapota.

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Interrelationship between abiotic factors and incidence of *Bemisia tabaci* and *Chromatomyia horticola* on gerbera and their management under polyhouse in Kashmir

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ABSTRACT

A study carried out in an experimental unit of the Division of Floriculture and Landscaping Architecture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, under polyhouse conditions during 2020-2021 revealed peak whitefly incidence on gerbera during 28th SMW (3.55 whiteflies leaf⁻¹ and 16.5 whiteflies flower⁻¹) at a mean maximum temperature of 37.7°C, while the leaf miner incidence peaked in 22nd and 23rd SMW (0.3 grubs/pupae leaf⁻¹) at a mean maximum temperature of 28.2°C and 32.6°C, respectively. Correlation studies revealed whitefly and leaf miner populations to be highly significantly and positively correlated with temperature, while negatively correlated with R.H. While testing the efficacy of various treatments against whitefly and leaf-miner, acetamiprid 20% SP @ 0.5 g L⁻¹ was found to be the most effective treatment against both pests.

Key words: Correlation, gerbera, leaf miner, management, whitefly

In India, the floriculture business has developed as a financially sound sector that has piqued the interest of entrepreneurs. The industry is expanding at a pace of 15 to 20 per cent every year (Bhat *et al.*, 2017). The favourable temperature as well as rich natural resources including soil, water and geographical variation of Kashmir valley make it ideal for cultivating almost any economically productive flower. In 2019-20, J&K's floriculture area was estimated to be 279.15 ha, with a loose flower yield of 2065.62 MT (Anonymous, 2019).

Gerbera (*Gerbera jamesonii* Bolus) is a financially lucrative flower crop grown in Kashmir region and is in high demand in the floriculture business, ranking fifth among the world's top ten cut flowers (Prodhan *et al.*, 2017). However, pest infestation is one of the most significant barriers to its commercial production. Whitefly, a sucking pest, causes direct deformation of the plants. Indirectly, they are responsible for the growth of sooty mold fungi due to honeydew secretions thereby affecting the physiological processes of the plant. In addition, they serve as vectors for the spread of plant viruses (Seddigh and Kiani, 2012). Leaf miner larvae live in the palisade mesophyll and feed on the same (Parrella *et al.*, 1985) resulting in the decreased

photosynthesis and yield. This directly affects the marketable quality of the flowers (Abraham *et al.*, 2013). Since whitefly and leaf-miner infestations are serious obstacle to gerbera cultivation in Kashmir, the present study on seasonal abundance and management of whitefly and leaf-miner was investigated.

MATERIALS AND METHODS

The study was undertaken using the gerbera variety Felicks at a spacing of 35 × 40 cm in the experimental plot of the Division of Floriculture and Landscaping Architecture, Faculty of Horticulture, SKUAST-K, Shalimar, Srinagar. The abundance of whitefly and leaf-miner were recorded at weekly intervals from March, 2020 to February, 2021. Ten plants were chosen at random for taking the readings. Under protected conditions, the incidence of whitefly and leaf-miner on gerbera were correlated with meteorological parameters such as temperature and relative humidity recorded on daily basis using a digital temperature and humidity meter and the data was statistically analysed.

For the management of whitefly and leaf-miner, the study was carried out in a Randomized Complete Block Design (RCBD) with 10 treatments (one botanical, one

entomopathogen, seven new molecular pesticides and an untreated control) in three replications. Table 1 lists all of the treatments in detail. One day before the spray, the population was counted and then two rounds of spray were applied at 14 day interval. The observations were taken after both sprays at 1, 3, 7 and 15 days from three randomly chosen plants from each treatment (3 leaves and 1 flower bud from each plant) and the data was analysed statistically with the help of OPSTAT software.

Table 1. Treatment details against whitefly and leaf-miner under polyhouse conditions

T ₁	Azadirachtin 0.03% EC @ 5 ml/L
T ₂	Spinosad 45% SC @ 0.5 ml/L
T ₃	Chlorfenapyr 10% SC @ 1 ml/L
T ₄	Emamectin Benzoate 5% WG @ 0.5 g/L
T ₅	Spiromesifen 5% EC @ 1 ml/L
T ₆	Acetamiprid 20% SP @ 0.5 g/L
T ₇	Thiamethoxam 25% WG @ 0.2 g/L
T ₈	Fipronil 5% SC @ 1 ml/L
T ₉	<i>Lecanicillium lecani</i> (1x10 ⁸ CFU's/ml) @ 2 ml/L
T ₁₀	Control

RESULTS AND DISCUSSION

Seasonal Incidence

The population density of whiteflies (*Bemisia tabaci*) on gerbera leaves ranged from 0.05 to 3.55 per leaf during the course of investigation (Fig. 1). No incidence was recorded in 12th SMW (March) following which the population started to increase steadily from 13th SMW (March) with 0.05 whiteflies leaf⁻¹ reaching the peak infestation level in 28th SMW (July) with 3.55 whiteflies leaf⁻¹ at a mean maximum temperature of 37.7°C. Thereafter, the population started to decline in a gradual manner till 51st SMW (December) with 0.05 whiteflies leaf⁻¹. There was no whitefly incidence from 52nd to 5th SMW after which slight population buildup was recorded from 6th SMW (February) with 0.05 whiteflies leaf⁻¹ up to 8th SMW (0.35 whiteflies leaf⁻¹). The population density of whiteflies on gerbera flowers ranged 0.05 to 16.5 whiteflies flower⁻¹ during the investigation period (Fig. 1). Least population was observed in 12th SMW (March) with 0.1 whiteflies flower⁻¹ followed by the gradual increase in the infestation levels reaching the peak infestation level in 28th SMW (July) with 16.5 whiteflies flower⁻¹ when the mean maximum temperature was 37.7°C. Thereafter, population showed steady decline till 8th SMW (February) with 2.05 whiteflies flower⁻¹. Results were in line with Gupta (2016) who also noticed commencement of whitefly population from March. Further, the results were in agreement with Syed *et al.* (2015) who also reported the peak whitefly incidence at 37.4°C. This could be because of higher temperatures influencing overall insect's activity.

The number of grubs/pupae of dipteran leaf miner (*Chromatomyia horticola*) on gerbera leaves ranged from 0.05 to 0.3 grubs/pupae leaf⁻¹ during the investigation period (Fig. 2). No incidence of leaf miner was recorded between 12th to 15th SMW (March- second week of April) following which the slight incidence was recorded from 16th SMW (April) with 0.05 grubs/pupae leaf⁻¹ reaching the peak incidence (0.3 grubs/pupae leaf⁻¹) in 22nd and 23rd SMW (May- June) when the mean maximum temperature was 28.2°C and 32.6°C, respectively. This was followed by the steady decline in infestation level up to 34th SMW (August) with 0.1 grubs/pupae leaf⁻¹. Further, no incidence was recorded from 35th to 8th SMW. The results were almost in agreement with Rather *et al.* (2020) who documented the peak infestation of leaf miner during the month of May and complete disappearance of pest with the beginning of winter. The possible reason could be that the mesophyll content of the available foliage remains soft in the spring and early summer (April to June), allowing the grubs/maggots to feed voraciously as compared to later months when the available foliage begins to dry and becomes considerably tougher due to the deposition of cellulose, hemicelluloses, pectin and other materials.

Correlation and regression analysis

A positive and highly significant correlation was found between whitefly on leaves and flowers and minimum ($r = 0.833$ & $r = 0.865$) and maximum temperature ($r = 0.781$ & $r = 0.864$), respectively. Also, a negative and highly significant correlation was observed between whitefly population on leaves and flowers and minimum ($r = -0.395$ & $r = -0.561$) and maximum relative humidity ($r = -0.673$ & $r = -0.623$), respectively. The multiple regression studies revealed 71 and 82 per cent fluctuation of whitefly population on account of weather parameters on leaves and flowers, respectively (Table 2). The results are in conformity with Sharma *et al.* (2017) who also reported a positive correlation between whitefly population and temperature. This is ascribed to the whitefly's increased rate of development and reproduction in relation to higher temperature. The similar findings of whitefly population being negatively correlated with RH were presented by Subba *et al.* (2017). This could be probably due to insect's growth and development significantly hampered by higher humidity levels.

A positive and highly significant correlation between leaf miner and minimum ($r = 0.673$) and maximum temperature ($r = 0.584$) was observed, whereas negative and highly significant correlation was found with maximum relative humidity ($r = -0.588$). Further, 59 per cent variation in leaf miner population was observed due to weather parameters (Table 2). The research findings were in

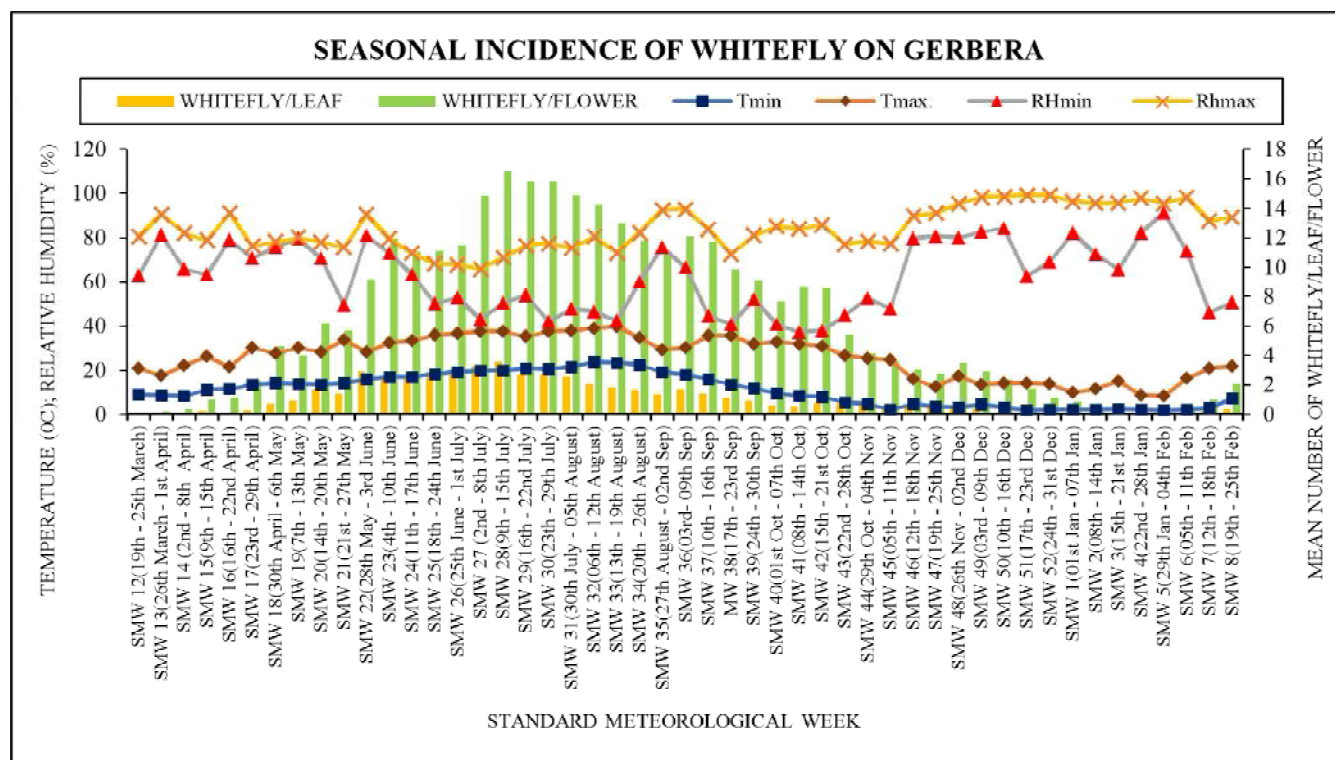


Fig. 1. Seasonal incidence of whitefly on leaves and flowers in Gerbera under protected conditions during 2020-2021

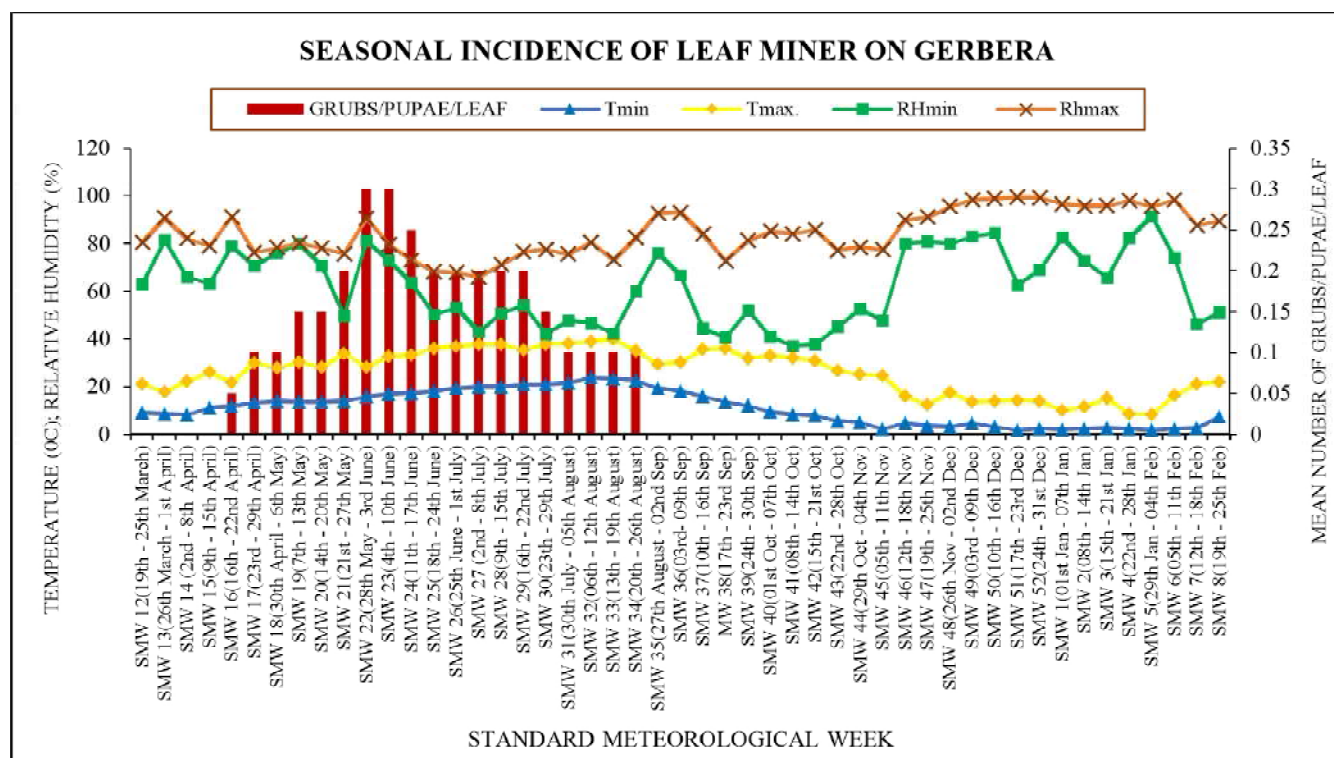


Fig. 2. Seasonal incidence of leaf miner on leaves in Gerbera under protected conditions during 2020-21

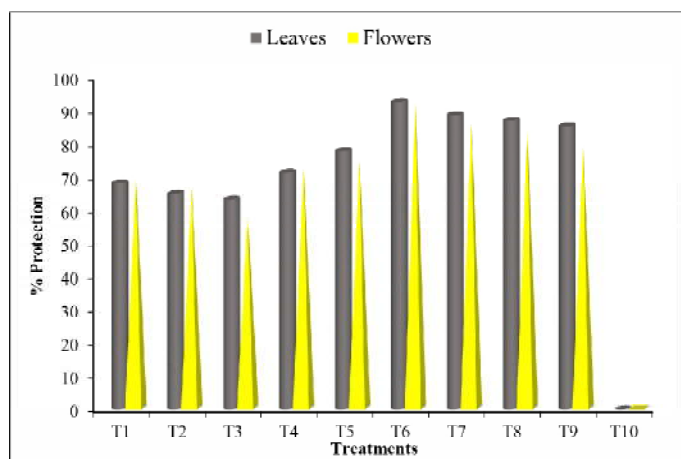


Fig. 3. Effect of different treatments against whitefly in leaves and flowers of gerbera

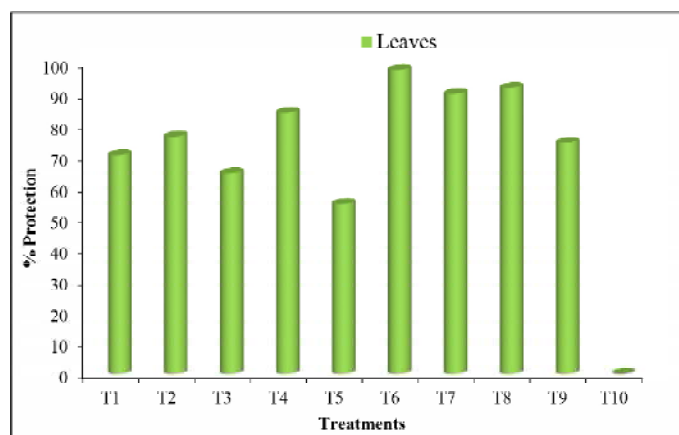


Fig. 4. Effect of different treatments against leaf miner in leaves of gerbera

Table 2. Relationship between whitefly and leaf-miner population and weather parameters (temperature, °C and relative humidity, %) under protected condition

Insect Pests	Correlation coefficient values (r)				R ²	Multiple Regression Equation
	Temperature (°C)		Relative Humidity (%)			
	Minimum (X ₁)	Maximum (X ₂)	Minimum (X ₃)	Maximum (X ₄)		
Number of whitefly leaf ⁻¹	0.833**	0.781**	-0.395*	-0.673**	0.71	Y= 1.61 + 0.10X ₁ +0.002X ₂ +0.0006X ₃ -0.02X ₄
Number of whitefly flower ⁻¹	0.865**	0.864**	-0.561**	-0.623**	0.82	Y= -10.21 + 0.47X ₁ +0.19X ₂ - 0.07X ₃ +0.12X ₄
Number of leaf-miner grubs/pupae leaf ⁻¹	0.673**	0.584**	-0.1	-0.588**	0.59	Y= 0.07 + 0.002X ₁ +0.004X ₂ +0.003X ₃ -0.004X ₄

*-Correlation is significant at 0.05 level

** -Correlation is significant at 0.01 level

Table 3. Evaluation of treatments against whitefly infesting gerbera leaves

Treatments	Number of whitefly leaf ⁻¹ (1 st spray)					Number of whitefly leaf ⁻¹ (2 nd spray)				Per cent protection
	1DBS	1DAS	3DAS	7DAS	15DAS	1DAS	3DAS	7DAS	15DAS	
T ₁ : Azadirachtin 0.03% EC @ 5 ml L ⁻¹	6.00 (2.64)	6.11 (2.66)	5.99 (2.63)	5.66 (2.58)	5.22 (2.49)	4.89 (2.42)	4.77 (2.40)	4.55 (2.35)	4.33 (2.30)	68.04
T ₂ : Spinosad 45% SC @ 0.5 ml L ⁻¹	6.33 (2.71)	6.33 (2.70)	6.22 (2.68)	5.88 (2.62)	5.55 (2.56)	5.00 (2.44)	4.89 (2.42)	4.77 (2.40)	4.77 (2.40)	64.79
T ₃ : Chlorfenapyr 10% SC @ 1 ml L ⁻¹	6.55 (2.74)	6.33 (2.70)	6.44 (2.73)	6.00 (2.64)	5.77 (2.60)	5.55 (2.55)	5.33 (2.51)	5.00 (2.45)	5.00 (2.44)	63.09
T ₄ : Emamectin Benzoate 5% WG @ 0.5 g L ⁻¹	6.00 (2.64)	6.00 (2.64)	5.66 (2.57)	5.33 (2.51)	5.00 (2.44)	4.77 (2.39)	4.33 (2.30)	4.00 (2.23)	3.89 (2.20)	71.29
T ₅ : Spiromesifen 5% EC @ 1 ml L ⁻¹	5.77 (2.59)	5.66 (2.58)	5.55 (2.55)	5.00 (2.45)	4.66 (2.37)	4.22 (2.28)	4.00 (2.22)	3.66 (2.16)	3.00 (1.98)	77.85
T ₆ : Acetamiprid 20% SP @ 0.5 g L ⁻¹	5.11 (2.47)	4.89 (2.43)	4.66 (2.37)	3.55 (2.13)	3.00 (1.99)	2.66 (1.90)	2.00 (1.72)	1.44 (1.56)	1.00 (1.41)	92.61
T ₇ : Thiamethoxam 25% WG @ 0.2 g L ⁻¹	5.44 (2.54)	5.00 (2.44)	4.55 (2.35)	3.77 (2.17)	3.33 (2.07)	3.00 (1.99)	2.66 (1.91)	2.22 (1.77)	1.55 (1.60)	88.56
T ₈ : Fipronil 5% SC @ 1 ml L ⁻¹	5.55 (2.55)	5.33 (2.51)	4.88 (2.42)	3.89 (2.21)	3.55 (2.12)	3.33 (2.07)	2.89 (1.97)	2.66 (1.91)	1.77 (1.66)	86.93
T ₉ : <i>Lecanicillium lecanii</i> (1x10 ⁸ CFU's ml ⁻¹) @ 2 ml L ⁻¹	5.66 (2.58)	5.44 (2.53)	5.00 (2.45)	4.66 (2.38)	4.22 (2.28)	3.89 (2.21)	3.55 (2.13)	3.00 (1.99)	2.00 (1.72)	85.23
T ₁₀ : Control	6.66 (2.76)	6.55 (2.75)	7.11 (2.84)	9.55 (3.25)	9.77 (3.28)	11.22 (3.49)	12.55 (3.68)	12.77 (3.71)	13.55 (3.81)	
C.D (P ≤ 0.05)	NS	NS	NS	0.32	0.34	0.41	0.36	0.32	0.34	
S.E(m) ±	0.12	0.10	0.13	0.11	0.11	0.14	0.12	0.11	0.11	
C.V.	7.93	6.44	9.10	7.43	8.19	9.90	9.00	8.29	9.03	

DBS- Day before spray, DAS- Days after spray, Figures in parentheses are square root transformations and NS-Non-significant

congruence with Chaudhuri and Senapati (2004) who also reported a positive correlation between leaf miner population and temperature, possible reason of which could be overall influence of temperature on biological parameters including accelerated physiological responses and rise in metabolic rates leading to an increase in population size. In addition, a negative correlation of leaf miner with relative humidity was observed in the present study which was in compliance with the results of Singh (2017). This could probably be due to inhibitory effect of high humidity on insect's growth and development.

Management of white fly and leaf miner

Pre-treatment count of whiteflies ranged between 5.11 to 6.66 whiteflies leaf⁻¹ (Table 3). After 1st spray, the whitefly population ranged from 4.89 to 6.55 per leaf after 1 DAS exhibiting non-significant variation among different treatments. Similar trend of non-significance was noticed after 3 DAS in the population. At 7 DAS, T₆ (acetamiprid 20% SP @ 0.5g L⁻¹) with the population of 3.55 whiteflies leaf⁻¹ was best treatment followed by T₇ (thiamethoxam 25% WG @ 0.2 g L⁻¹) with 3.77 whiteflies leaf⁻¹ and T₈ (fipronil 5% SC @ 1 ml L⁻¹) with 3.89 whiteflies leaf⁻¹. At 15 DAS, T₆ (3.00 whiteflies leaf⁻¹) followed by T₇ (3.33 whiteflies leaf⁻¹) recorded the lowest population which exhibited non-significant

variation between each other. After second spray, at 1 DAS, T₆ with 2.66 whiteflies leaf⁻¹ followed by T₇ with 3.00 whiteflies leaf⁻¹ recorded the lowest whitefly population and exhibited non-significant variation with each other. At 3 DAS, T₆ proved to be superior to other treatments with 2.00 whiteflies leaf⁻¹ followed by T₇ and T₈ with 2.66 and 2.89 whiteflies leaf⁻¹, respectively. At 7 DAS, T₆ (1.44 whiteflies leaf⁻¹) recorded the lowest whitefly population followed by T₇ (2.22 whiteflies leaf⁻¹). At 15 DAS, T₆ maintained its superiority over other treatments by recording the lowest whitefly population (1.00 whiteflies leaf⁻¹) followed by T₇ (1.55 whiteflies leaf⁻¹), T₈ (1.77 whiteflies leaf⁻¹) and T₉ (2.00 whiteflies leaf⁻¹).

On flowers, pre-treatment count of whiteflies ranged between 4.33 to 6.77 whiteflies flower⁻¹ (Table 4). After 1st spray, 1 DAS, the lowest population was recorded in T₆ (4.00 whiteflies flower⁻¹) followed by, T₇ (4.22 whiteflies flower⁻¹). At 3 DAS, T₆ (3.00 whiteflies flower⁻¹) recorded the lowest population of whiteflies followed by T₇ (3.55 whiteflies flower⁻¹) and T₈ (3.78 whiteflies flower⁻¹). At 7 and 15 DAS, the best results were observed in T₆ (3.00 and 2.66 whiteflies flower⁻¹, respectively), T₇ (3.11 and 2.88 whiteflies flower⁻¹, respectively) and T₈ (3.33 and 3.00 whiteflies flower⁻¹, respectively) which were statistically at par. Following

Table 4. Evaluation of treatments against whitefly infesting gerbera flowers

Treatments		Number of whitefly flower ⁻¹ bud (1 st spray)					Number of whitefly flower ⁻¹ bud (2 nd spray)				Per cent protection
		1DBS	1DAS	3DAS	7DAS	15DAS	1DAS	3DAS	7DAS	15DAS	
T ₁ :	Azadirachtin 0.03% EC @ 5 ml L ⁻¹	5.44 (2.53)	5.44 (2.53)	5.00 (2.44)	4.55 (2.35)	3.89 (2.21)	4.00 (2.23)	3.55 (2.13)	3.33 (2.08)	3.33 (2.08)	68.76
T ₂ :	Spinosad 45% SC @ 0.5 ml L ⁻¹	5.44 (2.54)	5.89 (2.62)	5.33 (2.51)	4.66 (2.38)	4.00 (2.23)	4.00 (2.23)	3.88 (2.21)	3.55 (2.13)	3.66 (2.15)	65.66
T ₃ :	Chlorfenapyr 10% SC @ 1 ml L ⁻¹	6.33 (2.69)	6.00 (2.64)	5.66 (2.58)	5.00 (2.44)	4.66 (2.37)	4.66 (2.37)	4.00 (2.23)	4.22 (2.28)	4.55 (2.36)	57.31
T ₄ :	Emamectin Benzoate 5% WG @ .5 g L ⁻¹	5.33 (2.51)	5.00 (2.44)	5.00 (2.44)	4.00 (2.23)	4.33 (2.30)	3.88 (2.21)	3.33 (2.07)	3.22 (2.05)	3.00 (1.99)	71.85
T ₅ :	Spiromesifen 5% EC @ 1 ml L ⁻¹	4.66 (2.37)	4.44 (2.32)	4.00 (2.22)	3.89 (2.20)	3.77 (2.18)	3.44 (2.10)	3.00 (1.99)	3.00 (2.00)	2.77 (1.94)	74.01
T ₆ :	Acetamiprid 20% SP @ 0.5 g L ⁻¹	4.33 (2.30)	4.00 (2.23)	3.00 (1.99)	3.00 (1.99)	2.66 (1.90)	2.22 (1.79)	2.00 (1.72)	1.55 (1.58)	0.89 (1.37)	91.65
T ₇ :	Thiamethoxam 25% WG @ 0.2 g L ⁻¹	4.44 (2.32)	4.22 (2.27)	3.55 (2.12)	3.11 (2.02)	2.88 (1.95)	2.55 (1.88)	2.22 (1.78)	2.00 (1.72)	1.55 (1.60)	85.45
T ₈ :	Fipronil 5% SC @ 1 ml L ⁻¹	4.66 (2.38)	4.33 (2.31)	3.78 (2.18)	3.33 (2.07)	3.00 (1.99)	2.77 (1.92)	2.33 (1.81)	2.11 (1.76)	1.77 (1.66)	83.39
T ₉ :	<i>Lecanicillium lecanii</i> (1x10 ⁸ CFU's ml ⁻¹) 2 ml L ⁻¹	4.66 (2.37)	4.33 (2.30)	4.00 (2.23)	3.55 (2.12)	3.33 (2.06)	3.00 (1.98)	2.88 (1.97)	2.55 (1.88)	2.33 (1.82)	78.14
T ₁₀ :	Control	6.77 (2.78)	6.55 (2.75)	7.33 (2.89)	9.66 (3.27)	9.33 (3.21)	9.44 (3.23)	11.00 (3.46)	12.00 (3.60)	10.66 (3.42)	
C.D (P ≤ 0.05)		NS	0.34	0.39	0.33	0.37	0.34	0.36	0.31	0.27	
S.E(m) ±		0.14	0.11	0.13	0.11	0.12	0.12	0.12	0.10	0.09	
C.V.		9.90	8.11	9.61	8.17	9.44	9.06	9.62	8.45	7.64	

DBS- Day before spray, DAS- Days after spray, Figures in parentheses are square root transformations and NS-Non-significant

second spray, at 1 DAS, T₆ and T₇ with 2.22 and 2.55 whiteflies flower⁻¹ recorded the lowest population and were statistically at par with each other. At 3 DAS, T₆, T₇ and T₈ with 2.00, 2.22 and 2.33 whiteflies flower⁻¹, respectively, maintained their superiority over other treatments exhibiting non-significant variation. At 7 and 15 DAS, T₆ (1.55 and 0.89 whiteflies flower⁻¹, respectively) emerged out as the best treatment against whiteflies followed by T₇ (2.00 and 1.55 whiteflies flower⁻¹, respectively) and T₈ (2.11 and 1.77 whiteflies flower⁻¹, respectively). However, T₃ showed the poor efficacy on all the days. The per cent protection values (Fig. 3) revealed that the highest protection was provided by T₆ (acetamiprid 20% SP @0.5g L⁻¹), i.e., 92.61 and 91.65 per cent, followed by T₇ (thiamethoxam 25% WG @0.2g L⁻¹), i.e., 88.56 and 85.45 per cent on leaves and flowers, respectively. The present investigation revealed that T₆ (acetamiprid 20% SP @0.5g L⁻¹) was the most effective treatment in reducing whitefly population, which was followed by T₇ (thiamethoxam 25% WG @0.2g L⁻¹) and T₈ (fipronil 5% SC @1ml L⁻¹). Subba *et al.* (2017) also observed that acetamiprid was most lethal against whitefly in tomato and brinjal, whereas Shalini *et al.* (2019) observed thiamethoxam and fipronil having high efficacy against whitefly in gerbera.

The number of grubs/pupae on leaves recorded one day prior to spray ranged between 1.96 to 3.48 grub/pupae

leaf⁻¹ (Table 5). After 1st spray 1 DAS, T₆ (1.66 grubs/pupae leaf⁻¹) and T₈ (1.77 grub/pupae leaf⁻¹) recorded the least number of grubs/pupae exhibiting non-significant variation with each other. At 3 DAS, T₆ was at par with T₈ and recorded lowest number of grubs/pupae (1.66 grubs/pupae leaf⁻¹). T₆ (1.44 grubs/pupae leaf⁻¹) maintained its dominance over other treatments, while T₅ (2.22 grubs/pupae leaf⁻¹) showed the least efficacy at 7DAS as well. At 15 DAS, T₆ (1.22 grubs/pupae leaf⁻¹) recorded the lowest number of grubs/pupae followed by T₇ and T₈ (1.44 grubs/pupae leaf⁻¹). Following the second spray, at 1DAS, T₆ (0.44 grubs/pupae leaf⁻¹) and T₈ (0.55 grubs/pupae leaf⁻¹) recorded the lowest number of grubs/pupae. At 3 DAS, T₆ (0.33 grubs/pupae leaf⁻¹) recorded the lowest number of grubs/pupae followed by T₈ (0.66 grubs/pupae leaf⁻¹). At 7 DAS, T₆ recorded the lowest number of grubs/pupae (0.22 grubs/pupae leaf⁻¹) followed by T₈ (0.55 grubs/pupae leaf⁻¹). At 15 DAS, T₆ (0.11 grubs/pupae leaf⁻¹) maintained its dominance over other treatments which was followed by T₈ (0.44 grubs/pupae leaf⁻¹) and T₇ (0.55 grubs/pupae leaf⁻¹). T₅ showed least efficiency against leaf miner infestation on all days, possible reason for which could be spiromesifen being an acaricide. The per cent protection values (Fig. 4) revealed that the highest protection was provided by T₆ (acetamiprid 20% SP @0.5g L⁻¹), i.e., 98.05 per cent followed by T₈ (fipronil 5% SC @1ml L⁻¹), i.e., 92.22 per

Table 5. Evaluation of treatments against leaf miner infesting gerbera leaves

Treatments	Number of grubs/pupae leaf ⁻¹ (1 st spray)					Number of grubs/pupae leaf ⁻¹ (2 nd spray)				Per cent protection
	1DBS	1DAS	3DAS	7DAS	15DAS	1DAS	3DAS	7DAS	15DAS	
T ₁ : Azadirachtin 0.03% EC @ 5 ml L ⁻¹	2.33 (1.82)	2.44 (1.85)	2.33 (1.82)	2.11 (1.76)	2.22 (1.79)	2.00 (1.73)	2.00 (1.72)	1.89 (1.69)	1.66 (1.63)	70.67
T ₂ : Spinosad 45% SC @ 0.5 ml L ⁻¹	2.11 (1.76)	2.00 (1.73)	2.00 (1.72)	1.99 (1.73)	1.55 (1.59)	1.33 (1.52)	1.33 (1.52)	1.33 (1.52)	1.33 (1.52)	76.50
T ₃ : Chlorfenapyr 10% SC @ 1 ml L ⁻¹	2.60 (1.90)	2.78 (1.94)	2.66 (1.91)	2.11 (1.76)	2.33 (1.82)	2.22 (1.79)	2.11 (1.76)	2.00 (1.73)	2.00 (1.72)	64.66
T ₄ : Emamectin Benzoate 5% WG @ 0.5 g L ⁻¹	1.96 (1.72)	2.00 (1.72)	1.89 (1.69)	1.77 (1.66)	1.55 (1.59)	1.33 (1.52)	1.11 (1.45)	0.77 (1.32)	0.89 (1.37)	84.27
T ₅ : Spiromesifen 5% EC @ 1 ml L ⁻¹	3.15 (2.03)	3.55 (2.13)	2.78 (1.94)	2.22 (1.79)	2.33 (1.82)	2.33 (1.81)	2.22 (1.79)	2.33 (1.82)	2.55 (1.88)	54.94
T ₆ : Acetamiprid 20% SP @ 0.5 g L ⁻¹	2.11 (1.76)	1.66 (1.63)	1.66 (1.63)	1.44 (1.56)	1.22 (1.48)	0.44 (1.20)	0.33 (1.15)	0.22 (1.10)	0.11 (1.05)	98.05
T ₇ : Thiamethoxam 25% WG @ 0.2 g L ⁻¹	2.11 (1.75)	1.89 (1.69)	1.77 (1.66)	1.66 (1.63)	1.44 (1.56)	1.22 (1.48)	1.00 (1.41)	0.66 (1.29)	0.55 (1.24)	90.28
T ₈ : Fipronil 5% SC @ 1 ml L ⁻¹	1.96 (1.72)	1.77 (1.65)	1.66 (1.62)	1.55 (1.59)	1.44 (1.56)	0.55 (1.24)	0.66 (1.29)	0.55 (1.24)	0.44 (1.20)	92.22
T ₉ : <i>Lecanicillium lecanii</i> (1x10 ⁸ CFU's ml ⁻¹) @ 2 ml L ⁻¹	2.55 (1.87)	2.33 (1.81)	2.22 (1.79)	2.00 (1.73)	1.66 (1.63)	1.33 (1.52)	1.66 (1.62)	1.33 (1.52)	1.44 (1.56)	74.55
T ₁₀ : Control	3.48 (2.12)	3.55 (2.13)	4.11 (2.26)	4.66 (2.38)	5.00 (2.45)	5.22 (2.49)	5.44 (2.54)	5.44 (2.54)	5.66 (2.58)	
C.D (P ≤ 0.05)	NS	0.31	0.31	0.29	0.29	0.27	0.27	0.23	0.26	
S.E(m) ±	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.08	0.09	
C.V.	9.25	9.65	9.95	9.38	9.59	9.45	9.76	8.57	9.54	

DBS- Day before spray, DAS- Days after spray, Figures in parentheses are square root transformations and NS-Non-significant

cent on leaves. Abhilasha and Shekharappa (2017) also found that acetamiprid was highly efficient against leaf miner in peas. Results also concurred with Shinde *et al.* (2017) who mentioned the remarkable role of thiamethoxam in controlling citrus leaf miner. Ravipati *et al.* (2021) observed that fipronil was most effective against leaf miner of a tomato.

CONCLUSION

Highest incidence of whitefly and leaf miner under polyhouse conditions was observed from May to July. On the basis of correlation studies, pest populations were found to be positively correlated with temperature and negatively correlated with relative humidity. Regression model further indicated the considerable influence of weather parameters on the pest populations on leaves and flowers. Acetamiprid 20% SP @ 0.5g L⁻¹ was found most efficient treatment against whitefly and leaf miner.

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Biodiversity of syrphid fly (order Diptera, Family Syrphidae) in Hamelmalo Agriculture College, State of Eritrea

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ABSTRACT

The syrphid flies are large and diverse group of insects and the larvae of the most of the species are predator of aphids and used as biological control aphids. Adults of syrphid flies are important pollinators of flowering plants. The study was conducted to determine the population dynamics of syrphid flies in HAC agricultural farm Karen, Eritrea and their identification of the flies were done which are found during the study period. The larvae were collected from the Horticultural, plant protection and Agronomy fields at weekly interval starting October 2018 up to March 2019. The samples were placed in glass jar containing aphid colony till the pupation of larvae. After emergence of the adult were identified and kept in collection box. During the period of six months study, total about 387 of adults were recorded. The larval population of syrphid flies varied in different monthly, the highest abundance was recorded in October 2018 while lowest in the months of January and February of 2019. The Pearson's correlation results revealed that, there was strong, positive/negative and no significance correlation with varying temperature were recorded. Moreover, relative humidity was negatively correlated with syrphid fly population and found non significant.

Keywords: Syrphid fly, Pearson's correlation, identification, population dynamics, *Episyrphus viridaureus*

Flower flies (Diptera: Syrphidae) are a large and diverse group of insects. Many species are important pollinators of flowering plants. In addition, the immatures of numerous species are predators of destructive aphids and other pests (Gilbert, 1981). These flies are expert fliers and can hover or fly backward, ability possessed by few insects other than syrphid flies. The adults mainly feed on nectar and pollen. The females must consume pollen since they need the proteins and amino acids of the pollen for maturation of their eggs. Nectar has only a small amount of these substances but much sugar. It is the fuel for the flies, enabling them to fly and hover actively. Being regular visitors of flowers, hoverflies are important pollinators of various plants including vegetables and fruit trees (e.g. Asteraceae, Brassicaceae, Rosaceae) and select the flowers mainly by their colours. Compared with the adults, the larvae are important predators, feeding primarily on aphids that attack citrus, subtropical fruit trees, grains, corn, alfalfa, cotton, grapes, lettuce and other vegetables, ornamentals, and many wild host plants of the aphids. Three large ecological groups can be distinguished: predators, miners and decomposers (living on dead organic material - saprophagous larvae). All species of the subfamily of Syrphinae have zoophagous

larvae. Their main preys are aphids (greenflies). The larvae of Microdontinae are associated with hymenopterans. The Microdontinae larvae are supposed to be zoophagous living in ant nests. Eumerus and Merodon larvae are plant eating (phytophagous) but miners in nature. The larvae of the remaining Eristaline species are saprophagous organisms; they live in various habitats (running or stagnant water, mud, compost heaps, rotten wood etc.) feeding on dead organic substances. Hoverflies can be found in every biotope but not in deserts. Each species tends to prefer a certain type of habitat and is limited to a distinct range within the country. In general, within a genus the needs and behavior of the species are similar. As a result, one tends to associate certain genera with particular habitats. For example Chrysogaster, Eristalinus, and Mesembrius (all with aquatic or semi-aquatic larvae) are typical found in wetlands, many tiny Paragus species live in grassland whereas species of Baccha, Melanostoma and Xylota prefer woodlands. Within a given habitat the hoverflies have an irregular distribution. Some prefer the low vegetation (like Melanostoma and Paragus), others can be observed in the tree canopies (like Mallota and Spheginobaccha). There are also differences in the horizontal distribution of the adults at a site since important structural

components like certain flowers or egg laying sites cannot be found everywhere within a habitat (Stubbs and Falk, 2002). The hoverflies can be efficient predators in cereal crops such as wheat, rice and corn.

Flies that visit or hover on flowers are not all referable to flower flies or hover flies, but those that do it usually by hovering for some time with a shrill hum are regarded flower flies or hover flies or Syrphidae (Datta and Mukherjee, 2004). The family includes small to rather large (3-18 mm), bristle less, brightly coloured flies, may be striped, banded or spotted yellow on a blue, black or metallic ground colour. Head variable, usually as broad as or a little broader than the thorax, thorax rather large and robust, moderately arched, rarely with bristles, abdomen variable in shape, composed of five or six visible segments, rarely four, wings comparatively large, most of which have a false or spurious vein, extending longitudinally and slightly diagonally between the third (R4+5) and (M1+2) longitudinal veins. The systematic study of the family Syrphidae has gradually progressed from the 17th century and presently 6,107 species under 209 genera are reported from the world (Pape and Evenhuis, 2013 and Miranda *et al.*, 2013). In India, 357 species under 14 tribes of three subfamilies are reported (Ghorpade, 2014). This study thus may provide an insight into the pollination biology of this important group in future as well as modern taxonomic approach may serve as important tool for their easy identification.

MATERIAL AND METHODOLOGY

The study was conducted in Hamelmalo Agricultural Collage state of Eritrea. Hamelmalo Agricultural Collage is located 12 kms northeast keren on the road keren to Nakfa. The altitude of the study area is about 1286m above sea level and its position is 15° to 53° N latitude and 38° to 66° E longitudes Annual rainfall is 450mm, with temperature varies from 16 to 38°C.

Larvae samples were collected from this fields of

Agronomy, Plant Protection, Horticulture including field crops, vegetables and ornamental crops at one week interval starting from October 2018 to April 2019.

Methods employed

The plant samples were placed in sample container containing aphid colony and available Syrphid larvae, both aphid and syrphid larvae were counted on each three replication of individual host plant samples.

The sample containers were covered with muslin cloth and tied with plastic rubber to provide aeration to the emerging insects. On the second day of collection aphid colony was provided and continued until pupation. Pupa were separated till the adult emerge. Finally labeling was done such as date of collection with the name of the host sample. The data of weather variables i.e. Temperature, humidity, of studied localities were collected from the Department of Land resources and environment.

Statistical analysis

The data were analyzed statistically using Pearson's correlation coefficient to measure the strength of linear relationship of biotic (host plants) and a-biotic (temperature, humidity, rainfall and cloudiness) factors with the abundance of hoverflies through SPSS 22 version software.

RESULTS AND DISCUSSION

The larvae of syrphid fly were collected and counted from okra, duranta (ornamental), cowpea, sorghum, maize, mustard, cabbage, cauliflower and bean during October 2018 to March 2019. The population mean was recorded monthly with average minimum and maximum temperatures and average relative humidity. The data were placed on Table and Fig. 1. The population was recorded from available crops collected in the month of maximum in duranta in all months except there was no aphid infestation in the month of February and minimum population were recorded from maize crop in the month of March.

Table 1: Mean population of syrphid fly on different crops March 2019

Month	Mean population of syrphid				Methrology		
	Okra	Ornamental Durranta	Cowpea	Sorghum	Ave T° min temp. (0°C)	Ave T° max temp. (0°C)	RH (%)
October 2018	5.07	3.32	2.16	0.00	15.12	34.50	71.23
November 2018	1.33	3.75	0.00	1.33	14.56	33.23	70.93
December 2018	6.33	1.89	0.00	2.55	8.16	28.85	75.50
January 2019	1.75	0.41	1.67	0.00	8.97	28.36	75.63
Feb. 2019	0.75	1.00	1.50	0.58	10.73	29.87	64.86
March 2019	2.00	0.33	0.25	1.33	15.06	34.03	69.39

Pearson's correlation coefficient analysis revealed that negative but non significant correlation i.e okra ($r=0.078$) ($p=0.922$) and duranta ($r=-0.111$) ($p=0.889$) but positive and not significant correlation with cowpea i.e ($r=0.373$) ($p=0.627$) for the month of October. In November according to pearson's correlation it was positive and non significant correlation i.e sorghum ($r=0.607$) ($p=0.393$) of temperature and relative humidity with abundance of hover flies. While in December temperature with abundance population correlated positive and non significant i.e ($r=0.961$) ($p=0.069$) and negatively correlated in okra ($r=-0.052$) ($p=0.948$). In the month of January over all population of syrphid fly was negative and had non significantly correlation. While positive pearsons correlation for sorghum and mustard on February. For march result revealed negative and positive for duranta and non significant correlated for the available host range.

Table 2. Pearson correlation of average population of syrphid larvae on different host plants with Temperature and Relative humidity

	Ave Temp (C°)	Ave RH (%)
AP Okra	0.103	0.213
AP Duranta	0.524	0.251
AP Sorghum	0.283	-0.169
AP Bean	-0.548	0.530
AP Cabbage	0.273	-0.617
AP Cowpea	0.418	-0.252
AP Cauliflower	-0.240	-0.704
AP Maize	0.486	-0.166
AP Mustard	-0.240	-0.708

- Sign indicates negative correlation

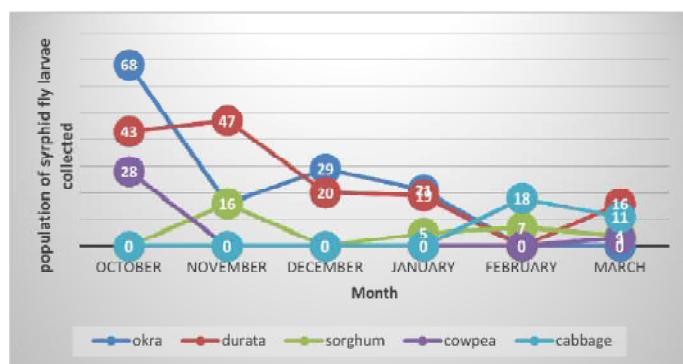


Figure 1. Syrphid fly population of different crops from October 2018 up to March 2019

According to our study the relation between pollinators (including hoverflies) and climatic factors usually vary with geographical distribution, Carvalho *et al.* (1991) have also reported a positive correlation between temperature and number of syrphids in tropics, while in sub tropical areas of world this relation could be negative as reported by (Sajjad *et al.*, 2010). Our result was also in accordance with the findings of (Sajjad *et al.*, 2010) and climatic factors (temperature, relative humidity) were negatively correlated with hoverfly abundance.

Correlation of syrphid fly larvae population on different hosts with temperature and relative humidity

CONCLUSION

The present studies were concluded that the population of syrphid flies at HAC farm in Eritrea was high during October on okra, duranta plants. The temperatures correlated positively with the population of syrphid flies. And the abundance of syrphid population dramatically affected by the season vegetation cover around the farm.

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On farm trials on management of pod borer complex in green gram

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ABSTRACT

Pulses productivity in Rajasthan is lesser than the national average due to the poor management of the crop. Green gram, an important pulse crop, is attacked by different pod borer species like gram pod borer, *Helicoverpa armigera*, spotted pod borer, *Maruca testulalis* and *M. vitrata*, spiny pod borer, *Etiella zinckenella*, etc. Pod borers directly feed on the pods and seeds causing appreciable deterioration in grain quality and quantity. Pod borer complex is a major constraint to increase production of green gram therefore the on farm trial (OFT) were undertaken by the Krishi Vigyan Kendra, Lunkaransar of Bikaner for two consecutive years 2019 and 2020. The results on the management of pod borer complex in green gram indicated that maximum per cent reduction in larval population of pod borers was observed in 79.25 and 82.69 per cent in *kharif* 2019 and 2020, respectively, in recommended spray (emamectin benzoate 5 SG 0.5 gm per litre water). The maximum benefit cost ratio of 2.77 and 4.00 were obtained in the recommended practices, while it was minimum 1.66 and 2.63 in farmers practice (quinalphos 25 EC @ 1.25 l ha⁻¹) during *kharif* 2019 and 2020.

Key words: Benefit cost ratio, green gram, larval population, OFT, pod borer complex

Green gram (*Vigna radiata* L. Wilczek) belongs to the family leguminosae. It is an important short duration and drought tolerant pulse crop in India. It ranks third after bengal gram and red gram in area, production and productivity in the country. India is the largest producer and consumer of pulses in the world, accounting for 25 per cent of global production and 15 per cent of consumption (Saraswati *et al.*, 2004). The major green gram growing states in the country are Bihar, Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh and Gujarat. Green gram seed contains 24.7 per cent protein, 0.5 per cent fat, 0.9 per cent fibre, 57.6 per cent carbohydrates and 3.7 per cent ash with adequate amounts of phosphorous, calcium and key vitamins (Chudhary *et al.*, 2010). Green gram crop plays a vital role in sustainable agriculture production because it is cultivated as mixed crop, inter crop and rotational crop to improve nitrogen status of soil or to break the disease or pest cycles (Jaiwal *et al.*, 2001). The lower productivity of green gram may be attributed to several factors like limited varietal improvement, low resilience to soil moisture stress, pest infestation, etc., among them, ravage of insect pests is the most important (Sandhya *et al.*, 2014). Pod borer complex, gram pod borer, *Helicoverpa armigera*, spotted pod borer, *Maruca testulalis* and *M. vitrata*, spiny pod borer, *Etiella zinckenella*, etc., cause major yield losses in green gram. It becomes a menace especially during

the flowering and pod formation stage of the crop. The larvae of the borers cause direct damage to the flowers and pods. The grain yield losses due to pod borer are estimated from 10 to 80 per cent in various crops (Sambathkumar *et al.*, 2014). The present farm trial was carried out to assess the recommended management practice of borer complex in green gram *vis-a-vis* farmers practice.

MATERIALS AND METHODS

An on farm trial was conducted by Krishi Vigyan Kendra, Lunkaransar, Bikaner on ten farmers fields in different villages during *kharif* 2019 and 2020. The experiment material consisted of two treatments *viz.*, T₁: spray of quinalphos 25 EC @ 1.25 L ha⁻¹ (farmers practice) and T₂: spray of emamectin benzoate 5 SG 0.5 gm L⁻¹ recommended practice against pod borer complex in green gram.

The percentage reduction in larval population was calculated by using the formula given by Henderson and Tilton (1955), which is the modification of Abbott's (1925) formula.

$$\text{Per cent reduction in population} = 100 \left[1 - \frac{T_a \times C_b}{T_b \times C_a} \right]$$

Where, Ta = number of insects after treatment, Tb = number of insects before treatment, Ca = number of insects in untreated check after treatment and Cb = number of insects in untreated check before treatment.

The per cent pod damage of each treatment was computed by following formula

$$\text{Pod damage (\%)} = \frac{\text{No. of infested pods}}{\text{Total number of pods}} \times 100$$

The avoidable loss and increase in grain yield over control was calculated for each treatment by the following formulas

Avoidable loss (%) =

$$\frac{\text{Highest yield in treated plot} - \text{Yield in the treatment}}{\text{Highest yield in treated plot}} \times 100$$

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

RESULTS AND DISCUSSION

The data presented in Table 1 revealed highest per cent reduction in larval population of 79.25 and 82.69 per cent during *kharif* 2019 and 2020, respectively under recommended practice (T₂) as against minimum per cent reduction of 61.50 and 63.48 per cent during *kharif* 2019 and 2020, respectively in farmers practice (T₁). During both the years minimum pod damage (6.04 and 7.90%) and damaged grain per cent (5.27 and 6.45%) was recorded in recommended practices in *kharif* 2019 and 2020, respectively, while it was more in farmers practices (21.34 and 23.54% pod damage and 15.24 and 18.32% damaged grain, in *kharif* 2019 and 2020, respectively). The results are similar to the findings of Singh and Singh (2017) who reported emamectin benzoate as a most effective treatment in reducing *M. vitrata* larval population in green gram, while Umbarkar and Parsana (2014) recorded higher per cent pod damage in the treatment of quinalphos against pod borer in green gram, which also supports present findings.

Economic performance of different treatments are presented in Table 2. Higher seed yield was obtained under the recommended practices during both the years, *i.e.*, 9.22

Table 1. Management of pod borer complex in green gram with recommended practice

Year	Treatments	Per cent reduction in larval population	Pods damaged (%)	Damaged grain (%)
2019	Farmers practice	61.50	21.34	15.24
	T ₁ : spray of quinalphos 25 EC @ 1.25 L ha ⁻¹			
	Recommended practice	79.25	6.04	5.27
2020	T ₂ : spray of emamectin benzoate 5 SG 0.5 gm L ⁻¹			
	Farmers practice	63.48	23.54	18.32
	T ₁ : spray of quinalphos 25 EC @ 1.25 L ha ⁻¹			
	Recommended practice	82.69	7.90	6.45
	T ₂ : spray of emamectin benzoate 5 SG in 0.5 gm L ⁻¹			

Table 2. Economic performance of green gram crop with recommended practice

Year	Treatments	Yield (q ha ⁻¹)	Per cent increase in yield over farmers practice	Total avoidable losses (q ha ⁻¹)	Total avoidable losses (%)	Net return (Rs. ha ⁻¹)	B:C ratio
2019	Farmers practice	6.50	-	2.72	29.50	28625	1.66
	T ₁ : spray of quinalphos 25 EC @ 1.25 L ha ⁻¹						
	Recommended practice	9.22	41.84	-	-	47801	2.77
2020	T ₂ : spray of emamectin benzoate 5 SG 0.5 gm L ⁻¹						
	Farmers practice	8.70	-	3.26	27.25	45405	2.63
	T ₁ : spray of quinalphos 25 EC @ 1.25 L ha ⁻¹						
	Recommended practice	11.96	37.47	-	-	68865	4.00
	T ₂ : spray of emamectin benzoate 5 SG 0.5 gm L ⁻¹						

and 11.96 q ha⁻¹ while it was minimum in the farmers practices, i.e., 6.50 and 8.70 q ha⁻¹ in *khari*f 2019 and 2020, respectively. The loss in yield was due to improper management of pod borer complex in green gram. The per cent avoidable losses in seed yield of green gram due to the attack of borers in farmers practice management was maximum (29.50 and 27.25% during *khari*f 2019 and 2020, respectively), while avoidable losses were zero in recommended practices (T2). The highest net return (Rs. 47801 and 68865 ha⁻¹) and benefit cost ratio (2.77 and 4.00) were obtained in the recommended practices during *khari*f 2019 and 2020, respectively. This may be due to the higher yield obtained under recommended practices. Lowest net return (Rs. 28625 and 45405 ha⁻¹) and benefit cost ratio (1.66 and 2.63) was obtained in the farmers practices during *khari*f 2019 and 2020 due to improper management of pod borers in green gram. Similar results were obtained by Hossain (2015) and Singh and Singh (2017).

CONCLUSION

On farm trial results conclude that application of emamectin benzoate 5 SG (@ 0.5 g l⁻¹) as spray, that brought about maximum of 79.25 and 82.69 per cent reduction in pod borers larval papulation and 2.77 and 4.00 cost-benefit ratio, could successfully be employed in the management of pod borer complex in green gram.

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Impact of carbon sources on *Isaria fumosorosea* (Wize) Brown and Smith and *Beauveria bassiana* (Balsamo) Vuillemin – entomopathogenic fungi

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ABSTRACT

The present investigation was carried out at Bio-Control Laboratory, Department of Plant Pathology, College of Agriculture, IGKV, Raipur during 2020-21. The *in vitro* study of the mycelial growth and biomass production of *I. fumosorosea* and *B. bassiana* and the effect of different eight carbon sources on the entomopathogenic fungi were observed. The mycelial growth and mycelial biomass of *I. fumosorosea* on media containing different carbon sources were maximum (8.43 cm) on cellulose and glucose (13.41 g), respectively. The mycelial growth and mycelial biomass of *B. bassiana* on media containing different carbon sources were maximum (9.00 cm) on starch and sucrose (14.50 g), respectively. From the study, it was concluded that *I. fumosorosea* and *B. bassiana* showed higher growth potentials on almost all the nutrients.

Key words: *Isaria fumosorosea*, *Beauveria bassiana*, mycelial growth, biomass, carbon sources.

Isaria fumosorosea (Wize) Brown and Smith and *Beauveria bassiana* (Balsamo) Vuillemin are entomopathogenic fungi (EPF) that occur naturally in the environment and have the potential as biological control agents against many insect pests. Entomopathogenic fungi can be used as a component of integrated pest management (IPM). Under natural conditions, these pathogens are frequent and often cause natural mortalities of insect populations. Nutrients are compounds that are employed in biosynthesis and energy release, and so serve as a critical impetus for an organism's viability, survival, and sustainability. It is critical to have a thorough understanding of the nutritional requirement of microorganisms in order to cultivate them at the maximum level. Carbon, oxygen, hydrogen, nitrogen, sulphur and phosphorus are essential components of carbohydrates, lipids, proteins, and nucleic acids, and these metabolically active groups are engaged in host-pathogen contact, self-defense, and perpetuation mechanisms directly or indirectly. All organic molecules require carbon as a skeleton element, and molecules that serve as carbon suppliers typically also supply oxygen and hydrogen. It was interesting to look at how different nutrition sources affected the growth and sporulation of a variety of biocontrol agents (Shah *et al.*, 2005 and Senthamizhlselvan *et al.*, 2010). Many insect pests can be managed using entomopathogenic fungus (EPF) as

biological control agents as part of integrated pest management (IPM). The present *in-vitro* study was undertaken to observe the effect of carbon sources on growth and biomass production of entomopathogenic fungi.

MATERIAL AND METHODS

Both entomopathogenic fungus, *Isaria fumosorosea* and *Beauveria bassiana*, culture were collected from Bio-control Laboratory, Department of Plant Pathology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur. Both entomopathogenic fungus culture were maintained on potato dextrose agar (PDA) in petri plates for further investigation. For the radial growth and biomass production *I. fumosorosea* and *B. bassiana* were grown on PDA media containing different carbon sources *viz.*, cellulose, fructose, glucose, lactose, maltose, mannitol, starch and sucrose.

For radial growth of *I. fumosorosea* and *B. bassiana*, all the agar carbon sources media were poured aseptically into petri plates with a diameter of 90 mm that had been sterilised (at 180°C for two hours in an electric oven). After solidification, a 2 mm diameter mycelia disc was cut aseptically with the cork borer from the growing tip of a 7-day old pure culture of *I. fumosorosea* and *B. bassiana* kept on PDA medium, and injected onto the petri plates. The petri plates were incubated at a temperature of 25 ± 1°C.

For biomass production of *I. fumosorosea* and *B. bassiana*, 100 ml liquid medium was added to each 250 ml conical flask. After being plugged with non-absorbent cotton, these flasks were sterilised in an autoclave at 15 lb pressure at 121°C for 30 minutes. After cooling the flasks containing broth were inoculated aseptically by introducing a 5 mm diameter culture disc from 7 days old pure culture. The flasks were incubated at a temperature of $25 \pm 1^\circ\text{C}$. After 30 days of inoculation, mycelial mats were harvested on previously weighed oven dried Whatman's filter paper. The filter paper containing mycelial matting was dried at 60°C oven in an until it attained a constant weight.

RESULTS AND DISCUSSION

Effect of different carbon sources on radial growth and biomass production of *I. fumosorosea*

Different carbon sources cellulose, glucose, fructose, lactose, maltose, mannitol, starch and sucrose were assayed to see their effectivity on mycelial growth of *I. fumosorosea* *in vitro* and the data is presented Table 1. Different sources of carbon significantly affected the growth of *I. fumosorosea*. The growth of *I. fumosorosea* was significantly superior in the medium substituted with cellulose (8.43 cm). However, least growth was observed in mannitol (6.80 cm), which was inferior to other carbon sources and control. The growth in cellulose (8.43 cm) and sucrose (8.30 cm) were at par. The growth was flat dull greyish with concentric rings and margin was even in cellulose medium, while in mannitol growth was dull greyish in centre and pale yellow at periphery and margin was uneven.

The fresh mycelial weight of *I. fumosorosea* was significantly more in medium containing glucose (13.41 g), sucrose (12.83 g) and maltose (12.23 g) and they were statistically at par (Table 1). However, significantly less (4.33 g) fresh mycelial weight was produced by cellulose which was significantly inferior to other evaluated carbon sources and control. The fresh mycelial weight was 11.43, 11.26 and 11.10 g in starch, control and lactose, respectively. Similarly, dry mycelial weight of *I. fumosorosea* was significantly higher in glucose (0.66 g) followed by maltose (0.62 g), sucrose (0.62 g) and control (0.60 g), but all were statistically at par. While significantly lowest weight was noticed in cellulose (0.13 g) as compared to other evaluated carbon sources and control. In other carbon sources dry weight did not differ and varied from 0.52-0.59 g. It was observed that the mycelial growth of *I. fumosorosea* was maximum (8.43 cm) on cellulose and minimum (6.14 cm) on mannitol containing media. The fresh and dry weight of the mycelial biomass was noted on media containing glucose

Table 1. Radial growth and fresh and dry weight of *I. fumosorosea* on different carbon sources

Carbon source	Radial growth (cm)*	Fresh weight (g)*	Dry weight (g)*
Cellulose	8.43	4.33	0.13
Glucose	7.36	13.41	0.66
Fructose	7.30	9.60	0.58
Lactose	8.10	11.10	0.59
Maltose	7.86	12.23	0.62
Mannitol	6.80	9.40	0.52
Starch	7.43	11.43	0.56
Sucrose	8.30	12.83	0.62
Control	7.73	11.26	0.60
SE(m) $\pm$	0.123	0.474	0.025
C.D. (5%)	0.367	1.41	0.07

*Average of three replications

(13.41 and 0.66g), and minimum on cellulose (4.33 and 0.13g), respectively.

Liu *et al.* (2018) studied the growth of *Isaria furinosa* on different carbon sources. Among 16 carbon sources studied, organic acid had no effect on mycelia growth. D (+) galactose produced the largest mycelial yield, followed by D (-) fructose. In both, citric acid containing medium and control medium, the growth was very slow.

Effect of different carbon sources on radial growth and biomass production of *B. bassiana*

The data presented in Table 2 exhibited that the growth of *B. bassiana* was significantly influenced by different carbon sources. The growth was significantly highest in starch (9.00 cm) containing media and control (8.66 cm) and both were at par. Mannitol gave significantly lowest (5.13 cm) growth. The growth was 8.33 and 8.23 cm in fructose and glucose, respectively and were at par and superior to other evaluated carbon sources. The other carbon sources had 7.23, 6.20, 6.10 and 5.63 cm mycelial growth in maltose, cellulose, lactose and sucrose, respectively.

The growth was creamy in centre with two concentric rings noted in starch. Raised growth was on rings, while flat at centre. Sparse and even growth at margin. In mannitol, growth was absolute white with wavy margin and concentric rings.

The fresh and dry mycelial weight of *B. bassiana* significantly obtained with respect to different carbon sources. Significantly more fresh mycelial weight was in sucrose (14.50 g), starch (11.16 g) and mannitol (10.20 g) and they were significantly different from each other statistically.

Table 2. Radial growth and fresh and dry mycelial weight of *B. bassiana* on carbon sources

Carbon Source	Radial growth (cm)*	Fresh weight (g)*	Dry weight (g)*
Cellulose	6.20	0.00	0.00
Glucose	8.23	7.93	0.44
Fructose	8.33	7.56	0.42
Lactose	6.10	8.23	0.47
Maltose	7.23	9.90	0.53
Mannitol	5.13	10.20	0.59
Starch	9.00	11.16	0.57
Sucrose	5.63	14.50	0.68
Control	8.86	9.23	0.49
SE(m)	0.148	0.564	0.020
C.D.	0.443	1.689	0.059

*Average of three replications

However, no growth (0.00 g) was noted in cellulose. In other carbon sources, fresh weight varied from 7.56-9.90 g. Similarly, dry mycelial weight of *B. bassiana* was significantly higher in sucrose medium (0.68 g) followed by mannitol (0.53g), starch (0.57g) and maltose (0.53g) which were significantly different from each other. In other carbon sources it varied from 0.05-0.42g. It was observed that the mycelial growth and biomass (fresh and dry) of *B. bassiana* on media containing different carbon sources was maximum (9.00 cm) on starch and minimum (5.13 cm) on mannitol, and maximum on sucrose (15.50 and 0.68g) and minimum on fructose (7.56 and 0.42g), respectively. Mycelial biomass was not visible in cellulose broth.

Monga (2012) reported that Czapeck Dox Broth media was useful *in vitro* of mycelial development and sporulation *T. viride* and *B. bassiana*, as well as the effect of different carbon and nitrogen sources on biofungicide and entomopathogenic fungi. *T. viride* showed high growth of biomass production in dextrose and *B. bassiana* showed high growth of biomass production in fructose medium as carbon

source. Mustafa and Kaur (2009) observed the effect of carbon and nitrogen sources on biomass of *B. bassiana* by using the basic YPD medium. The results showed that starch was the best carbon source, which recorded maximum dry biomass of the fungus followed by sucrose and fructose.

CONCLUSION

It could be concluded from the present study that cellulose was the best carbon source for the radial growth of *I. fumosorosea*, while starch was best for *B. bassiana*. Maximum fresh and dry weight of mycelia were recorded with glucose and sucrose as carbon sources in media in *I. fumosorosea* and *B. bassiana*, respectively.

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Performance of *Apis cerana* colonies with queens reared by different methods for revival of traditional beekeeping in Kashmir valley

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ABSTRACT

Kashmir valley has enormous potential of beekeeping. The colony performance of *Apis cerana indica* is determined by its foraging efficiency. The economy of the colony depends on the performance of the colony. The focus of the study was to determine the queen bee rearing techniques, accurate measurement in selection and offer the best technique in queen bee rearing for beekeepers. The experiment, a first step in the valley, was carried out in farmers apiary at Harwan Srinagar-Kashmir during 2018-19 with three bee raising methods viz., Miller (T_1), Division (T_2) and Supersedure (T_3). The efficiency and potential of supersedure queen was determined in comparison to other naturally raised queen in *Apis cerana* colonies. The results showed that supersedure queens performed well as naturally produced queen. The highest rate of mating percentage (83.33%) was recorded in supersedure method (T_3). The maximum brood area (1024 cm²) during 2nd fortnight of April, pollen area (198.00 cm²) in 1st week of March and honey store area (2422 cm²) during 1st fortnight of May, were recorded in split method of queen rearing (T_2). The minimum brood area (844.00 cm²) was recorded in supersedure method of queen rearing (T_3). Significant differences were observed among all the treatments.

Key words: Performance, *Apis cerana*, queen revival, rearing methods, traditional

Honey bees colony reveals a strong reproductive division of labour with three types of individual groups as queen, worker and drone. Caste determination is a consequence of environmental conditions during development, when female larvae may become either queens or workers depending on their larval diet Wheeler (1986). Queen rearing is a highly specialized process and is an essential component of progressive beekeeping. Different practices of queen rearing are followed by beekeepers which are based on bee biology that the nurse bees in a queen less hive can produce some queens from young female larvae. Queen bee is an essential working part of the honey bee colony and she must ensure that the hive stays populated by controlling the gender of the eggs laid in order to keep balance in the hive. To optimize production of honey, egg and bees' behaviour, replacement of queen is essential. Queens are raised by worker bees in specially constructed queen cells Soller and Bar-Cohen (1967). A well fed mated queen can lay about 2000 eggs day⁻¹ during the spring build up Teweldemedhn and Tadsee (2016). Queen lays fertilized (female) or unfertilized (male) egg according to the width of cell Fani *et al.* (2014). The young queen larva develops differently because it is heavily fed with royal jelly, a protein

rich secretion from gland on the nurse bees. If not heavily fed the larva becomes regular worker bee Dodolugu *et al.* (2004). Emergency queens are generally raised in cells build out from the face of frames. When larva pupates with her head down, the workers cap the queen cell with bee wax from which virgin queen emerged subsequently. In natural conditions, during swarming season, the old queen leaves the nest with the prime swarm before the emergence of first virgin queen Abrol *et al.* (2005). Many techniques of rearing queen bees have been developed to allow beekeepers to reproduce good stock to replace old or undesirable queens in their colonies, or to start new colonies. Successful queen rearing demands suitable conditions. The quality of the queen bee determines the benefits received from bee colony as through the queen, via its progeny, the productivity, temperament and behavior of the colony can be manipulated by the beekeeper. Various environmental factors affect the quality of the queen and rate of queen development (Abbasi *et al.*, 2015).

MATERIAL AND METHODS

This Experiment was conducted in Farmers apiary located at Harwan during 2018-19. The experiment comprised

of nine bee colonies of *Apis cerana* having nearly equal bee strength with three treatments. Each treatment had three replications in Randomized Block Design. The treatments were: T1 (Miller method), T2 (Division method) and T3 (supersedure method). The comparative study of queen reared by different methods was evaluated on the basis of brood area, pollen area and honey store.

Colony development cycle adopted by Croatian country was calculated from the data on the area of brood, pollen and honey on frames with the help of measuring grid adopted by Rokonuzzaman (2015) method during different seasons of the year and according by colonies were ranked.

The assessment of colony performance index were studied in all seasons at fortnightly intervals. The data was collected from June to November to check the best performer colony and was ranked accordingly. The data was recorded by observing the number of pollen foragers entering the hive without disturbing the colonies. The formula/tool proposed by Punchihewa (1994) from Srilanka was used.

$$\text{CPI} = \frac{(\text{Number of pollen foragers entering the hive})^2}{\text{Total no. of bees entering the hive} \times \text{observation period in seconds}} \times 100$$

RESULT AND DISCUSSION

The target to increase the stock of colonies (*Apis cerana*) and replace old queens, three methods of queen rearing were employed in spring. The data showed that two frames were given to each colony under Miller, Division and Supersedure method of queen rearing. In Miller method (Fig. 1) of queen rearing 10 cells were raised by the colony with 80.00 per cent queen emergence and 83.33 per cent queen mating was recorded while in division method of queen rearing 77.77 per cent queen emergence was recorded and 66.66 per cent rate of mating was recorded. In case of supersedure method 71.42 per cent queen emergence with 75.00 per cent mating



Fig. 1. Queen rearing by Miller method

were recorded (Table 1). The data also depicted that highest (572.33 number of eggs laid/day/queen) was recorded in supersedure method of queen rearing followed by 545.33 number of eggs laid/day/queen in Miller method and least 396 eggs laid/day/queen in division method of queen rearing. The results were in conformity with findings of earlier workers (Dodoluglu *et al.*, 2004, Abrol and Sharma, 2005) who reported that queen bees produced by supersedure method were superior in performance as compared to other queen rearing methods.

Maximum brood area, pollen area and honey were 1024.00, 168, 1036.00 cm² were recorded in Division method during spring months on 2nd fortnight of March, while 780,00 cm² brood was recorded in Supersedure method (Table 2). The data also depicted maximum honey area (1668 cm²) during 2nd fortnight of April with highest pollen area (198 cm²) in Division method. Further, the data revealed that maximum brood area, pollen area and honey were 866, 112, 2642cm², respectively in Division method during 2nd fortnight of May of queen reared colonies, while 780,00 cm² brood were recorded. The data also showed that maximum honey area (1462 cm²) was recorded during 2nd fortnight of May in Supersedure queen reared method, while pollen area was 110 cm² recorded in Miller method of queen rearing. Significant ($p > 0.05$) differences were observed among all the treatments. The highest (12.66) colony performance index (CPI) was recorded during first fortnight of May in division method of queen reared colonies (Table 2).

CONCLUSION

The studies concluded that the honey queens artificially reared from young larvae showed higher reproductive potential, compared to queens reared from older larvae and subsequently affected on the growth of the colony they headed.

Table 1. Comparison of different methods of queen rearing methods in *Apis cerana* in Kashmir

Parameters	Methods of queen rearing/treatments		
	Miller method (T1)	Division method (T2)	Supersedure method (T3)
No. of frames given	2	2	2
No. of cells raised	10	9	7
Emergence of new queen (%)	8 (80.00)	7 (77.77)	5 (71.42)
No. of emerging bees given to nuclei	6	6	4
Number of mating queen bees	5	4	3
Rate of mating (%)	83.33	66.66	75.00

Table 2. Performance of the selected colonies of *Apis cerana* with different methods of queen rearing

Queen rearing method	Quantitative parameters of the honey bee colonies			
	Brood area (cm ²)	Pollen area (cm ²)	Honey area (cm ²)	CPI
March-2019 (1 st fortnight)				
Division method	1012	190	866	12.29
Miller method	766	122	986	6.56
Supersedure method	508	134	788.00	6.00
March-2019 (2 nd fortnight)				
Division method	1024.00	168	1036.00	8.21
Miller method	500.00	118	988.00	6.00
Supersedure method	780.00	120	968.00	7.12
April-2019 (1 st fortnight)				
Division method	846.00	192	1291.00	12.35
Miller method	584.00	190	1122	8.71
Supersedure method	642.00	162	1066	8.77
April-2019 (2 nd fortnight)				
Division method	888.00	198	1668	12.54
Miller method	788.00	158.6	1242	8.77
Supersedure method	844.00	144	1222	7.64
May-2019 (1 st fortnight)				
Division method	892	166	2422	12.66
Miller method	792	142	1624	7.44
Supersedure method	866	134	1424	6.34
May-2019 (2 nd fortnight)				
Division method	866	112	2642	8.44
Miller method	784	110	1422	5.44
Supersedure method	744	108	1462	5.12
CD (P=0.05)	2.43	2.61	2.38	

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Evaluation of different concentrations of bio-pesticide (NANMA) against sucking pests of potato under field condition

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ABSTRACT

A field trial was conducted at ICAR-Central Potato Research Station, Gwalior for two consecutive years (2018-19 and 2019-20) to study the effect of different concentrations of ICAR-CTCRI developed bio-pesticide Nanma @ 5, 7.5 and 10 ml L⁻¹ along with neem oil @ 2 ml L⁻¹, mineral oil @ 5 ml L⁻¹, *karanj* oil @ 2 ml L⁻¹ and untreated control against whitefly, (*Bemisia tabaci*) and thrips (*Thrips palmi*) on potato cv. Kufri Jyoti. Pre and post treatment observations of white fly and thrips were recorded from all the plots at 1 day before and 1, 3 and 7 days after spray during both the years. The pooled data of population revealed that 7 days after spray Nanma @ 10 ml L⁻¹ was the best treatment for controlling white fly and thrips as it recorded 72.95 and 74.29 per cent reduction in population over control, followed by Nanma @ 5 ml L⁻¹. Lowest per cent leaf curl disease (0.22) was recorded in Nanma @ 10 ml L⁻¹ treated plots followed by Nanma @ 7.5 ml L⁻¹. Considering incremental cost benefit ratio Nanma @ 10 ml L⁻¹ was found economical over other treatments for management of sucking pests in potato crop.

Key words: Nanma, neem oil, *karanj* oil, mineral oil, whitefly, (*Bemisia tabaci*), thrips (*Thrips palmi*)

In India, potato is cultivated in almost all states under very diverse agro-climatic conditions. More than 85 per cent of potatoes in India is grown in the Indo-Gangetic plains of north India from October to March during winter under short-day conditions. Among the states, Uttar Pradesh, West Bengal and Bihar account for nearly 71 per cent area and 76 per cent production of the country. In Madhya Pradesh potato is the most important food crop and state ranks fifth in area (310.97 thousand ha) and production (7281.67 MT). Most potatoes are produced by large-scale commercial farmers.

Whitefly (*Bemisia tabaci* (Gennadius)) was first described in 1889 by Gennadius in Greece as a pest of tobacco (*Nicotiana tabacum*). It is a polyphagous pest distributed worldwide in tropical, subtropical and temperate zones. Over 900 plants have been identified as its host, and 111 plant viruses species of the genera Begomovirus (*Geminiviridae*), Crinivirus (*Closteroviridae*), Carlavirus or Ipomovirus (*Potyviridae*) have been transmitted by the pest. *B. tabaci*, *B. giffardi*, *B. grossa*, *B. hancocki*, *B. leakii*, *B. moringae* and *B. religiosa* are the seven species of *Bemisia* prevalent in India, but only *B. tabaci* is associated with potato. Among the 37 species of whiteflies identified, *B. tabaci* (Gennadius) is

the most important and ubiquitous pest inflicting directly and indirectly to the plants. In India *B. tabaci* was first reported in 1905 and in 1919 as a serious pest of cotton in Punjab. Recently it emerged as a very serious pest in potato seed production, particularly in the autumn crop in the Indo-Gangetic plains and newly emerging vector in central India transmitting apical leaf curl disease in potato crop.

Climatic factors have a pivotal role in their population build up. Higher temperature and lower humidity are the congenial conditions for their fast multiplication. High reproductive potential, broad host range and resistance to insecticides are some of the constraints affecting their management. The most feasible method for management of whitefly is proper field sanitation and cultivation of resistant varieties. Removal of crop residues and rouging of infested plants also check the risk of carryover population.

Karanj oil has shown greater biological activity than other *karanj* extracts. The *karanj* has shown good synergistic effect with a number of chemical insecticides. Therefore, *karanj* has great potential to be used as biopesticide because of its antifeedant, oviposition deterrent, ovicidal, roachicidal, juvenile hormone activity and insecticidal properties against a wide range of insect pests.

As there is little knowledge about the effect of Nanma, mineral oil, neem and karanj oil on potato sucking pest under north-central Indian conditions, the present study was undertaken.

MATERIAL AND METHODS

A field experiment was conducted at ICAR-Central Potato Research Station (RS), Gwalior. The experimental site was geographically located at 26.27°N latitude, 78.21° longitude and 207 M above MSL. during 2018-19 and 2019-20 to evaluate the bio-efficacy of different concentrations of Nanma along with neem oil, karanj oil, mineral oil and untreated control against whitefly, (*Bemisia tabaci*) and thrips (*Thrips palmi*) on potato. The experiments were carried out in last week of October in Randomized Block Design with seven treatments viz., T1- Nanma @ 5 ml L⁻¹, T2- Nanma @ 7.5 ml L⁻¹, T3- Nanma @ 10 ml L⁻¹, T4- Neem oil @ 2 ml L⁻¹, T5- Karanj oil @ 2 ml L⁻¹, T6- Mineral oil @ 5 ml L⁻¹, T7- control, treatments were replicated thrice using potato variety Kufri Jyoti. Crop raised by following the standard agronomic practices recommended for central India. Experiment was planted with well sprouted tubers of 40-60 g in plot size 3 x 3m. Row to row distance was 60 cm and plant to plant distance was 20 cm. Recommended dose of fertilizers (N: P: K) was applied @ 180:80:120 kg N, P₂O₅, K₂O ha⁻¹. Fifty per cent of N and full dose of P and K were applied at the time of planting. Rest fifty per cent of N was applied at the time of earthing up. 4 or 5 irrigations were given as per requirement of the crop at 12-15 days interval. Whitefly and thrips population were counted on three fully expanded compound leaves per plant on 5 fixed plants (each from top, middle and bottom). Pre and post treatment observations of whitefly and thrips were recorded from each plot at 1 day before and 1, 2, 3 and 7 days after spray during both the years. Incidence of severe and mild mosaic diseases and yield (q ha⁻¹) were also recorded. Harvesting was done in the last week of February. Pooled data of two year was analyzed.

The phyto-toxicity was also observed in each treatment. For benefit cost analysis, the cost of insecticide application was calculated as cost of insecticide + number of labour + machine cost, etc. Similarly, the price of harvested potato was calculated as per the prevailing market rate. Benefit cost ratio was calculated using the formula

Cost: benefit ratio = Net return (Rs ha⁻¹) / Cost of cultivation (Rs ha⁻¹)

RESULTS AND DISCUSSION

Efficacy of bio-pesticide (NANMA) against potato whitefly (*Bemisia tabaci*)

The effects of insecticidal treatments are presented in

(Table 1). Pre-count whitefly population did not vary significantly among the treatments. All the treatments were significantly superior over the control in respect of reducing whitefly population. Pooled data of both the years revealed that whitefly population per three leaves of 5 tagged plants in the pre treatment during the spraying varied between 16.00 to 12.67 (Table 1). In both the years after 7 days of spray with Nanma @ 10 ml L⁻¹, lowest mean whitefly population (2.33 whitefly 5 plants⁻¹) was recorded which was highest per cent population reduction (72.95). It was followed by Nanma @ 7.5 ml L⁻¹ (4.00 whitefly 5 plants⁻¹) and Mineral oil @ 5 ml L⁻¹ (4.50 whitefly 5 plants⁻¹), per cent population reduction were 53.80 and 55.2, respectively over untreated control. The overall efficacy after spray inferred that Nanma @ 10 ml L⁻¹ was significantly effective in reducing the pest population in comparison to Mineral oil @ 5 ml L⁻¹ and was at par with Nanma @ 7.5 ml L⁻¹. There were no phyto-toxicity symptoms observed in any treatment.

Fourteen insecticides were tested against whitefly, *Bemisia tabaci*, in cassava at different concentrations out of which Nanma (3, 4, 5 ml L⁻¹), Bioneem (3, 4, 5 ml L⁻¹) and Guard (3, 4, 5 ml L⁻¹) were found effective to manage whitefly (ICAR-CTCRI, Annual Report, 2018). Byju and Jaganathan (2018) reported that use of Nanma was effective for both prophylactic as well as curative control of the pest in integrated management package of banana/ horticultural crops. Sucking pests such as mealy bug, thrips, scale insects, mites, etc., in horticultural crops could also be controlled by Nanma. Similar findings were reported by Mani *et al.* (2016), Jayaprakas *et al.* (2000) and Sreerag *et al.* (2014). Spraying the bio-formulations Shreya (7ml L⁻¹) followed by Nanma (7ml L⁻¹) can satisfactorily manage the mealy bug pest. Both these bio-formulations are a mixture of Neem oil and extract of cassava leaf at different combinations. Spraying a mixture of Neem oil (20 ml) and soap solution (2-5 ml) also controlled the pest (Jayaprakas *et al.* 2020). Pooled data showed that lowest leaf curl disease (0.22%) was recorded in Nanma @ 10 ml L⁻¹ followed by Nanma @ 7.5 ml L⁻¹ (0.44%) and Karanj oil @ 2 ml L⁻¹ (0.44%) (Table 1).

Efficacy of bio-pesticide (NANMA) against potato thrips (*thrips palmi*)

The effects of insecticidal treatments were presented in Table 2. Pre-count thrips population did not vary significantly among the treatments. All the treatments were significantly superior over the control in respect of reducing thrips population. Pooled data revealed that the thrips population per three leaves of 5 tagged plants in the pre treatment during the spraying varied between 39.50 to 32.83 (Table 2). After 7 days of spray with Nanma @ 10 ml L⁻¹,

Table 1. Efficacy of bio-pesticide (NANMA) against whitefly (*Bemisia tabaci*) in potato (Pooled data 2018-19 and 2019-20)

Treatments	Mean whitefly population per 5 plants					Mean population	Redu. in popu. over control (%)	LCD (%)
	Before spray	Days after spray (DAS)						
		1 DAS	2 DAS	3DAS	7 DAS			
T1-Nanma @ 5 ml L ⁻¹	14.00 (3.81)	10.83 (3.36)	9.33 (3.13)	7.00 (2.73)	5.17 (2.38)	8.08	45.35	0.67
T2-Nanma @ 7.5 ml L ⁻¹	13.50 (3.74)	9.17 (3.10)	8.17 (2.94)	6.00 (2.55)	4.00 (2.10)	6.83	53.80	0.44
T3-Nanma @ 10 ml L ⁻¹	13.00 (3.67)	5.83 (2.51)	4.50 (2.23)	3.33 (1.95)	2.33 (1.67)	4.00	72.95	0.22
T4-Neem oil @ 2 ml L ⁻¹	16.17 (4.08)	10.50 (3.30)	8.67 (3.01)	8.00 (2.91)	7.00 (2.73)	8.54	42.25	0.89
T5-Karanj oil @ 2 ml L ⁻¹	12.67 (3.62)	10.50 (3.31)	9.50 (3.16)	9.33 (3.13)	8.67 (3.02)	9.50	35.77	0.44
T6-Mineral oil @ 5 ml L ⁻¹	14.67 (3.89)	8.50 (2.99)	7.50 (2.82)	6.00 (2.53)	4.50 (2.23)	6.63	55.21	1.11
T7- Control	16.00 (4.05)	15.67 (4.02)	15.00 (3.93)	15.50 (4.00)	13.00 (3.66)	14.79	-	1.33
S.Em±	0.12	0.19	0.13	0.11	0.17		-	-
CD at 5%	NS	0.58	0.40	0.33	0.51		-	-

Figures in the parenthesis are $\sqrt{(x+0.5)}$ transformed values, NS- Non significant DAS- Days After Spray, LCD-Leaf Curl Disease

lowest count of mean thrips population (4.83 thrips 5 plants⁻¹) was recorded with highest per cent population reduction (74.29) followed by Nanma @ 7.5 ml L⁻¹ (7.67 thrips 5 plants⁻¹) and Mineral oil @ 5 ml L⁻¹ (8.67 thrips 5 plants⁻¹), wherein per cent population reduction of 62.55 and 65.38, respectively over untreated control were noted. The overall efficacy after spray inferred that Nanma @ 10ml L⁻¹ was significantly effective along with treatment Nanma @ 7.5 ml L⁻¹ and Mineral oil @ 5 ml L⁻¹ in suppressing the thrips

population. Byju and Jaganathan (2018) reported that use of Nanma was effective for both prophylactic as well as curative control of the pest in integrated management package of banana/ horticultural crops.

Tuber yield and economics

Pooled data of two years showed that tuber yield was non-significant. Nanma 10 ml L⁻¹ recorded maximum tuber yield (302.17 q ha⁻¹) with highest benefit cost ratio (1:1.88)

Table 2. Efficacy of bio-pesticide (NANMA) against thrips (*thrips palmi*) on potato. (Pooled data 2018-19 and 2019-20)

Treatments	Mean thrips population per 5 plants					Mean popu.	Redu. of popu. over control %
	Before spray	Days after spray (DAS)					
		1 DAS	2 DAS	3 DAS	7 DAS		
T1-Nanma @ 5 ml L ⁻¹	37.00 (6.12)	17.00 (4.18)	13.17 (3.69)	11.33 (3.44)	10.00 (3.23)	12.88	54.08
T2- Nanma @ 7.5 ml L ⁻¹	39.50 (6.32)	13.67 (3.76)	11.50 (3.46)	9.17 (3.10)	7.67 (2.85)	10.50	62.55
T3-Nanma @ 10 ml L ⁻¹	35.67 (6.01)	9.83 (3.21)	7.67 (2.85)	6.50 (2.64)	4.83 (2.31)	7.21	74.29
T4-Neem oil @ 2 ml L ⁻¹	36.17 (6.05)	12.00 (3.53)	11.17 (3.41)	10.33 (3.29)	9.50 (3.15)	10.75	61.66
T5-Karanj oil @ 2 ml L ⁻¹	34.17 (5.87)	14.83 (3.91)	13.33 (3.71)	11.33 (3.44)	10.17 (3.26)	12.42	55.72
T6-Mineral oil @ 5 ml L ⁻¹	32.83 (5.77)	11.00 (3.38)	10.00 (3.24)	9.17 (3.11)	8.67 (3.02)	9.71	65.38
T7- Control	34.00 (5.87)	32.83 (5.77)	30.83 (5.60)	26.33 (5.18)	22.17 (4.76)	28.04	-
S.Em±	0.12	0.16	0.14	0.11	0.14	-	-
CD at 5%	NS	0.50	0.42	0.34	0.43	-	-

Figures in the parenthesis are $\sqrt{(x+0.5)}$ transformed values, NS- Non significant DAS- Days After Spray

Table 3. Economics of different treatments (Pooled data of 2018-19 and 2019-20)

Treatments	% Germination	Tuber yield (q h ⁻¹)	Add. Yield over control q h ⁻¹	*Additional income over control (Rs.)	Cost of cultivation + Cost of treatments (Rs.)	Monetary returns (Rs.)	Net income (Rs.)	B:C ratio
		Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
T1-Nanma @ 5 ml L ⁻¹	86.00	286.87	18.54	12051	102157	186466	84309	1 : 1.82
T2- Nanma @ 7.5 ml L ⁻¹	85.56	292.85	24.52	15938	103007	190353	87346	1 : 1.84
T3-Nanma @ 10 ml L ⁻¹	87.11	302.17	33.84	21996	103957	196411	92454	1 : 1.88
T4-Neem oil @ 2 ml L ⁻¹	85.78	287.80	19.47	12655	101357	187070	85713	1 : 1.84
T5-Karanj oil @ 2 ml L ⁻¹	83.78	285.20	16.87	10966	101257	185380	84123	1 : 1.83
T6-Mineral oil @ 5 ml L ⁻¹	86.67	284.43	16.10	10465	103297	184880	81583	1 : 1.78
T7-Untreated control	83.78	268.33	-	-	99757	174415	74658	1 : 1.74
S.Em±	2.47	13.49	-					
CD at 5%	NS	NS	-					

Total cost of cultivation except bio-pesticides control: Rs. 99757 ha⁻¹. *Avg. price of potato: Rs. 650 q⁻¹.

**Cost of plant protection= labour+ bio-pesticides application+ machine charges

1. Nanma @ 5, 7.5, 10 ml L⁻¹: (Rs. 2400, 3250, 4200 ha⁻¹) 2. Neem oil @ 2 ml L⁻¹: Rs. 1600 ha⁻¹
3. Karanj oil @ 2 ml L⁻¹: 1500 ha⁻¹ 4. Mineral oil @ 5 ml L⁻¹ : Rs. 1850 ha⁻¹

which was followed by Nanma @ 7.5 ml L⁻¹ and Neem oil @ 2 ml L⁻¹ over untreated control (Table 3).

CONCLUSION

The results indicated that Nanma @ 10 ml L⁻¹ was most effective with highest per cent population reduction of whitefly and thrips followed by Nanma @ 7.5 ml L⁻¹ and Mineral oil @ 5 ml L⁻¹ over untreated control. Therefore, it could be concluded that Nanma @ 10 ml L⁻¹ is useful in management of sucking pests of potato crop as it is safer and economically cheapest.

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Different flavours of honey, their properties and health benefits

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ABSTRACT

Honey is a sweet, natural, viscous product made by honey bees of the genus *Apis* (Apidae). It not only gives us honey but also play a very important role in our environment, *i.e.*, pollination. They produce honey by collecting the nectar from different flowers of various plants. Most of the nectar is collected by the bees from the plant families like, fabaceae, asteraceae and myrtaceae. Taste, composition (such as nutrients and bioactive compounds), quality, and quantity of nectar are mostly determined by the blooms of various plant families from which the nectar is derived. Honey comes in a range of flavours and is prepared to meet a number of health and beauty needs. Honey vary in color and flavour depending on which nectar source (flowers) the honey bees visit. Twenty flavours of honey as well as their origins have been discussed. The price of honey varied between Rs. 300 to Rs. 6184 500 g⁻¹, the minimum price (Rs. 300 500 g⁻¹) was noticed in multifloral honey, while maximum price (Rs. 6184 500 g⁻¹) was observed in honey from manuka.

Key words: Honey, properties, flavour, health benefit

Honey is a delectable, sticky liquid made by honey bees naturally collecting nectar from a variety of flowers. For over 5500 years, our predecessors have ingested it for its nutritional, medicinal, and healing properties. Honey has a long shelf life and will not spoil if stored at room temperature. Honey is becoming more popular as a natural sweetener with anti-diabetic properties (Samarghandian *et al.*, 2017).

Honey is available in a wide range of colours and flavours, ranging from nearly colourless to dark brown, depending on where the honey bees are foraging. Honey with a light tint has a mild flavour, but honey with a dark colour has a stronger flavour. Honey is classed by taste and origin, such as blossom honey (*e.g.*, orange blossom honey), multifloral honey (*e.g.*, wildflower honey), monofloral honey (*e.g.*, manuka honey), and so on. The physical and chemical characteristics of honey indicate or serve as an indicator of both its quality and the location from whence it was generated. Honey's flavour and appearance, such as colour and thickness, are mostly affected by the flower from which honey bees take nectar, the natural habitat, and practices associated with beekeeping (Pavlova *et al.*, 2019).

Natural honey contains over 200 components, including amino acids, vitamins, minerals, and enzymes, although it mostly combines with sugar and water. Sugar is present in the dry matter in the range of 95 to 99 per cent. The major sugars, glucose (32.56-38.5 g) and fructose (28.54-31.3 g) account for 85 to 95 per cent of total sugars in honey (Table 1). These carbohydrates are easily digested by our gastro-

intestinal tract. Saccharides such as maltose, sucrose, isomaltose, turanose, nigerose, melibiose, panose, maltotriose and melezitose are examples of other sugars present in honey. The probiotic agent fructo-oligosaccharide is present in a concentration of about 4-5 per cent. Water is the honey's second most important component. It includes 0.57 per cent organic acid and is made up of a by-product known as gluconic acid, which is created when glucose is broken down. Honey's flavour is also controlled by the amount of organic acids it contains. The accumulation of macro and micro nutrients in honey ranges between 0.1-1.0 per cent. The amount of potassium is substantially high, which is about 52 per cent, and followed by calcium, magnesium, sodium, sulphur and phosphorous. The micronutrients are iron, copper, zinc and manganese.

Vitamins like C, B₁ and B₂ are the nitrogenous compound, whereas riboflavin, nicotinic acid, B6 and panthothenic acid are complex vitamins which are also present in traces. Proteins are traced in small amounts (0.1-0.5%).

The flower offers the bees with two types of nourishment. Nectar is one of them, while pollen is the next food source (from the anthers of blossoms). Bees execute various steps in the production of honey, including processing, breakdown, digestion, and desiccation. These amazing flying insects can carry the nectar or pollen equivalent to their whole weight. They swoop down on the blossoms and drink the nectar. The bees collect nectar

Table 1. Nutritional value of honey per 100 g

Constituent	Average
Carbohydrate	82.4 g
Glucose	38.5 g
Fructose	31.3 g
Sucrose	1.0 g
Other sugars	11.7 g
Dietary fibre	0.2 g
Fat	Nil
Protein	0.3 g
Water	17.1 g
Riboflavin (Vitamin B ₂)	0.038 mg
Niacin (Vitamin B ₃)	0.121 mg
Pantothenic Acid (Vitamin B ₅)	0.068 mg
Pyridoxine (Vitamin B ₆)	0.024 mg
Folate (Vitamin B ₉)	0.002 mg
Vitamin C	0.5 mg
Calcium	6.0 mg
Iron	0.42 mg
Magnesium	0.2 mg
Phosphorus	4.0 mg
Potassium	52 mg
Sodium	4.0 mg
Zinc	0.22 mg

from 50 to 100 blooms per day on average. Nectar is a sweet liquid that contains a lot of sugar (Hadley, 2021).

The nectar is stored in the bee's fictitious stomach (this is not the real stomach of honey bee but it is only used to store the nectar of the flower) (Bista and Shivakoti, 2001). If a honey bee requires energy, they transfer some nectar by opening a nectar sac valve, then transfer some nectar through the sac to their main stomach, where it is consumed to provide the required energy. When the pouch of bee is completely filled with nectar that is loaded with disaccharides (sucrose and water) then they confirm their return to their respective hives and it is separated into monosaccharides (glucose, fructose and water molecule) and started to move the nectar from one bee to another bee mouth present in hive until the moisture level of the nectar reached at 20 per cent from 70 per cent or they can reduce the moisture level of honey by beating their wings then they place the produced honey in the hexagonal structure for maturing by covering them with bee wax.

Sometimes the nectar is directly placed into the hexagonal compartment by the bees. In this process the mouth to mouth movement of nectar is not performed by the bees. The nectar later converted into the honey after desiccation and it happens naturally and desiccation starts at 32.5° celsius. The temperature inside the hive maintained naturally because of its hexagonal honeycomb structure.

Flavours of honey

Ajwain/Carom honey

Trachyspermum ammi is an annual herb in the family Apiaceae. It is moderately runny, smooth and light golden in colour. In some states of India like Rajasthan, Madhya Pradesh and Maharashtra ajwain is grown on large scale. The bee travels to the near field and extracts the nectar from the flower of ajwain and returns back to their respective hives and converts it into honey (Bee Farms Products, 2021). Ajwain honey aids in indigestion, act as a powerhouse of antioxidants and has antimicrobial properties.

Eucalyptus honey

It is obtained from genus (*Eucalyptus*), with more than 660 species of shrubs and tall trees of the myrtle family (Myrtaceae). Eucalyptus Honey is harvested in mainly fewer states of India like Punjab, Bihar, Uttar Pradesh, Haryana and Himachal Pradesh. It can be produced by honey bees by collecting the nectar from the flowers of eucalyptus tree. If the bees are not able to get the required amount of honey from the flowers then they try to get the honeydew by exploring the bark of eucalyptus tree. But the ratio of composition of nectar extracted from the flower is always on the higher amount when compared to the amount of honeydew extracted from the bark. It has thick liquid consistency and dark brownish-orange or dark amber in appearance. The honey can be stored up to 1.8 years (Bharat Honey, 2021). Among health benefits of eucalyptus honey, it is very effective in cold and cough and headache. It is also used as an anti-inflammatory.

Lychee honey

The fruit lychee (*Litchi chinensis* Sonn.) is a major member of the Soapberry family, which includes approximately 2,000 species and 150 taxa. This honey is mainly produced in Uttarakhand but now it can also be harvested in Bihar and Uttar Pradesh. The honey is produced by the nectar mainly collected by bees from the flowers of lychee tree. The consistency of the honey is moderately thick and it can be appeared white to light amber when observed. When there is a drop in room temperature the lychee honey becomes crystalline (Nature Hug, 2021). Lychee honey resolves the problem related to digestion. It helps in blood regulation and also helps to improve the disorders related to cognition.

Sunflower honey

Helianthus annuus also known as sunflower associated with the family Asteraceae. This is the biggest plant family, including about 24 thousand species. Only the producer in Maharashtra is allowed to harvest sunflower honey. Honey

is made by bees who collect nectar from sunflowers to make honey. The honey is bright yellow in colour and has a thick consistency. When exposed to ambient temperature, the honey begins to crystallise. Sunflower honey has a 24-month shelf life. Sunflower honey gives you rapid energy, which is why it is popular among athletes. It is also good for hair development. It is effective in the treatment of lung disorders and in cleansing of human blood. It can be used as a face mask once it crystallizes.

Rapeseed/Mustard honey

Brassica juncea (mustard) belongs to the family *Brassicaceae* having genera is about three hundred seventy five and approximately thirty-two hundred species. Honey is mostly produced in the Indian state of Rajasthan. The nectar taken by honey bees is the principal element of mustard honey, and pollen is also added by bees during the extraction process. After 15-25 days of harvesting, or even before collecting, honey begins to crystallize (Nature Word, 2021). The honey has a spreadable or soft-solid viscosity and a white yellow to milky yellow colour. One of the most important health benefits of mustard honey is that it boosts metabolism. It also aids in the improvement of digestion and the treatment of skin issues such as itching and rashes.

Indian Blueberry/Jamun honey

Jamun (*Syzygium cumini*) is from the Myrtaceae family. The honey is harvested in some parts of Uttar Pradesh, Maharashtra and Uttarakhand. The farmers have done plantation of Jamun tree at large scale in Bijnor, U.P., Haridwar, Uttarakhand and Akeri, West Maharashtra. The honey is produced naturally by collection of nectar perform by bees. The hue of the honey is dark amber and it is fairly runny or smooth thick. Honey is high in antioxidants and has a shelf life ranging from 12 to 18 months, depending on the producer's processes from harvesting to packaging (Cerana Meads, 2021). It is beneficial to the heart and is excellent in stimulating and enhancing digestion. It also has anti-diabetic properties.

Acacia honey

Wattle is another name for acacia, which belongs to the Fabaceae family. Kashmir is where the honey is primarily harvested. Honeybees can make it by sucking nectar from blooming acacia flowers. Acacia honey has a fluid consistency and a somewhat yellow colour. In comparison to other honeys, this honey has a higher sugar content. It appears to be crystal clear when observed. Because of the high fructose content, the crystallisation process is also slow. It can last up to 24 months, while still being runny (Outlook Traveller, 2021). It can aid to enhance coronary circulation. It aids in function of the kidneys and liver. It can improve the

function of both male and female reproductive systems. It can also be used to treat various respiratory related issues like tuberculosis, asthma, bronchitis. It is also used to treat skin diseases like eczema, ulcers and psoriasis.

Sidr or wild berry honey

The botanical name for sidr is *Frangulaalnus*, and it belongs to the Rhamnaceae family. Rajasthan is the only place where this honey is produced. The nectar taken from the blossoms of sidr or jujube tree is used to make honey. Because bees rely solely on sidr trees for food and survival, sidr honey is more valuable on the international market, and it can only be obtained twice a year. The honey has a medium to dark amber colour and a thick consistency. It aids in the treatment of cancer. It also aids in blood cleansing and increases the body's stamina and potency. It aids in the health of the gums and teeth (Health Upshot, 2021).

Karanj honey

Karanj is also known as *Millettiapinnata* scientifically and comes under the family *Fabaceae*. *Karanj* honey is primarily produced in Chhattisgarh. Honey is made by bees harvesting nectar from the Pongamia Pinnata and Ungue trees. *Karanj* honey has reasonably a thick consistency and light amber colour. *Karanj* honey has a flavour that is akin to apricot and lemon. *Karanj* has medicinal characteristics that have been discussed in Ayurveda as well. It has a 485-day shelf life, which is more than enough when compared to other honeys. It has been shown to have the ability to heal wounds. It has hydrating and anti-aging qualities. It aids in the reduction of bacterial-related gastrointestinal problems. It possesses anti-bacterial and anti-inflammatory effects.

Apple honey

Apple (*Mallus domestica*) belongs to the family Rosaceae. There are 4828 species divided into 91 genera. The honey is gathered from apple orchards in the Himalayan region. During the spring season, bees gather nectar from the blossoms of apple trees to make honey. The honey has a bright golden amber hue and a consistency that ranges from moderately runny to silky. This honey contains significant amount of iron, which meets the iron requirements of pregnant women. It has a 12-month shelf life. It is anti-acne and anti-inflammatory. It can be used to treat skin conditions such as eczema. It aids in the immune system's enhancement (Bharat Honey, 2021).

Mango honey

Magnifera indica (mango) belongs to the Anacardiaceae family. *Magnifera* is a genus that contains about 30 species. Honey is collected in Karnataka and Tamil Nadu's forested areas. The nectar is extracted by bees from mango tree flowers

(called *manjar* in tribal language) and pollen is accidentally added to honey. The honey is of exceptional quality since it is produced entirely by Indian bees, with no European or Italian bees involved. The honey is only gathered once per year. The honey has a thick viscosity and a yellowish to orangish colour. It aids in the improvement of immunity. It also helps to maintain a healthy gut flora (The Murmu, 2021).

Orange honey

Citrus x sinensis, scientifically known as *Citrus x sinensis*, is a member of the Rutaceae family. Orange blossom honey is produced in the states of Nagaland and Maharashtra. Bees generate monofloral honey by gathering nectar from orange blossom flowers and converting it to honey. The honey has a light golden tint and is somewhat runny to smooth. Citrus honey has a basic honey flavour, although it may have a citrus flavour and is light in comparison to other honeys. It aids in the reduction of acid reflux. It aids in the reduction of triglyceride release, which acts as a resistance to insulin synthesis in the human body (Bees Wiki, 2021).

Tulsi honey

Ocimum tenuiflorum commonly known as *Tulsi* or holy Basil is from the family *Lamiaceae*. The *Lamiaceae* family is known as the 'Mother of All Medicine,' and is also known as the 'Queen of Plants,' due to its scientifically established health benefits. *Tulsi* honey is only made in city Udaipur located in Rajasthan. It is made by collecting nectar from the blossoms of the holy basil plant. The colour of the honey is dark golden, and its consistency is slightly thinner. It takes long time to crystallise. It has a distinct and powerful flavour. It contains lot of carbohydrates. It has 18-month shelf life. It aids in the improvement of immunity. It also aids in the development of stamina. It possesses anti-inflammatory and anti-microbial properties. It also assists in the reduction of stress.

Fireweed honey

Fireweed is botanically called *Chamaenerion angustifolium* and comes in the family of *Onagraceae*. In 17 genera, the *Onagraceae* family has roughly 650 shrub, herb, and tree species. Canada produces the majority of the honey. Honey is made by honey bees taking the nectar from fireweed blossoms and converting it to honey. The colour of the fireweed flower is pink, and it grows in the open forests to a height of 3 to 5 feet, with spikes on the stems. The honey has a light golden tint and a smooth and thick consistency. Honey has a creamy, pleasant flavour. It is a drug that is used to treat gastrointestinal problems. It is anti-inflammatory as well as anti-microbial. It is chock-full of antioxidants.

Clover honey

Clover is a member of the *Fabaceae* family and is formally known as *Trifolium*. There are roughly 300 species in the genus of the family. Clover honey is produced in the United States, Canada, and New Zealand. The nectar of clover blossoms is consumed by the bees. The colour of the honey is determined by the colour of the clover blossom, which might be red, alsike, white, or yellow sweet clover. Clover honey's hue is also affected by the time and stage of harvesting. The honey has a creamy consistency and a watery to light amber colour. Clover honey crystallises faster than other honeys because the glucose content is higher than the fructose content. (National Honey Board, 2021). It may aid in the reduction of harmful cholesterol levels in the body. It helps in body's blood pressure regulation. It also helps in proper functioning of heart and central nervous system. Clover honey is also beneficial to brain's wellness.

Buckwheat honey

Scientifically buckwheat is called as *Fagopyrum esculentum* and belongs from the family of *Polygonaceae*. The buckwheat honey is produced by extracting the nectar from buckwheat flowers by bees. It is produced by America in the states of Minnesota, Ohio, Pennsylvania, and Canada. It has thick and sticky texture and it has coppery yellow, black and reddish amber. As compared to other light honeys it contains more antioxidants. The taste of buckwheat honey is similar to gur molasses (Best Herbal Health, 2021). It is used in the treatment of scar and sun burn. It helps in preventing pre-mature aging. It helps in protecting the intestinal micro-biota. It has both anti-viral and anti-bacterial properties.

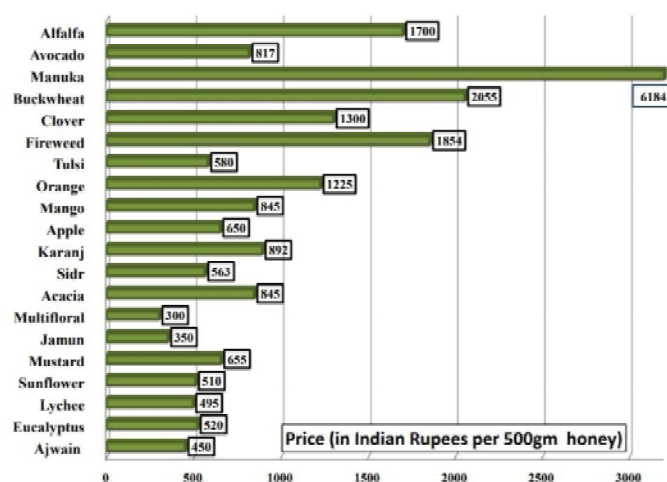


Figure 1. The pricing of various varieties of honey per 500gm from around the world.

Table 2. Different type of flavours of honey with their references

Flavor Honey	of Region	References
Ajwain Honey	Madhya Pradesh, Maharashtra, Gujarat, Rajasthan	https://beefarm.co.in/product/ajwain-honey/?v=c86ee0d9d7ed https://surefoods.in/products/ajwain-honey?variant=39304777662618 https://www.thehoneyshopindia.com/product/ajwain-honey/ https://www.utmt.in/products/litchi-honey?variant=31339468357709
Eucalyptus Honey	Himachal Pradesh, Punjab	(Aashna Dhiman) https://www.outlookindia.com/outlooktraveller/explore/story/71081/honey-wise-sugar-foolish-8 https://www.bharathoney.com/product/eucalyptus-honey/ https://diethive.com/eucalyptus-honey/ (Catherine day) https://beeswiki.com/eucalyptus-honey/ https://www.utmt.in/products/eucalyptus-honey
Lychee Honey	Uttarakhand, U.P. & Bihar	(Aashna Dhiman & Cerena Meads) https://www.outlookindia.com/outlooktraveller/explore/story/71081/honey-wise-sugar-foolish-8 https://ceranameads.com/types-of-honey-in-india/ https://www.flirt.com/nature-hpkaug-raw-rosewood-honey-500g-lychee-combo-1000-g-pack-2/p/itmfeqkj7fwzzqus https://www.apisindia.com/lychee.php https://naturehug.in/products/lichi-honey
Sunflower Honey	Maharashtra	https://www.miel-lerucherdelours.fr/en/honey/18-sunflower-honey.html https://www.amazon.in/HONEY-SHOP-Sunflower-Collected-Natural/dp/B079VLZXQP https://www.ganpatihoney.in/wordpress/products/sunflower-honey-2/ https://www.indiamart.com/pvk-agro-products/sunflower-honey.html
Rapeseed / Mustard Honey	J&K, Assam, Jharkhand, M.P., U.P., Rajasthan, Haryana, H.P.	http://www.thedailyrecords.com/2018-2019-2020-2021/ https://www.moonshinemeadery.com/products/mustard-honey https://www.natureword.com/properties-and-benefits-of-rapeseed-honey/ https://www.eiwahoney.com/products/mustard-honey
Jamun Honey	Maharashtra	https://www.bharathoney.com/product/bharat-jamun-honey/ https://www.amazon.in/Superbee-Jamun-Honey-Mustard-Cream/dp/B07F8X7YK7 https://www.indiamart.com/proddetail/jamun-natural-flavoured-honey-13067298648.html
Multifloral Honey	Meghalaya	(Aashna Dhiman) https://www.outlookindia.com/outlooktraveller/explore/story/71081/honey-wise-sugar-foolish-8 https://www.bharathoney.com/product/bharat-multiflora-honey/ https://beefarm.co.in/product/honey/?v=c86ee0d9d7ed
Acacia Honey	Kashmir	(Aashna Dhiman) https://www.outlookindia.com/outlooktraveller/explore/story/71081/honey-wise-sugar-foolish-8 https://en.techexpertolux.com/prochee/akacievij-med.html https://www.rawartisanhoney.com/products/raw-acacia-honey https://www.utmt.in/products/acacia-honey
Sidr or Wild Berry Honey	Rajasthan	(Cerena Meads) https://ceranameads.com/types-of-honey-in-india/ https://www.bharathoney.com/product/bharat-sidr-honey/ https://www.healthupshot.com/sidr-honey-benefits/ https://www.thehoneyshopindia.com/product/wild-berry-sidr-honey/
Karanj Honey	Chhattisgarh	https://www.utmt.in/products/karanj-honey https://beecrafthoney.com/product/karanj-honey/ https://www.tribesindia.com/shop/tribes-vandhan-naturals/honey-jams/karanj-honey-250-grams/ http://beeglobal.co.in/product/karanj-honey/
Apple Honey	Kashmir, Himachal Pradesh	https://www.amazon.in/dp/B09CH7MGP7/ref=cm_sw_r_wa_apan_glt_fabc_292NJN38ZM3R6NRQ7ZCB https://healthywithhoney.com/the-rare-and-delicious-apple-honey/ https://simplythegreat.ae/products/apple-blossom-honey
Mango Honey	Karnataka & Tamil Nadu	https://www.amazon.in/BEST-INDIA-COMPANY-Indigenous-HONEY

Table 2. Contd.....

Flavor Honey	of Region	References
Orange Honey	Maharashtra, Nagaland	https://www.amazon.in/dp/B08RXT99LF/ref=cm_sw_r_wa_apan_glt_fabc_NKGST4T74EJ3K9HRWZK7?_encoding=UTF8&psc=1 https://beeswiki.com/orange-blossom-honey/ https://simplythegreat.ae/products/orange-blossom-honey
Tulsi Honey	Rajasthan	https://www.utmt.in/products/tulsi-honey https://www.eiwahoney.com/products/tulsi-honey https://www.qtrove.com/products/holy-basil-honey-sunflower-honey-combo-pack-of-2
Fireweed Honey	Canada	https://honey.com/newsroom/presskit/honey-color-and-flavor https://diethive.com/fireweed-honey/ https://www.daburhoney.com/benefits-of-honey/honey-for-health/types-of-honey
Clover Honey	United States	https://honey.com/newsroom/presskit/honey-color-and-flavor https://www.thehoneyjarhome.com/why-does-honey-vary-in-color-texture-and-taste https://www.delightedcooking.com/what-is-clover-honey.htm https://www.browningshoney.com/what-is-clover-honey/ https://www.amazon.in/dp/B00LBPH2LS/ref=cm_sw_r_wa_apan_glt_fabc_WC5QHRVEJRX9C9ME3F7M8
Buckwheat Honey	Canada and USA	https://honey.com/newsroom/presskit/honey-color-and-flavor https://www.bestherbalhealth.com/buckwheat-honey-benefits/ https://beeswiki.com/buckwheat-honey/ https://www.desertcart.in/products/48064488-eco-raw-buckwheat-honey-1-25kg-pure-natural-unpasteurised-dark-honey-in-a-glass-jar-unfiltered-unheated-unprocessed-from-non-sugar-fed-bees-wellnesstore-uk
Manuka Honey (Monofloral)	New Zealand	https://en.wikipedia.org/wiki/M%C4%81nuka_honey https://diethive.com/manuka-honey/ https://www.manukadoctor.com/blogs/content/is-manuka-honey-always-the-same-color https://www.foodunfolded.com/article/manuka-honey-and-jarrah-honey-how-its-made https://krishijagran.com/health-lifestyle/where-can-we-find-different-types-of-honey/ https://www.amazon.in/dp/B01DTAIXAG/ref=cm_sw_r_wa_apan_glt_fabc_RSVFNNTMM51WA14HF5T
Avocado Honey	California, USA	https://diethive.com/avocado-honey/ https://www.mybeeline.co/en/p/what-is-avocado-honey https://krishijagran.com/health-lifestyle/where-can-we-find-different-types-of-honey/ https://www.bloomhoney.com/products/avocado-honey
Alfalfa Honey	U.S.A., Zeland and Africa	https://beeswiki.com/alfalfa-honey/ https://diethive.com/alfalfa-honey/ https://www.daburhoney.com/benefits-of-honey/honey-for-health/types-of-honey https://krishijagran.com/health-lifestyle/where-can-we-find-different-types-of-honey/ https://averygirlhoney.com/alfalfa-honey/ https://therawhoney.in/product/alfalfa-honey/

Manuka honey

Leptospermum scoparium is the scientific name of manuka and it is from Myrtaceae family. New Zealand is the only country that produces manuka honey. Bees can make it by gathering nectar from the blossoms of the manuka tree. It's also known as the honey superfood. The consistency of manuka honey is thick and spreadable and hue is cream to brown. When manuka honey is brought to room temperature, it begins to crystallise. When compared to other honeys, manuka honey has a larger range of therapeutic capabilities. Due to the rarity of the manuka tree, it is one of the most costly honeys. Due to the presence of methylglyoxal, it has a higher healing ability than other flavours of honey. It is used to treat eczema and acne by acting as an anti-irritant and anti-inflammatory. It aids in the relief of IBS and the prevention of stomach ulcers. It is used to treat brain tumours, fibrosis, and cholesterol levels (Manuka Doctor, 2021).

Avocado honey

Persia americana is the scientific name for avocado, which belongs to the Lauraceae family. California is the only place where honey is produced. The avocado bloom is the primary food source for bees, who convert it to honey. The avocado tree has a lot of phosphorus and potassium (Krishi Jagran, 2021). As a result, honey bees select blooms that provide sufficient food. As a response, avocado honey is produced in smaller quantities than acacia or orange blossom honey. Honey has a rich, creamy texture and a dark amber colour. Avocado honey has a similar glucose and fructose content to other honeys, but the crystallisation process is much slower due to the presence of persitol, which is not found in any other honey. Due to its high carbohydrate content, it should be consumed in moderation. One of the many advantages of avocado honey is its ability to treat the common flu. Because of its high vitamin and mineral content,

it helps to boost the immune system and prevent sickness. It can assist the skin in regaining its radiance and hydration.

Alfalfa honey

Medicago sativa is the scientific name for alfalfa, which belongs to the fabaceae family. Honey made from alfalfa can be found all over Canada and the United States. Honey is made by honey bees by collecting nectar from the blue or purple flowers of the alfalfa plant. Alfalfa provides a lot of nectar and pollen, which the bees need to survive. The viscosity of alfalfa honey is fairly thick, and the hue ranges from white to light amber. The flavour of alfalfa honey is mildly flowery and fragrant. It aids in the promotion of excellent gut health and lowers cholesterol levels in the body when included in the diet. It aids in the reduction of fever and the suppression of hunger. It has antimicrobial effects as well (Dabur Honey, 2021).

Multiflora honey

Acanthaceae, Amaranthaceae, Alismataceae, Araceae and Berberidaceae are prominent among all multiflora plant families. Multiflora honey is mainly harvested in Meghalaya but now it can also be harvested in Uttarakhand. The bee collects the nectar from variety of flowers in forests so the colour of the honey varies from light amber to dark amber depending upon the source of nectar collected by bees. The appearance of multiflora honey is usually light amber to dark amber and it has thick consistency. The storage life of multiflora honey is up to 2 years. It improves the function of heart and thus lowers the risk of heart failure. It helps in preventing acid reflux and also improves the respiratory related disorders. It also helps in aiding insomnia.

Comparison in price of different flavours of honey

The price of honey is decided by their productivity and availability in the following country. The varied prices of honey per 500gm are indicated in Figure 1. The graph depicts the pricing of various honey varieties in India, based on their productivity, availability, and, in certain cases their health advantages. Because of its great productivity and easy availability, ajwain, lychee, jamun, and multiflora honey have low prices, whereas sidr, *tulsi*, apple, mustard, sunflower, and eucalyptus have average prices due to their production and availability. When it comes to avocado, acacia, *karanj*, and mango, the prices are high due to limited productivity and availability. Because alfalfa, buckwheat, fireweed and clover are not produced in India, their prices are relatively higher. Manuka honey is the most expensive of all the honeys listed because of its therapeutic properties.

CONCLUSION

Prices of honey depended on the productivity, availability and their therapeutic values. Accordingly the

ajwain, Jamun and multiflora honey are the cheapest; sidr, tulsi, eucalyptus, apple, mustard and sunflower honeys are moderately priced while avocado, acacia, *Karanj* and mango because of lowest productivity are the costliest honey in the country. The manuka honey in New Zealand is the costliest (Rs. 6184 500 g⁻¹) because of its high therapeutic properties.

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Biopriming and integrated management of powdery mildew and anthracnose disease of chilli caused by *Colletotrichum capsici* (Sydow)

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ABSTRACT

Field experiment evaluating therein the effect of integrated use of seed treatment, vermicompost enriched with *Tricoderma harzianum*, seedling dip and foliar application of fungicides, conducted with the aim of finding safer alternatives to chemical fungicides for management of foliar diseases of chilli powdery mildew and anthracnose/fruit rot diseases during *kharif* 2015 and 2016 revealed that seed treatment with *T. harzianum* @ 10 g kg⁻¹ at nursery followed by seedling dip with *Pseudomonas fluorescens* @ 10 g L⁻¹ and spot application of enriched *P. fluorescens* (1.0 kg *P. fluorescens* enriched in 100 kg farm yard manure) @ 250 kg ha⁻¹ followed by spray of (tebuconazole 50% + trifloxystrobin 25% WG) @ 0.5 g L⁻¹ recorded least per cent disease index 47.80 and 33.30 per cent for anthracnose and powdery mildew, respectively, and recorded highest dry chilli yield (12.76 q ha⁻¹) with net returns of ₹ 99,598 and highest B: C ratio (1:2.74) as compared to untreated check with 73.82 and 69.10 per cent disease index and dry chilli yield of 5.37 q ha⁻¹.

Key words: Chilli, biopriming, integrated management, anthracnose, powdery mildew

Chilli (*Capsicum annum* L.) is a remunerative vegetable, spice cum commercial crop worldwide, which belongs to the *Solanaceae* family and represents a diverse plant group. Chilli is grown in tropical and sub-tropical climate. Both green and ripe fruits are used to impart pungency to the food. Chillies are the source of proteins, carbohydrates, ascorbic acid, capsaicin, phenol and sugars. These biochemical constituents are known to be reduced by the infection. (Hegde and Anahosur, 2001). As a condiment, it has become indispensable in every Indian house. It is also used in medicines, chutneys and pickles. India has become world's largest producer and exporter of chilli to USA, Canada, UK, Saudi Arabia, Singapore, Malaysia, Germany and many other countries of the world. India contributes 25 per cent of the world's total production of chilli. Indian chillies have been dominating international chilli market (Yadav *et al.*, 2017). In India, chilli is extensively cultivated in Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, West Bengal, Odisha, Maharashtra and Tamil Nadu. India's area, production and productivity of green chillies are 364 thousand hectares, 3851 thousand metric tonnes (MT) and 10.58 MT/ha, respectively. Dry chillies are grown in an area of 683 thousand hectares, 1702 thousand MT production with productivity of 2.50 MT/ha. Among the states, Karnataka with 673.81 000' MT occupies prime position in green chillies production followed by Madhya Pradesh (669.16 000' MT) and Bihar with 451.19 000' MT (www.indiastat.com, 2019).

A number of limiting factors have been attributed to low productivity of chillis among them fungal, bacterial and viral diseases as well as ravages caused by insect pests are significant ones. Among the fungal diseases, powdery mildew and anthracnose or fruit rot are predominant. The powdery mildew caused by *Leveillula taurica* (Lev.) Arn. is one of the devastating diseases of chilli that cause significant yield loss up to 24 per cent (Gohokar and Peshney, 1981). Chilli production in India is adversely affected (yield loss ranging from 14 to 30%), due to severe defoliation and reduction in photosynthesis, size and number of fruits per plant (Mathur *et al.*, 1972 and Sivaprakasam *et al.*, 1976).

Anthracnose or dieback or ripe fruit rot in chillies is a common disease caused by *Colletotrichum capsici* (Sydow) Butler and Bisby, the hyphae of which proliferate within the host tissue and form lesions on the fruits (Muthumary and Jayachandhra, 1994). In India, different species of *Colletotrichum* spp viz., *C. capsici*, *C. gloeosporioides* and *C. acutatum* are known to cause anthracnose in chilli. Kim *et al.* (2004) reported that different species cause disease to different parts of the chilli plant. The disease has been observed to occur in phases, seedling blight or damping off, leaf spot, die back and anthracnose or fruit rot. Fruits with diseased lesions have reduced marketability (Bosland and Votava, 2003 and Manandhar *et al.*, 1995). Chowdhary (1957) reported that 12 to 32 per cent fruits were affected by anthracnose in Assam. Many authors reported that only red

ripe stages of chilli fruits to be vulnerable for attack by the pathogen rather than green fruits (Chowdhury, 1957). The disease is both seed and air borne and affects seed germination and vigour to a greater extent (Asalmol *et al.*, 2001). Fruit rot up to 32 per cent and dieback up to 29 per cent have been noticed. Seedling decay and seed rot up to 21 per cent were recorded under Central Indian conditions. Thind and Jhooty (1985) reported that losses due to anthracnose of chilli varied between 66-84 per cent. They also reported that the powdery mildew disease affected the growth and yield of chilli.

Many systemic and non-systemic fungicides were reported to manage the powdery mildew and anthracnose diseases of chilli. The limited information is available on the efficacy of new combi fungicides against anthracnose and powdery mildew of chilli. Hence, there is a need to evaluate new fungicides against *Colletotrichum capsici* and *Leveillula taurica*. By considering the significant loss and the economic damage caused, the present investigation was carried out by using bioagents and different combi fungicides for effective management of anthracnose and powdery mildew of chilli under field conditions.

MATERIALS AND METHODS

Chilli variety popularly known as Byadagi Dabbi, commercially grown in Northern Karnataka and susceptible to anthracnose and powdery mildew, was used in the present study. The seedlings were raised in nursery bed and transplanted to field at a spacing of 60 x 60 cm in plot size of 3.6x4.2m in RCBD design with three replications under rainfed conditions following recommended package of practices at University of Agricultural Sciences, Dharwad during *kharif* 2015 and 2016. The enriched antagonist @ 250 kg/ha was applied as spot application at the time of transplanting. The seedlings were dipped in *Trichoderma harzianum* and *Pseudomonas fluorescens* @ 10 g L⁻¹ and

transplanted to main field. The first spray of fungicides was given immediately after appearance of symptoms. The remaining sprays were given at an interval of 15 days treatment details are as under.

The observations on severity of powdery mildew and anthracnose were recorded at fruit ripening stage on randomly selected plants by following 0-9 rating scale (Mayee and Datar, 1986) as given below.

Score	Disease reaction	Description
0	Immune (I)	No symptoms on the leaf or branch or fruit
1	Highly resistant (HR)	0-10% infection on the leaf or branch or fruit
3	Resistant (R)	11-25% infection on the leaf or branch or fruit
5	Moderately resistant (MR)	26-50% infection on leaf or branch or fruit
7	Moderately susceptible (MS)	51-75% infection on leaf or branch or fruit
9	Highly susceptible (HS)	75% and above infection on leaf or branch or fruit

The per cent disease index was calculated using formula of Wheeler (1969).

Per cent disease index (%)

$$= \frac{\text{Sum of individual rating}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum disease grade}}$$

The dry chilli yield was recorded and the data was analyzed using standard statistical procedure (Panse and Sukhatme, 1978).

RESULTS AND DISCUSSION

The fungicide (tebuconazole 50% + trifloxistrobin 25% WG) is considered as new generation fungicide that contains two active ingredients *viz.*, tebuconazole and trifloxytrobin.

Sl. No.	Treatment details
T ₁	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + vermicompost (1:100) @ 250 kg ha ⁻¹ spray of (carbendazim 12% + mancozeb 63% 75 WP) @ 2 g L ⁻¹
T ₂	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + farm yard manure (1:100) @ 250 kg ha ⁻¹ - spray of amistar @ 1 ml L ⁻¹
T ₃	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + neem cake (1:100) @ 250 kg ha ⁻¹ - spray of (metiram 55% + pyraclostrobin 5% WG) @ 2 g L ⁻¹
T ₄	Seedling dip with <i>Pseudomonas fluorescens</i> @ 10 g L ⁻¹ + spot application of enriched <i>P. fluorescens</i> + vermicompost (1:100) @ 250 kg ha ⁻¹ - spray of (cymoxanil 8% + mancozeb 64%) @ 2 g L ⁻¹
T ₅	Seedling dip with <i>Pseudomonas fluorescens</i> @ 10 g L ⁻¹ + spot application of enriched <i>P. fluorescens</i> + farm yard manure (1:100) @ 250 kg ha ⁻¹ - spray of (tebuconazole 50% + trifloxistrobin 25% WG) @ 0.5 g L ⁻¹
T ₆	Seed treatment with carbendazim @ 2 g kg ⁻¹ followed by carbendazim spray @ 1 g L ⁻¹ (treated check)
T ₇	Seed treatment with carbendazim @ 2 g kg ⁻¹ followed by spray of difenconazole @ 1 ml L ⁻¹ (treated check)
T ₈	Untreated check

Note: Seed treatment with *Trichoderma harzianum* @ 10 g kg⁻¹ is common in nursery for treatments one to five.

The fungicide (tebuconazole 50% + trifloxystrobin 25% WG) delivers through the protection and strobilurin boost of trifloxystrobin, safely combined with the curative and protectant triazole properties of tebuconazole. Both of these fungicides are one among the strobilurin and triazole class of systemic fungicide, with bioefficacy against all fungal species since it inhibit mitochondrial respiration. Spraying of (tebuconazole 50% + trifloxystrobin 25% WG) has checked the anthracnose development. The disease incidence reduced more when (tebuconazole 50% + trifloxystrobin 25% WG) was sprayed at 0.2 or 0.4 g L⁻¹. Treating vines with these concentrations provided 100 per cent reduction of anthracnose and other black berries diseases compared to

untreated vines for which disease incidence were 29.85 and 49.68 PDI, respectively (Ann *et al.*, 2017). The controlling effect was mainly due to translaminar and systemic movement of tebuconazole and trifloxytrobin inside the tissue. The fungicide at said concentration not only suppressed development of anthracnose incidence but also increased the production. Several other studies demonstrated the efficacy of tebuconazole and trifloxytrobin in reducing disease severity. Li *et al.* (2012) reported that trifloxytrobin effectively controlled downy mildew (*Plasmopora viticola*) and powdery mildew (*Uncinula necator*) of grapevines as against control.



Seed treatment with *Trichoderma harzianum* @ 10 g kg⁻¹, Seedling dip with *Pseudomonas fluorescens* @ 10 g L⁻¹, spot application of enriched *P. fluorescens* (1 kg *P. fluorescens* + 100 kg FYM) @ 250 kg ha⁻¹ followed by spray of (Tebuconazole 50% + Trifloxystrobin 25% WG) @ 0.5 g L⁻¹ of water at 15 days interval

Fig. 1. Photographs showing treated and untreated anthracnose and powdery mildew of chilli

Results revealed that during *kharif* 2015 foliar disease die back/fruit rot of chilli, caused by *Colletotrichum capsici*, was severe followed by traces of powdery mildew and *Cercospora* leaf spot. The observations on foliage and fruit infection due to *Colletotrichum capsici* indicated that the seed treatment with *Trichoderma harzianum* @ 10g kg⁻¹ at nursery followed by seedling dip with *Pseudomonas fluorescens* @ 10g L⁻¹ + spot application of enriched *P. fluorescens* + farm yard manure (1:100) @ 250 kg ha⁻¹ followed by spray of (tebuconazole 50% + trifloxistrobin 25% WG) @ 0.5 g L⁻¹ recorded least per cent disease index (46.30) and highest dry chilli yield of 5.92 q ha⁻¹ (Table 1). Next best treatment was seedling dip with *T. harzianum* @ 10 g L⁻¹ + spot application of enriched *T. harzianum* + farm yard manure (1:100) @ 250 kg ha⁻¹ spray of amistar @ 1 ml L⁻¹ recorded (51.76) per cent disease index with 5.05 q ha⁻¹ yield (Table 1). The low yield recorded during *kharif* 2015 was due to prolonged moisture stress at fruit initiation stage. During *kharif* 2016 both the foliar diseases were severe followed by traces of *Cercospora* leaf spot. The observations recorded on foliage and fruits indicated that the severity of anthracnose and powdery

mildew were in the range of 49.30 to 74.50 and 33.30 to 69.30 per cent disease index, respectively. The seedling dip with *P. fluorescens* @ 10 g L⁻¹ + spot application of enriched *P. fluorescens* + farm yard manure (1:100) @ 250 kg ha⁻¹ followed by spray of (tebuconazole 50% + trifloxistrobin 25% WG) @ 0.5 g L⁻¹ recorded least per cent disease index (49.30) for anthracnose and 33.30 for powdery mildew and recorded highest yield of 19.60 q ha⁻¹. The present results are in accordance with results of Salma Begum *et al.* (2015).

The pooled analysis of data during *kharif* 2015 and 2016 exhibited that the seed treatment with *T. harzianum* @ 10g kg⁻¹ and seedling dip with *P. fluorescens* @ 10 g L⁻¹, spot application of enriched *P. fluorescens* (1 kg *P. fluorescens* + 100 kg FYM) @ 250 kg ha⁻¹ followed by spray of combi fungicide (tebuconazole 50% + trifloxistrobin 25% WG) @ 0.5 g L⁻¹ at 15 days interval recorded least per cent disease index (47.80) for anthracnose and recorded highest yield of 12.76 q ha⁻¹. Next in the order of superiority was foliar spray of difenconazole @ 1 ml L⁻¹ especially for powdery mildew with 47.70 PDI with dry chilli yield of 9.48 q ha⁻¹. Whereas maximum PDI of anthracnose (73.82) and powdery mildew

Table 1. Integrated management of foliar diseases of chilli

Sl. No.	Treatment details	Per cent disease index (PDI)				Dry chilli yield (q ha ⁻¹)			B:C ratio
		Die back/ fruit rot		Powdery mildew		<i>kharif</i>		Pooled Mean	
		<i>kharif</i>		<i>kharif</i>					
		2015	2016	Pooled Mean	2016	2015	2016		
T ₁	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + vermicompost (1:100) @ 250 kg ha ⁻¹ - spray of (carbendazim 12% + mancozeb 63 % 75WP) @ 2 g L ⁻¹	65.43 (54.13)	69.90 (57.00)	67.67 (55.57)	63.92 (53.20)	5.20	12.20	8.70	1.78
T ₂	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + farm yard manure (1:100) @ 250 kg ha ⁻¹ - spray of amistar @ 1 ml L ⁻¹	51.76 (46.03)	68.10 (55.80)	59.93 (50.92)	60.51 (51.10)	5.05	11.91	8.48	1.57
T ₃	Seedling dip with <i>Trichoderma harzianum</i> @ 10 g L ⁻¹ + spot application of enriched <i>T. harzianum</i> + neem cake (1:100) @ 250 kg ha ⁻¹ - spray of (metiram 55% + pyraclostrobin 5% WG) @ 2 g L ⁻¹	66.88 (54.93)	55.40 (48.10)	61.14 (51.52)	66.82 (53.80)	4.32	14.20	9.26	1.96
T ₄	Seedling dip with <i>Pseudomonas fluorescens</i> @ 10 g L ⁻¹ + spot application of enriched <i>P. fluorescens</i> + vermicompost (1:100) @ 250 kg ha ⁻¹ - spray of (cymoxanil 8% + mancozeb 64%) @ 2 g L ⁻¹	66.77 (54.80)	74.50 (59.80)	70.64 (57.30)	69.05 (56.20)	3.83	14.70	9.27	2.10
T ₅	Seedling dip with <i>Pseudomonas fluorescens</i> @ 10 g L ⁻¹ + spot application of enriched <i>P. fluorescens</i> + farm yard manure (1:100) @ 250 kg ha ⁻¹ - spray of (tebuconazole 50% + trifloxistrobin 25% WG) @ 0.5 g L ⁻¹	46.30 (42.87)	49.30 (44.60)	47.80 (43.74)	33.30 (35.20)	5.92	19.60	12.76	2.74
T ₆	Seed treatment with carbendazim @ 2 g kg ⁻¹ followed by carbendazim spray @ 1 g L ⁻¹ (treated check)	69.37 (56.40)	72.90 (58.70)	71.14 (57.55)	69.30 (56.40)	4.59	12.90	8.75	1.98
T ₇	Seed treatment with carbendazim @ 2 g kg ⁻¹ followed by spray of difenconazole @ 1 ml L ⁻¹ (treated check)	71.98 (58.02)	64.80 (53.80)	68.39 (55.91)	47.70 (43.60)	3.66	15.30	9.48	2.11
T ₈	Untreated check	73.43 (59.28)	74.20 (59.80)	73.82 (59.54)	69.10 (56.50)	3.14	7.60	5.37	-
	S.Em ±	2.37	3.20	2.02	2.54	0.36	0.65	0.44	
	C.D. at 5%	7.20	9.71	6.12	7.71	1.09	1.98	1.32	
	CV (%)	7.71	10.14	6.50	8.68	13.90	8.32	8.41	

Figures in parenthesis are angular transformed values.

(69.10) were noticed in untreated check with least dry chilli yield (5.37 q ha^{-1}) (Table 1). The present investigation was in line with the efficacy of (tebuconazole 50% + trifloxystrobin 25% WG) for the management of *Cercospora* leaf spot and powdery mildew of sesame as reported by Palakshappa *et al.* (2020). However, Ajithkumar *et al.* (2014) reported that UPF 509 (azoxystrobin 8.3% + mancozeb 66.7%) 75% WG was more effective in reducing powdery mildew and anthracnose disease in chilli without any phytotoxic symptoms on the plants.

The economics of fungicides on severity of anthracnose and powdery mildew with dry chilli yield (tebuconazole 50% + trifloxystrobin 25% WG) @ 0.5 g L^{-1} recorded highest average fruit yield (12.76 q ha^{-1}) and B:C ratio of 1:2.74 followed by treated check (difenconazole) @ 1 ml L^{-1} with fruit yield of 9.48 q ha^{-1} and B: C ratio of 1: 2.11 by considering the average market price prevailed for three months in the Agricultural Produce Market Committee (APMC).

CONCLUSION

Findings of the studies conclude that spray of (tebuconazole 50% + trifloxystrobin 25% WG) @ 0.5 g L^{-1} are effective in reducing anthracnose and powdery mildew diseases of chilli without any phytotoxic symptoms on the plants. The information on the efficacy of new combination fungicide (tebuconazole 50% + trifloxystrobin 25% WG) @ 0.5 g L^{-1} also fulfills the prerequisite criteria for the selection of appropriate dose of fungicide in order to develop an eco-friendly disease management of powdery mildew and anthracnose of chilli in field conditions.

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Relative antagonistic efficacy of *Trichoderma* spp. against *Sclerotium rolfsii* (Sacc.) causing collar rot of chickpea (*Cicer arietinum* L.)

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ABSTRACT

The present study was undertaken in order to find out the relative antagonistic efficacy of four *Trichoderma* species viz., *Trichoderma viride*, *Trichoderma harzianum*, *Trichoderma virens* and *Trichoderma azospirillum*, against *Sclerotium rolfsii* incited collar rot in chickpea. Under *in-vitro* condition, four species of *Trichoderma* were tested against *S. rolfsii*. Minimum radial growth of the *S. rolfsii* was recorded in the *T. viride* (20.40 mm), 4 days after inoculation with maximum growth inhibition of 54.67 per cent, statistically superior among all *Trichoderma* spp. tested, which was followed by *T. harzianum*, radial growth (22.20 mm) and inhibition (50.67%), by dual culture technique. After 20 days of incubation, maximum per cent reduction of sclerotia formation was recorded in *T. virens* (73.56%). Efficacy of best *in-vitro* bioagents, *Trichoderma viride* and *T. harzianum*, were evaluated against collar rot disease of chickpea in pot experiment. Impact of treatment application method viz., soil application, seed treatment and integration of both soil application and seed treatment of bioagents were also studied. All the treatments proved significantly superior when compared with pathogen inoculated control. Maximum per cent reduction in pre-emergence seed rot (90.91%) and post emergence seedling mortality (43.75%) were recorded in *Trichoderma viride* applied through integration of soil application and seed treatment. *T. harzianum* recorded 81.82 per cent reduction in pre-emergence seed rot and 37.50 per cent post emergence seedling mortality. Maximum per cent final plant population (66.67%) was observed in *T. viride* applied through integration of soil application and seed treatment. *Trichoderma* spp. had synergistic impact on plant vigour and grain yield.

Key words: *Trichoderma* spp., *Sclerotium rolfsii*, chickpea, per cent pre-emergence seed rotting (PESR), per cent post emergence seedling mortality (PESM).

The chickpea (*Cicer arietinum*) is a legume crop in temperate and sub-tropical regions. It belongs to family *Fabaceae*. It is also called by various names such as gram, Bengal gram, Garbanzo, Garbanzo bean, Egyptian pea, *chana* and *chhole* in various places. Chickpea, the most important pulse crop widely grown in India, accounts for nearly 75 per cent of the total pulse production in the world (Keote *et al.*, 2019). There are two types of *gram* – Desi and Kabuli. Around 80 per cent of the *chana* produced worldwide is of Desi type and the rest is of Kabuli variety. In India desi variety is also the most commonly cultivated. It is grown as a *rabi* season crop, under irrigated and rainfed conditions having a very important position in the arid and semi-arid farming system. It also adds plenty of organic matter which improves soil health and fertility. Because of its deep taproot system it can resist drought by extracting water from deeper layers in the soil profile (Kashiwagi *et al.*, 2005 and Krishnamurthy *et al.*, 2003).

India ranks first in chickpea production and consumption in the world. In India, area under chickpea was 10.57 million hectares with a production of 11.15 million tonnes and productivity of 1055 kg ha⁻¹, whereas in Rajasthan it was grown on 1.38 million hectares with a production of 1.47 million tonnes and productivity of 1065 kg ha⁻¹ during *rabi* 2017-18 (Anonymus, 2019). Despite the high total production and more nutritive value, productivity of chickpea was low due to many biotic and abiotic constraints. Among the biotic constraints chickpea crop is attacked by 172 pathogens (67 fungi, 22 viruses, 3 bacteria, 80 nematodes and mycoplasma) from the entire world (Nene *et al.*, 1996). Among the soil borne diseases such as fusarium wilt (*Fusarium oxysporum* f. sp. *ciceri*), dry root rot (*Rhizoctonia bataticola*) and collar rot (*Sclerotium rolfsii*) are the major limiting factors in chickpea production. Chickpea diseases may cause yield losses up to 100 per cent depending on time of infection. Dry root rot and collar rot are emerging as a

major threat to chickpea production due to drastic climate change (Pande *et al.*, 2010). *S. rolfisii* is an economically important pathogen on numerous crops worldwide. It has an extensive host range, at least 500 species in 100 families are susceptible, the most common hosts are legumes, crucifers and cucurbits, and commonly occurs in the tropics, subtropics, and other warm temperate regions (Hemanth *et al.*, 2016).

Among these collar rot caused by *Sclerotium rolfisii* Sacc. [teleomorph: *Athelia rolfisii* (Curzi)] is a devastating soil-borne disease of fungal origin (Kokub *et al.*, 2007) causing plant mortality from 54.7 to 95 per cent (Kotasthane *et al.*, 1976). It was first reported in India by Butler (1918). Management of soil borne plant pathogens including *S. rolfisii* can be achieved by different fungicides, soil fumigants (methyl bromide) and bioagents. Frequent application of fungicides cause environmental pollution therefore there is a need to reduce the amount of chemicals applied to soil (Hemanth *et al.*, 2016). The fast growth of the *S. rolfisii* and its capability of producing excessive sclerotia that may persist in soil for several years (Singh *et al.*, 2012). Hence, management of *S. rolfisii* causing collar rot of chickpea is difficult to achieve chemically. In this context bioagents can be used as an alternative source for controlling soil-borne diseases since they comprise a rich source of bioactive substance (Jegathambigai *et al.*, 2010). Biological control of plant diseases has been the subject of extensive research in the last two decades. *Trichoderma* spp. is well documented as effective biological control agents of plant diseases (Sain and Pandey, 2016). Therefore, the present investigation was carried out to evaluate the *Trichoderma* spp. against *S. rolfisii* causing collar rot of chickpea.

MATERIALS AND METHODS

Infected plants showing typical collar rot symptoms were collected during the months of October to December, 2018 from the chickpea fields of Agriculture Research Station, Ummedganj (Kota). Isolation of fungus was carried out through standard tissue isolation through infected plant parts and the pure culture of fungus was obtained by further growing culture under aseptic conditions on PDA slants at 4±1°C. Pathogenicity was proved through soil inoculation. Pathogen was identified from ITCC (Indian Type Culture Collection) Lab, IARI, Division of Plant Pathology, New Delhi.

Efficacy of bioagents against the pathogen *in-vitro*

In-vitro evaluation of bioagent was carried out with complete randomized design with 5 treatments *viz.*, T₁-*Trichoderma viride*, T₂-*T. harzianum*, T₃-*T. virens*, T₄-*T. azospirillum* and T₅-control with 5 replications.

The per cent inhibition of growth of pathogen was calculated by using the formula suggested by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where, I = per cent inhibition, C = growth in control and T = growth in treatment.

Efficacy of bioagents against disease under pot experiment

Two most effective bioagents from *in-vitro* were further evaluated in pot experiment to find out efficacy for management of collar rot.

Soil sterilization: For pot study the soil was sterilized by using formaldehyde by the following procedure. For this raised soil bed was prepared and watered the soil up to saturation level and left undisturbed for two days. After two days the soil was moistened by 4% formaldehyde solution (40 ml formaldehyde per liter of water) up to saturation level and covered by polythene sheet and kept undisturbed for five days. Polythene sheet was removed after five days and soil was exposed to open for seven days to remove the traces of formaldehyde present in soil. This soil was filled to the disinfected pots to carry out further studies.

Soil inoculation of pathogen: The sterilized soil was mixed with *Sclerotium rolfisii* which was isolated from diseased plants or mass cultured on SSM. 10 g mass culture of *S. rolfisii* grown on sorghum seeds was added to upper 15 cm layer of soil in pots and mixed thoroughly. The mixed soil was placed in cemented pots. Apparently healthy seeds of chickpea cv. (JG-14) were soaked overnight in water and surface sterilized with 0.1 per cent HgCl₂ solution, washed thrice in tap water before sown in the pots. Ten seeds were placed in one cemented pot after 24 hrs. of inoculation. Three replications were maintained for each treatment. These pots were kept in a net house. Moisture content in the soil was maintained to field capacity by adding required amount of water daily. Proper isolation was maintained to avoid other pathogens. Observations on germination and pre and post emergence mortality were recorded.

Mass culture of *Trichoderma* spp.

Sorghum was soaked in distilled water for 72 hours and were dried on paper. The grains were taken in tray and calcium carbonate @ 25 g kg⁻¹ was added to avoid clumping. About 150 g moistened grains and 75 g dry sand was filled in each 500 ml flask. The conical flasks were plugged with cotton plug, wrapped with paper and autoclaved for 30 min at 121.6°C and 1.05 kg/cm² pressure 2 times by keeping 24 hrs. gap between the 2 successive autoclaving. The grains in

flasks were inoculated with the pure culture of each *T. viride* and *T. harzianum* (6-8 bit) of mycelial disc of 6 mm cut with the help of sterilized cork borer under aseptic condition and incubated at $28 \pm 1^\circ\text{C}$ for 2 weeks. The flasks were shaken on alternate days to avoid clumping of grains and to facilitate early growth of the fungus on the grains. The grains turned blackish dark green due to mycelial growth of the bioagents. The giant culture of each bioagent was used separately for soil application @ 6g/kg soil per pot before 7 days of pathogen inoculation.

Spore suspension of *Trichoderma* spp.: Bioagents *Trichoderma viride* and *T. harzianum*, were cultured in potato dextrose agar (PDA) media and spores were harvested from 7 days old culture plates separately. The seeds of chickpea (var. JG-14) were treated with spore suspension of *Trichoderma* spp. and adjusted to 1×10^8 /ml by serial dilution method. Seeds were treated individually with these spore suspension using carboxy methyl cellulose (CMC) as base. Such treated seeds were sown in pots @ 10 seeds/pot 24 h after pathogen inoculation. The experiment was conducted with 8 treatments in CRD with 3 replications. The treatment details are as under -

T_6 = Soil application (SA) of mass culture of *Trichoderma viride* 72 hrs. before pathogen inoculation, @ 6 g kg^{-1} soil of pots mixed thoroughly, T_7 = Soil application of mass culture of *T. harzianum* 72 hrs. before pathogen inoculation, @ 6 g/kg soil of pots mixed thoroughly, T_8 = Seed treatment (ST) with spore suspension of *T. viride* containing the approximate spore concentrations 1×10^8 spores/ml, T_9 = Seed treatment in spore suspension of *T. harzianum* containing the approximate spore concentrations 1×10^8 spores/ml, $T_{10} = T_6 + T_7$, $T_{11} = T_8 + T_9$, T_{12} = Inoculated control (pathogen), and T_{13} = Uninoculated control.

The percentage seed germination, pre-emergence seed rot and post-emergence seedling mortality were calculated by the formulae give below and yield per pot was recorded

- a) Germination (%) = $\frac{\text{Number of seed germinated}}{\text{Total number of seed sown}} \times 100$
- b) Pre-emergence seed rotting % (PESR) = $\frac{\text{Number of seed not germinated}}{\text{Total number of seed sown}} \times 100$
- c) Post-emergence seedling mortality % (PESM) = $\frac{\text{Number of seedling died}}{\text{Total number of seedling}} \times 100$

$$\text{d) Reduction (\% in PESR \& PESM)} = \frac{C - T}{C} \times 100$$

Where, C = Per cent seed rot/mortality in inoculated control pots and T = Per cent rot/mortality in treated pots.

Analysis and interpretation of the experimental data was done by using completely randomized design (CRD) for both as well as laboratory and pot experiments as suggested by Panse and Sukathme (1985).

RESULTS AND DISCUSSION

In-vitro effect of bio-agents against *S. rolfsii* through dual culture technique

The bio-agents viz., *Trichoderma viride*, *T. harzianum*, *T. virens* and *T. azospirillum*, were evaluated by dual culture technique for their antagonistic effect against *S. rolfsii* under *in-vitro* conditions. The results obtained are presented in Table 1 and illustrated in Fig. 1 (a and b) and Plate 1 (a and b). Data documented in Table 1 clearly indicated that minimum radial growth (20.40 mm) of *S. rolfsii* was recorded with *T. viride* with maximum growth inhibition (54.67%), which was statistically superior among all *Trichoderma* spp. tested. It was followed by *T. harzianum* with radial growth (22.20 mm) and inhibition (50.67%) after four days of incubation. The remaining two *Trichoderma* spp. though showed significant growth inhibition of the *S. rolfsii* over control but statistically inferior with other *Trichoderma* spp. reported above. After 20 days of incubation, maximum per cent reduction of sclerotia formation was recorded in *T. virens* (73.56%) followed by *T. viride* (70.34%) and *T. harzianum* (70.80%). The complete lysis mycelium and parasitized sclerotia of pathogen by all tested bio-agents was also observed.

All the species of *Trichoderma* showed hyphal inhibition of test organism. This could be due to higher competitive ability of *Trichoderma* spp. Weindling (1932) found over growth of hyphae of *T. viride* Pers. on hypha of *S. rolfsii*. It secreted some substance which was found lethal to *S. rolfsii*. Later, Brain (1951) identified the antagonistic substance as gliotoxin. McMilan *et al.* (1949) suggested that reduction in germinability of sclerotia was due to the action of antagonistic organisms. The isolates of *T. viride*, *T. harzianum* and *T. virens* inhibited mycelial growth of the collar rot pathogen significantly (Prasad *et al.*, 2001). Ali and Javaid (2015) found that antagonistic behaviour of *T. viride* was best followed by *T. harzianum* causing 68 and 57 per cent reduction in pathogen growth. The antagonistic effect of *Trichoderma* spp. on *S. rolfsii* reported by many other researchers (Nagamma

Table 1. Efficacy of *Trichoderma* spp. against *S. rolfii*, in-vitro through dual culture technique at 25±1!.

Treatments	Radial growth of <i>S. rolfii</i> at 4 DAI (mm)	Growth inhibition at 4 DAI (%)	No. of sclerotia in radial area of per plates at 20 DAI	Reduction in sclerotia formation at 20 DAI (%)
T ₁ - <i>Trichoderma viride</i>	20.40*	54.67 (47.68) **	129.00	70.34
T ₂ - <i>Trichoderma harzianum</i>	22.20	50.67 (45.38)	127.00	70.80
T ₃ - <i>Trichoderma virens</i>	24.60	45.33 (42.32)	115.00	73.56
T ₄ - <i>Trichoderma azospirillum</i>	23.40	48.00 (43.85)	138.00	68.28
T ₅ -Control	45.00	0.00	435.00	0.00
S Em. ±		0.20		
C.D. at 0.05%		0.60		

*Mean of five replications, **Figures in parentheses are Arc sine transformed values, DAI = days after inoculation.

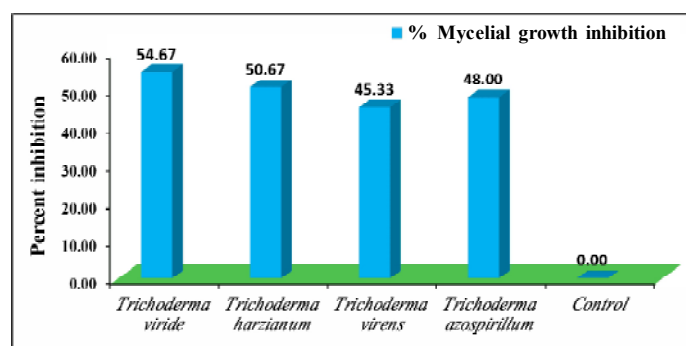


Fig. 1(a). In-vitro efficacy of *Trichoderma* spp. against *S. rolfii*, on per cent mycelial growth inhibition through dual culture technique

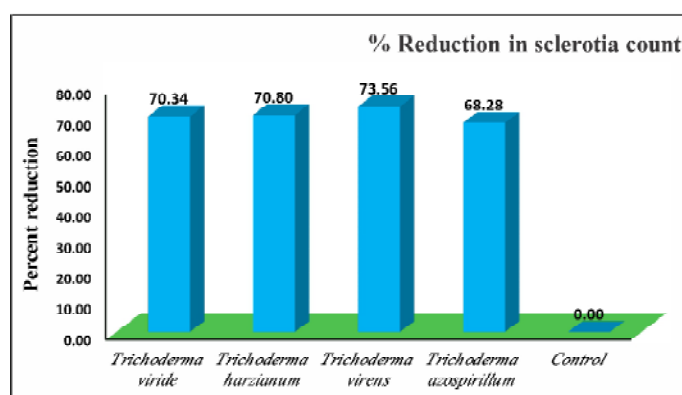


Fig. 1(b). In-vitro efficacy of *Trichoderma* spp. against *S. rolfii*, on per cent reduction in sclerotia numbers through dual culture technique.



Plate 1(a): Efficacy of different *Trichoderma* spp. on growth inhibition of *S. rolfii*, 4 days after inoculation.

and Nagaraja, 2015, Prajapati *et al.*, 2015 and Desai *et al.*, 2018). Salvi *et al.*, 2017 observed maximum growth inhibition (83.33%) against pathogen by *Trichoderma viride*.

Efficacy of bioagents under pot experiments

The data on impact of treatment application method in pot experiment on per cent germination, per cent pre-emergence seed rotting (PESR), per cent reduction in PESR,

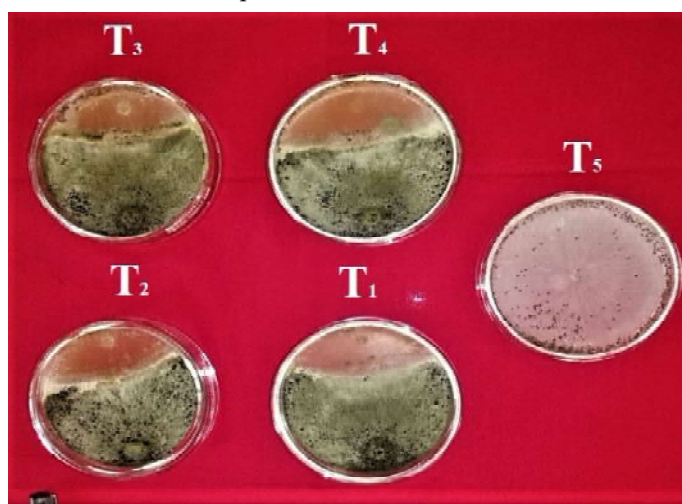


Plate 1(b): Efficacy of different *Trichoderma* spp. on reduction in numbers sclerotia formation by *S. rolfii*, 20 days after inoculation.

per cent post emergence seedling mortality (PESM), per cent reduction in PESH, per cent final plant population and yield per pot (g) are presented in Table 2, Fig. 2 and Plate 2. All the treatments proved significantly superior when compared

Table 2. Efficacy of *in-vitro* evaluation of bioagents along with their application methods against collar rot of chickpea under pot experiment

Treatments	No. of plant emerged	Germination (%)	No. of seed pre-emerged (rotting)	Pre-emergence seed rotting (%)	Reduction in PESR (%)	No. of seedling post emerged (died)	Post emergence seedling mortality (%)	Reduction in PESM (%)	No. of final plant stand	Final plant population (%)	Yield pot ⁻¹ (g)
T ₆	8.00 *	80.00 (63.43) **	1.33	13.33 (21.42)	63.64 (52.91)	3.67	45.83 (42.61)	31.25 (33.99)	4.33	54.17 (47.39)	28.17
T ₇	7.67	76.67 (61.12)	1.67	16.67 (24.09)	54.55 (47.61)	4.00	52.17 (46.25)	25.00 (30.00)	3.67	47.83 (43.75)	23.83
T ₈	8.67	86.67 (68.58)	0.67	6.67 (14.96)	81.82 (64.76)	4.00	46.15 (42.79)	25.00 (30.00)	4.67	53.85 (47.21)	30.33
T ₉	8.33	83.33 (65.91)	1.00	10.00 (18.43)	72.73 (58.52)	4.33	52.00 (46.15)	18.75 (25.66)	4.00	48.00 (43.85)	26.00
T ₁₀	9.00	90.00 (71.57)	0.33	3.33 (10.52)	90.91 (72.45)	3.00	33.33 (35.26)	43.75 (41.41)	6.00	66.67 (54.74)	42.00
T ₁₁	8.67	86.67 (68.58)	0.67	6.67 (14.96)	81.82 (64.76)	3.33	38.46 (38.33)	37.50 (37.76)	5.33	61.54 (51.67)	37.33
T ₁₂	5.67	56.67 (48.83)	3.67	36.67 (37.27)	0.00 (0.00)	5.33	94.12 (75.96)	0.00 (0.00)	0.33	5.88 (14.04)	2.17
T ₁₃	9.33	93.33 (75.04)	—	—	—	—	—	—	9.33	100.00 (90.00)	60.67
			Germination	Pre-emergence seed rotting		Post emergence seedling mortality			Final plant stand	Yield per pot	
S Em. ± =			0.38	1.25		0.49			0.90	3.03	
C.D. at 0.05% =			1.13	3.75		1.46			2.71	9.08	

*Average of three replications, **Figures in parentheses are Arc sine transformed values.

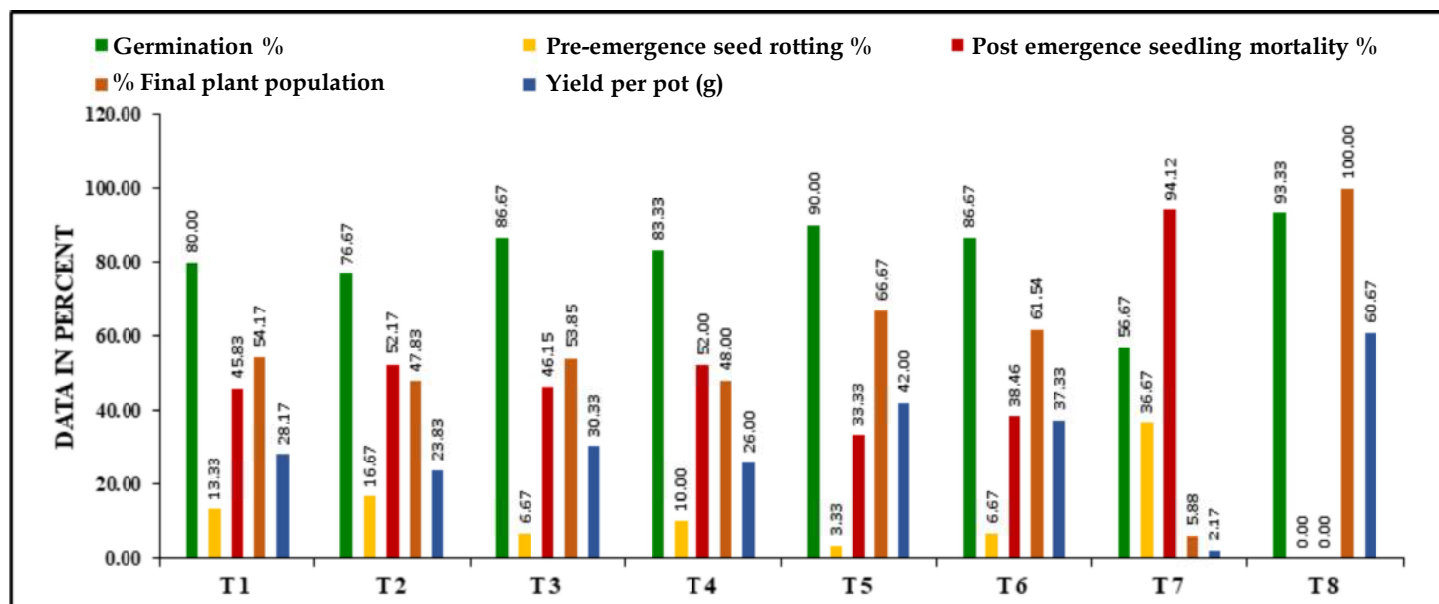
Fig. 2: Efficacy of best *in-vitro* evaluate bioagents against disease under pot experiment.



Plate 2: Mass multiplication of pathogen (*S. rolfsii*) and bioagents (*Trichoderma viride* and *Trichoderma harzianum*)



T₅ = T₁ Soil application (SA) of mass culture of *T. viride* 72 hrs. before pathogen inoculation, @ 6 g kg⁻¹ soil of pots mixed thoroughly, + T₃ = Seeds treatment (ST) with spore suspension of *T. viride* containing the approximate spore concentrations 1x10⁸ spores/ml, T₆ = T₂ SA of mass culture of *T. harzianum* 72 hrs. before pathogen inoculation, @ 6 g kg⁻¹ soil of pots mixed thoroughly + T₄ = ST in spore suspension of *T. harzianum* containing the approximate spore concentrations 1x10⁸ spores/ml, T₇ = Inoculated control (Pathogen), T₈ = Un-inoculated control.

Plate 3: Best performed bioagents along with application method under pot experiment

with pathogen inoculated control. Maximum per cent reduction in PESR (90.91%) and PESM (43.75%) were recorded in *T. viride* applied through integration of soil application and seed treatment, followed by *T. harzianum* which recorded PESR (81.82%) and PESM (37.50%) in same method of application. The seed treatment alone reduced PESR, while soil application reduced PESM thus obtaining more yield. Maximum per cent final plant population (66.67%) was observed in *T. viride* applied through integration of soil application and seed treatment, followed by *T. harzianum* (61.54%). Highest grain yield (42.00 g/pot) recorded in *T. viride* applied through integration of soil application and seed treatment, followed by *T. harzianum* (37.33 g/pot) among treated pots, indicating that *Trichoderma* spp. had synergistic impact on plant vigour and grain yield. Singh (2008) also concluded that higher yield was observed

when seeds were treated with a combination of *T. viride* in sunflower crop. Tripathi (2009) reported that seed treatment with *Trichoderma* spp. were effective against *Sclerotium rolfsii* in increasing germination and decreasing the mortality of seedlings over control. Lahre *et al.*, (2012) accounted similar findings that seed treatment with *Trichoderma* spp. was found to be most effective with maximum germination (96.29%) and least total mortality (18.51%). Yuvraj *et al.* (2018) recorded data of plant population and number of dead plants and observed that both strains, *T. viride* and *T. harzianum*, were significantly superior in management of collar rot of chickpea caused by *Sclerotium rolfsii*. Ahsan *et al.* (2018) reported that maximum disease control was recorded in treatment where *T. harzianum* was applied @ 20 g pot⁻¹ and minimum in 5 g pot⁻¹. A positive relationship in increasing dose of application of *T. harzianum* and disease management was observed. Swathi *et al.* (2018) reported that *Trichoderma* isolates applied through seed and soil application methods. In pot culture, isolate gave more than 50 per cent disease control.

CONCLUSION

Among the four species of *Trichoderma* tested against *S. rolfsii*, significantly minimum radial growth of the *S. rolfsii* was recorded after 4 DAI in *T. viride* (20.40 mm) with maximum growth inhibition (54.67%), which was followed by *T. harzianum* radial growth and 50.67 per cent inhibition under *in-vitro* conditions by dual culture technique. After 20 days of incubation maximum per cent reduction (73.56%) of sclerotia formation was recorded in *T. virens*. Maximum per cent reduction in PESR (90.91%) and PESM (43.75%) were recorded in *T. viride* when applied through integration of soil application and seed treatment. Per cent final plant population (66.67%) was also increased by *T. viride* application through integration of soil application and seed treatment.

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Identification of hot spots of rust disease in cowpea during different cropping seasons in northern Karnataka

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ABSTRACT

Extensive survey carried out to assess the severity of cowpea rust disease in four districts of northern Karnataka viz., Dharwad, Belagavi, Bagalkot and Haveri during *kharif*, *rabi* and summer seasons of 2014-15 registered maximum mean severity of cowpea rust in Dharwad district (35.29%) followed by Belagavi (34.06%) and Haveri district (31.38%). The minimum severity was noticed in Bagalkot district (29.98%). The severity of rust varied in *kharif* (39.30%), *rabi* (21.76%) and summer (17.55%), and places such as MARS, Dharwad, Inchal and Yattinagudda were identified as hotspots for cowpea rust in northern Karnataka. Survey gave information about existence of variability among the pathogen, in particular agro climatic zones, and the intensity with which it affected the yield and quality.

Key words: Cowpea rust, growing environment, hotspots, survey

Pulses provide the vital protein in the diet of majority of Indians. In addition, they provide nutritious fodder to the cattle. These crops play an important role in Indian agriculture and are best known as “poor man’s meat”, which constitute the major source of dietary protein. Pulses contain 20 to 30 per cent protein, which is 2.5 to 3.0 times more than the value normally found in cereals. Besides their high nutritional value, they have a unique characteristics of maintaining and restoring soil fertility through biological nitrogen fixation, which plays a vital role in sustainable agriculture (Asthana, 1998).

In India, cowpea is grown in an area of about 3.9 m. ha with a production of 2.2 mt at a productivity level of 625 kg ha⁻¹. In Karnataka, cowpea is grown in area of about 0.78 m. ha, production of 0.22 mt with productivity of 302 kg ha⁻¹ (Anon, 2013). Cowpea varieties C-152 and TVX-1839-9E are mainly grown for seed purpose, while S-488 and Pusa Barsathi are for vegetable purpose. Diseases are the important limiting factors for the production of cowpea in Karnataka in last few years because of changing climatic conditions. The rust severity is increasing in all the major cowpea growing areas. In order to assess the severity of disease in different seasons and also to identify the hot spots for the rust, the present survey was undertaken in major cowpea growing northern Karnataka district.

MATERIAL AND METHODS

A roving survey was conducted during *kharif*, *rabi* and summer seasons of 2014-15 in major cowpea growing areas

of northern Karnataka viz., Dharwad, Bagalkot, Haveri and Belgaum districts. Five villages from each district and one to three fields from each village were surveyed. The disease severity was recorded from 15 selected plants in each field following 0-9 scale (Mayee and Datar, 1986). Based on this, the data on per cent disease index was assessed as per method of Wheeler (1969).

Observations on disease severity were recorded on leaves, stems and pod. Disease severity was adsonotenat stage of the crop, irrigated, rainfed and cropping system. The infected samples were collected from the farmers fields during the survey and the spores were dislodged from the leaves using a camel foot brush and collected. Both spores and leaves samples were collected and stored at -70°C for various *in vitro* and pot culture experiments in glass house.

RESULTS AND DISCUSSION

The results on severity of rust in northern Karnataka are presented in Tables 1 to 3. The maximum mean severity of cowpea rust was observed in Dharwad district (35.29%) followed by Belagavi (34.06%) and Haveri (31.38%) districts. The minimum severity was noticed in Bagalkot district (29.98%).

In Dharwad district, maximum disease severity (PDI) of cowpea rust was recorded at MARS, Dharwad (43.55%) during *kharif* followed by Yattinagudda village (40.88%) at pod development stage (Table 1). However, least disease severity was observed in Selavadi village of Navalgund taluk

Table 1. Survey on the severity of cowpea rust disease in northern Karnataka during *khari*f 2014-15.

District	Taluk	Village	Stage of the crop	Type of cultivation	PDI (%)
Bagalkot	Bagalkot	Bevinamatti	Flowering	Rainfed	31.96
		Honnakatti	Pod development	Rainfed	33.37
		Sorkoppa	Pod development	Rainfed	31.59
	Taluk mean				32.38
	Badami	Guledagudda	Flowering	Rainfed	33.46
		Kerur	Pod development	Irrigated	30.92
		Kulgeri	Flowering	Rainfed	29.77
	Taluk mean				31.38
	Bilagi	Badagandi	Pod development	Rainfed	27.28
		Girisagara	Flowering	Rainfed	29.97
		Teggi	Flowering	Rainfed	26.98
	Taluk mean				27.41
	Hungund	Amingad	Pod development	Rainfed	31.68
		Kodihal	Flowering	Rainfed	23.35
		Ilkal	Flowering	Rainfed	33.28
	Taluk mean				29.43
	Mudhol	Dadanatti	Pod development	Rainfed	30.44
		Killa Hoskote	Flowering	Rainfed	27.33
		Shirur	Flowering	Rainfed	28.22
	Taluk mean				28.66
	District mean				29.98
Belagavi	Bailhongal	Belavadi	Flowering	Irrigated	39.78
		Budarkatti	Pod development	Irrigated	33.67
		Honaga	Flowering	Rainfed	36.22
		Inchal	Pod development	Rainfed	41.00
		Kakati	Pod development	Irrigated	34.67
	Taluk mean				36.35
		Boregal	Pod development	Irrigated	25.67
		Goturu	Flowering	Rainfed	36.00
		Kavali katti	Flowering	Rainfed	25.32
	Gokak	Khanapura	Pod development	Irrigated	28.67
		Musaguppi	Flowering	Rainfed	28.78
	Taluk mean				31.78
	District mean				34.06
Dharwad	Dharwad	Amminabhavi	Flowering	Rainfed	32.44
		Hebballi	Flowering	Rainfed	33.33
		Kannvihonnapur	Pod development	Rainfed	37.77
		MARS, Dharwad	Pod development	Rainfed	43.55
		Mugali	Pod development	Rainfed	40.11
		Narendra	Pod development	Rainfed	30.33
		Yattinagudda	Pod development	Rainfed	40.88
	Taluk mean				36.93
	Hubballi	Amargola	Pod development	Rainfed	32.44
		Gabbur	Pod development	Rainfed	34.33
		Bomma samudra	Maturity	Rainfed	36.66
		Belagali	Pod development	Rainfed	38.60
		Siraguppi	Pod development	Rainfed	36.11
	Taluk mean				35.62
	Kundagol	Gudenkatti	Flowering	Rainfed	32.55
		Ramanakoppa	Flowering	Rainfed	35.64
		Samsi	Flowering	Rainfed	36.55
	Taluk mean				34.91
	Navalgund	Annigeri	Pod development	Irrigated	32.11
		Basapur	Pod development	Rainfed	36.22
		Majjigudda	Pod development	Rainfed	34.22
		Sasvihalli	Flowering	Rainfed	35.71
		Selavadi	Flowering	Irrigated	30.30
	Taluk mean				33.71
	District mean				35.29

Contd..

District	Taluk	Village	Stage of the crop	Type of cultivation	PDI (%)
Haveri	Hanagal	Akkialur	Flowering	Rainfed	33.67
		Masanagatti	Pod development	Rainfed	39.11
		Tilavalli	Pod development	Rainfed	35.00
	Haveri			Taluk mean	35.92
		Guttal	Flowering	Rainfed	31.00
		Haveri	Flowering	Rainfed	28.55
		Negalur	Flowering	Rainfed	25.22
	Ranebennur			Taluk mean	28.25
		Asundi	Flowering	Rainfed	37.22
		Chalageri	Maturity	Rainfed	31.13
		Itagi	Pod development	Rainfed	27.61
	Shiggaon			Taluk mean	31.98
		Bankapur	Flowering	Rainfed	34.67
		Hulagur	Flowering	Rainfed	25.94
		Kengapur	Flowering	Rainfed	24.75
				Taluk mean	28.45
				District mean	31.38

(30.30%) at flowering stage of the crop. Among four taluks surveyed, the highest average severity of cowpea rust was observed in Dharwad taluk (36.93%) followed by Hubballi (35.62%) and Kundagol (34.91%) taluks, respectively.

In Belagavi district, the maximum severity of cowpea rust was recorded in Inchal village (41.00%) of Bailhongal taluk, at pod development stage followed by Belavadi village (39.78%) of Bailhongal taluk at flowering stage (Table 1). The minimum severity was observed in Kavalikatti village (25.32%) of Gokak taluk followed by Boregal (25.67%) of Gokak taluk at pod development stage. Among the two talukas surveyed the highest average disease severity (36.35%) was observed in Bailhongal taluk. The least disease severity was observed in Gokak taluk (31.78%).

In Bagalkot district, the maximum disease severity of cowpea rust was recorded in Guledagudda (33.46%) of Badami taluk at flowering stage followed by Honnakatti (33.37%) of Bagalkot taluk at pod development stage (Table 1). The minimum severity was observed in Kodihal village (23.35%) of Hunagunda taluk at flowering stage. Among the five taluks surveyed, the highest average disease severity was observed in Bagalkot taluk (32.38%) followed by Badami taluk (31.38%). The least disease severity was observed in Bilagi taluk (28.28%).

In Haveri district, the maximum severity of cowpea rust was recorded in Masanagatti village (39.11%) of Hanagal taluk at pod development stage followed by Asundi village (37.22%) of Ranebennur taluk at flowering stage (Table 1). The minimum severity was observed in Kengapur village (24.75%) of Shiggaon taluk at flowering stage. Among the

four taluks surveyed the highest average severity of cowpea rust was observed in Hanagal taluk (35.92%). The least disease severity was observed in Haveri taluk (28.25%).

The results on severity of rust in *rabi* season are presented in Table 2. The maximum mean severity of cowpea rust was observed in Dharwad district (17.09%) followed by Belagavi district (12.92%) and Haveri district (12.76%), respectively. The minimum severity was noticed in Bagalkot district (2.99%).

In Dharwad district the maximum disease severity of cowpea rust was recorded at MARS, Dharwad (27.44%) at pod development stage followed by Somaopur village (20.00%) at flowering stage. However, least disease severity was observed in Bhadrappuru village of Navalgund taluk (11.00%) at pod development of the crop. Among these three talukas surveyed, the highest average severity of cowpea rust was observed in Dharwad taluk (19.08%) followed by Hubballi taluk (18.51%) the least average severity was observed in Navalgund taluk (13.70%). In most of the areas least severity of rust disease was recorded.

In Bagalkot district, the disease severity of cowpea rust was recorded in Neerlkeri village (15.56%) of Bagalkot taluk at pod development stage.

In Haveri district, the maximum severity of cowpea rust was recorded in Asundi village (31.11%) of Ranebennur taluk followed by Itagi village (20.00%) of Ranebennur taluk at pod development stage. The minimum severity was observed in Hanumanamatti village (10.00%) of taluk Ranebennur at flowering stage.

In Belagavi district, the maximum severity of cowpea rust was recorded in Badal Anakalagi village (15.56%) of Bailhongal taluk at flowering stage followed by Kakati village (14.75%) of Belagavi taluk at pod development stage. The

minimum severity was observed in Vantamuri village (10.00%) of Balagavi taluk at pod flowering stage. Among the two taluks surveyed the highest average disease severity (13.22%) was observed in Bailhongal taluk.

Table 2. Survey on the severity of cowpea rust disease in northern Karnataka during *rabi* 2014-15

District	Taluk	Village	Stage of the crop	Type of cultivation	PDI (%)
Bagalkot	Bagalkot	Kankanakoppa	Pod development	Irrigated	11.11
		Neerlkeri	Pod development	Irrigated	15.56
		Sulikeri	Pod development	Rainfed	--
	Badami	Belure	Pod development	Rainfed	Taluk mean 13.33
			Flowering	Irrigated	0.00
			Pod development	Rainfed	0.00
		Katapur	Pod development	Rainfed	0.00
	Hungunda	Bhimanagada	Flowering	Irrigated	Taluk mean 0.00
			Pod development	Irrigated	0.00
			Flowering	Irrigated	0.00
		Gudur	Flowering	Irrigated	Taluk mean 0.00
Belagavi	Bailhongal	Badal anakalagi	Flowering	Irrigated	District mean 0.00
		Belavadi	Flowering	Rainfed	15.56
		Budarkatti	Pod development	Irrigated	13.00
	Belagavi	Kakati	Pod development	Irrigated	11.11
			Flowering	Irrigated	Taluk mean 13.22
			Flowering	Irrigated	14.75
	Dharwad	Hebbli	Pod development	Rainfed	13.33
			Flowering	Rainfed	27.44
			Pod development	Rainfed	15.56
	Hubballi	Amargola	Flowering	Rainfed	20.00
			Pod development	Rainfed	Taluk mean 19.08
			Flowering	Rainfed	20.00
Dharwad	Navalagunda	Bhadrapur	Pod development	Rainfed	13.30
			Pod development	Rainfed	22.25
			Flowering	Rainfed	0.00
	Haveri	Devihosur	Pod development	Rainfed	Taluk mean 11.22
			Flowering	Rainfed	11.00
			Pod development	Rainfed	15.56
	Ranebennur	Asundi	Flowering	Rainfed	14.44
			Pod development	Rainfed	Taluk mean 13.70
			Flowering	Rainfed	District mean 17.09
	Haveri	Karajagi	Pod development	Irrigated	0.00
			Flowering	Irrigated	0.00
			Pod development	Irrigated	0.00
Haveri	Ranebennur	Hanumanamatti	Flowering	Irrigated	Taluk mean 0.00
			Pod development	Irrigated	31.11
			Flowering	Rainfed	10.00
	Ranebennur	Itagi	Pod development	Irrigated	20.00
			Pod development	Irrigated	15.56
			Flowering	Irrigated	Taluk mean 25.52
	Ranebennur	Kakol	Pod development	Irrigated	District mean 12.95
			Flowering	Irrigated	12.95
			Pod development	Irrigated	12.95

The results on severity of rust in summer season are presented in Table 3. In Dharwad district, Botanical garden of MARS, Dharwad the incidence of rust severity was 17.55 per cent, In Haveri district rust incidence was (22.55%) in Asundi Village of Ranebennur taluk.

In Bagalkot district there was no cowpea rust disease, and also there was no severity of cowpea rust disease in

other two districts (Table 3). This rust disease was only severe in the *kharif* season, while in *rabi* only few per cent of disease was present. Whereas, in summer there was no incidence of rust. Survey gave information about existence of variability among the pathogen in particular agro climatic zones and the intensity with which it effected the yield and quality. It is necessary to conduct a systematic survey of disease to

Table 3. Survey on the severity of cowpea rust disease in northern Karnataka during summer 2014-15

District	Taluk	Village	Stage of the crop	Type of cultivation	PDI (%)	
Bagalkot	Bagalkot	Honnakatti	Pod development	Rainfed	0.00	
		Neelgund	Pod development	Rainfed	0.00	
		Sulla	Pod development	Irrigated	0.00	
	Taluk mean				0.00	
	Badami	Holehalure	Pod development	Rainfed	0.00	
		Hosur	Pod development	Rainfed	0.00	
		Kerur	Flowering	Irrigated	0.00	
	Taluk mean				0.00	
	Hunagund	Basavanal	Pod development	Rainfed	0.00	
		Ilakal	Flowering	Irrigated	0.00	
		Kamatagi	Flowering	Irrigated	0.00	
	Taluk mean				0.00	
	District mean				0.00	
	Belagavi	Bailhongal	Belavadi	Flowering	Rainfed	0.00
			Inchal	Pod development	Irrigated	0.00
			Nesargi	Flowering	Irrigated	0.00
Gokaka		Lolasur	Flowering	Irrigated	0.00	
		Musaguppi	Flowering	Rainfed	0.00	
		Tigadi	Pod development	Irrigated	0.00	
Taluk mean				0.00		
District mean				0.00		
Dharwad		Dharwad	Amminabavi	Pod development	Rainfed	0.00
			IGFRI Block	Flowering	Rainfed	0.00
	MARS, Dharwad		Flowering	Rainfed	17.55	
	Narendra		Pod development	Rainfed	10.12	
	Taluk mean				13.83	
	Hubballi	Bhadrapur	Flowering	Rainfed	0.00	
		Hubballi	Pod development	Irrigated	0.00	
		Sirguppi	Pod development	Rainfed	0.00	
	Navalagund	Alagavadi	Pod development	Rainfed	0.00	
		Annigeri	Flowering	Rainfed	0.00	
Amaragol		Pod development	Rainfed	0.00		
Taluk mean				0.00		
District mean				4.61		
Haveri	Haveri	Devihosur	Pod development	Irrigated	0.00	
		Nelogal	Flowering	Rainfed	0.00	
		Devagiri	Pod development	Irrigated	0.00	
	Ranebennur	Haveri	Flowering	Rainfed	0.00	
		Asundi	Pod development	Irrigated	22.55	
		Halageri	Flowering	Irrigated	0.00	
		Hanumanamatti	Flowering	Rainfed	0.00	
	Kakol	Pod development	Rainfed	0.00		
	Taluk mean				22.55	
	District mean				11.27	

understand its appearance, prevalence, distribution and extent of its spread to identify endemic areas or hot spots. The data on survey revealed that the disease severity varied from locality to locality. The severity of cowpea rust varied from (23.35 to 43.55%). Maximum mean severity of cowpea rust was observed in Dharwad district (35.29%) followed by Belagavi district (34.04%) and Haveri district (31.38%). The minimum severity was noticed in Bagalkot district (29.98%). The study further indicated that severity of rust was more in *kharif* season compared to *rabi* and negligible in summer. The places such as MARS, Dharwad and Yattinagudda in Dharwad taluk were identified as hotspots.

CONCLUSION

Based on the survey, it could be concluded that the severity of rust disease in cowpea varied in *kharif* (39.3%),

rabi (21.76%) and summer (17.55%) and the places like MARS, Dharwad, Inchal and Yattinagudda are the hotspots of rust disease in cowpea in northern Karnataka.

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Systemic resistance: Plant responses to interaction with fungal bio-control agents

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ABSTRACT

Systemic resistance in plant against phytopathogens is mainly associated with systemic acquired resistance (SAR) and induced systemic resistance (ISR). SAR and ISR are mechanisms of induced defense that confers long-lasting protection against a broad spectrum of phytopathogens. SAR requires the signal molecule salicylic acid (SA) while ISR signal molecules are jasmonic acid (JA) and ethylene. These are associated with accumulation of pathogenesis-related proteins (PRP) which contribute resistance inside plant. Bio-control fungi (BCF) such as *Trichoderma* spp. and *Pseudomonas* spp. are agents that control plant diseases. They have the ability to control numerous soil-borne as well as many foliar and fruit pathogens. BCF also augments nutrient uptake and increase nitrogen use efficiency in crop plants. Some strains also have abilities to improve photosynthetic efficiency of plants. Furthermore, PcPCL1606 has displayed additional traits regarding its fitness in soil and plant root environments such as soil survival, efficient plant root colonization, promotion of plant growth. The present review highlights systemic resistance in plant concerns with SAR and ISR-mediated functional traits, such as enhancement of plant growth and bio-control of phytopathogens.

Keywords: SAR, ISR, BCF, *Trichoderma*, *Pseudomonas*, defense response

Plants possess important type of defense triggers mechanism against different types of plant pathogens. The two main mechanisms recognized are : systemic acquired resistance (SAR) and induced systemic resistance (ISR). SAR, typically triggered by local infection, provides long-term systemic resistance to succeeding pathogen attack, is related with the activation of PR genes and needs the involvement of the signal molecule salicylic acid (SA) (Durrant and Dong, 2004). Second mechanism ISR is thought to be the result of formation of roots surrounded by nonpathogenic rhizospheric bacterium (Harman and Shores, 2007). SAR mechanism is mainly dependent upon salicylic acid for signaling transmission but ISR isn't SA-dependent, rather needs jasmonic acid (JA) as signaling pathway followed by the ethylene signaling pathway. Bio-control fungi (BCF) are beneficial organisms that reduce the negative effects of plant pathogens and promote positive responses within the plant. Recent concepts indicate that their skills to manage plant diseases are solely a set of their capabilities. They manage diseases and additionally produce other advantages, as well as melioration of intrinsic physiological stresses in seeds and mitigation of abiotic stresses. They improve photosynthetic efficiency in plants subjected to many type of stresses. Many fungi increase nitrogen use efficiency in plants. As a consequence, plants treated with beneficial fungi

could also be larger and healthier and have greater yield potential.

Newer researches indicate that a primary technique of pathogen management happens through the ability of the fungi to reprogram plant gene expression. As a consequence, induced systemic resistance (ISR) happens. Genetic reprogramming additionally induces mechanisms within the plant that improve physiological and abiotic stresses and also improve nitrogen use efficiency (NUE) in the plants. However, BCF acts directly with the plants. This describes new information concerning BCF's abilities and also the molecular mechanisms for induction of plant responses.

Formation of the interaction and local plant responses

Many *Trichoderma* strains colonize plant roots of dicots and monocots (Harman and Shores, 2007). *Trichoderma* hyphae coil around the roots by forming appressoria-like structures, and eventually penetrate the root cortex (Yedidia *et al.*, 1999). *Trichoderma* grows intercellularly within the root epidermis and cortex and induces the surrounding plant cells to deposit cell membrane material and produce phenolic resin compounds. This plant reaction limits the *Trichoderma* growth within the root (Yedidia *et al.*, 1999). The plants have the benefit of this relationship through the raised root and

shoot growth, raised macro- and micro-nutrient uptake, and protection from diseases (Gosal *et al.*, 2007, Harman, 2000, Harman and Donzelli, 2001, Serfling *et al.*, 2007, Sherameti *et al.*, 2005, Singh *et al.*, 2000, Yedidia *et al.*, 1999, 2001). This interaction of BCF with the plant leads to reprogramming plant transcriptome and proteome (Alfano *et al.*, 2007, Marra *et al.*, 2006, Schäfer *et al.*, 2009, Segarra *et al.*, 2007, Shores and Harman, 2008a, 2008b, Waller *et al.*, 2008). Hence, this interaction is interdependent on condition that *Trichoderma* spp. and alternative fungi are capable of living freely in soil; they ought to be thought-about as opportunist plant symbionts.

Induced systemic resistance and systemic acquired resistance

A number of plant species are known to develop systemic acquired resistance (SAR) in response to local infection with necrotizing pathogens conferring a broad-range resistance (Durrant and Dong, 2004 and Glazebrook, 2005). SAR is characterized by an early increase in endogenous salicylic acid (SA) and accumulation of pathogens related (PR) proteins (Durrant and Dong, 2004 and Van Loon and Van Strien, 1999). Apparently, evoked systemic responses are not simply initiated by pathogens, however additionally could result from interactions with avirulent microbes. The formation of the rhizosphere by bound strains of plant growth-promoting rhizobacteria (PGPR) results in a state of delicate resistance to resulting pathogen attack, a development typically called induced systemic resistance (ISR); (Pieterse *et al.*, 2003). Rhizobacteria-mediated ISR will occur in several plant species and was additionally incontestable to be effective against a broad range of pathogens not like SA-dependent SAR, extensive work with *Arabidopsis thaliana* has incontestable that ISR depends primarily on signal transduction pathways involving jasmonic acid (JA) and ethylene (Ton *et al.*, 2002). Recent findings indicate that there's cross-talk and an exact degree of overlap between SA and JA signaling pathways (Dong, 2001, Glazebrook *et al.*, 2003 and Schenk *et al.*, 2000). Each the pathways area unit dependent on the positive regulatory protein NPR1, that moves to the nucleus and interacts with TGA transcription issue to induce gene expression. The NPR1 differentially regulates ISR and SAR related gene expression, depending on the signaling pathways.

Fitness feature in fungi

PcPCL1606 showed strong antifungal activity, and hyper sensitive reaction (HPR) production was the most determinant within the antagonistic and bio-control phenotypes (Calderón *et al.*, 2013). Additionally HPR,

alternative antifungal is made by PcPCL1606, like pyrrolnitrin (PRN) or compound (HCN), yet as many exoenzymes like proteases, chitinases, or phosphatases (Vida *et al.*, 2017). Despite, HPR is quite an advanced mechanism against pathogenic fungi within the soil and will have further roles. Some alkyl resorcinol's (to that the compound HPR belongs) behave as quorum sensing-like signal molecules within the genus *Photorhabdus* (Brameyer *et al.*, 2015) and this might have an analogous role in HPR-producing *P. chlororaphis* strains. Thus, further HPR-dependent traits, that area unit totally different from antagonism, might have an essential role within the useful effects of PcPCL1606 on the plant, like the root formation or the biofilm formation (Calderon *et al.*, 2014, 2019).

Moreover, 2 bacteriocins (R-tailocins one and 2), recently described in PcPCL1606 would contribute to raised contend against alternative rhizosphere-associated bacterium (Dorosky *et al.*, 2017). Analysis of the PcPCL1606 genome confirmed a scarcity of phenazine biosynthetic genes, cyclic lipopeptides that are associated with the surfactant, and insecticidal properties, that are typical for *P. chlororaphis* (Raaijmakers *et al.*, 2006). However, PcPCL1606 exhibits a complete fit toxin (fit) cluster (Calderon *et al.*, 2015).

Fungal compounds concerned within the induction of plant defense responses

The elicitor-receptor interaction triggers the pathway that sets the defense system in a plant against pathogen. A standard early component of defense signaling is that the modification of the ion permeability of the cell membrane. Receptor molecule activation first stimulates the opening of ion channels across the membrane because of this, an inflow of calcium ions into the plant cells happens, that then activates reactive oxygen species (ROS) production in the cell. The accumulation of ROS around the location of proliferation has been found within the plant and bacterial pathogen infestation of plants.

Programmed cell death (PCD) initiated by pathogen attack involves the expression of a group of genes that organize the dismantling of cellular components and fast accumulation of toxic molecules, thereby depriving the pathogens of nutrients and ultimately leading to cell death (Pennell and Lamb, 1997). As a result, the remainder of the plant remains unaffected (Kumar *et al.*, 2001). It provides resistance against pathogens and is usually preceded by the rapid accumulation of ROS. This oxidative burst stimulates and contributes to cell death and alternative defense mechanisms. It should additionally act to kill the pathogens directly (Delledonne *et al.*, 2001).

Pathogenesis related (PR) proteins are made as a consequence of SAR, and these defense-related proteins are closely related to pathogen infection. An assortment of hydrolytic enzymes like glucanases, chitinases, and alternative hydrolases are evoked by plant invasion. Next, the synthesis of phytoalexins is initiated as a biochemical plant defense response. These molecule units are thought-about to be the best-studied response of plants to bacterial and plant invasion. Phytoalexins represent a chemically complex cluster of secondary metabolites with strong antimicrobial activity that accumulates round the website of infection and increases when pathogen attacks.

Elicitation of defense: elicitor molecules, the initiators of the defense cascade

Elicitor molecules do not have a signature structure and area unit made from molecules like oligosaccharides, peptides, lipids and proteins. They include molecules released from or made by pathogens (Boller, 1995 and D'Ovidio *et al.*, 2004) that provide information for plants to understand and acknowledge signal from pathogens by cell surface-localized receptors, leading to the activation of plant immunity (Boller, 1995). One major analysis challenge during this space is that the identification of receptors to elicitors, and up to now, only a few receptors are known for specific elicitor molecules. Many current reports have shown that plants are able to respond to the on top of array of elicitor molecules through the interaction with common elicitor motifs.

Non-pathogenic elicitor molecules: inducers of systemic resistance

Flagellin from the useful *Pseudomonas putida*-WCS358 has been according to induce systemic resistance against *P. syringae* in *Arabidopsis* (Meziane *et al.*, 2002). Similarly, the LPS of certain gram-negative bacterium have additionally been according to induce general resistance. These molecules are tripartite amphipathic which produces reactive oxygen species have potential to evoked ISR in *Pseudomonas fluorescens* pathosystems (Meziane *et al.*, 2002) and *P. putida* strains (De Vleeschauwer *et al.*, 2008 and Meziane *et al.*, 2002). They need additionally been according as effective ISR inducers in *Burkholderia cepacia* and *Phytophthora nicotianae* interact with bacterial genus (Tyler, 2002).

Receptor molecules: perception and activation

To date, solely a few receptors that act with elicitor molecules are known. The perception of elicitors involves surface-based receptors or intracellular receptors that may detect pathogenic patterns. In most cases, the surface-based

receptors are the primary detectors of pathogen-derived elicitors (Sanabria *et al.*, 2010).

Fungal receptor molecules-examples and mechanism of action

Chitin elicitor binding protein (CEBiP) is one of the receptor molecules concerned in fungal chitin-binding. This RLP is a LysM domain-containing protein and is essential in rice polymerase signaling, that has been proven through studies that used rice cells with CEBiP-RNAi (Kaku *et al.*, 2006). CEBiP could be a chitin-specific receptor molecule, and its response and activity aren't affected once other elicitor molecules like LPS and peptidoglycan are gift within the absence of chitin.

Plant signaling pathways evoked by bio-control fungi

In plant signaling transmission the best example is *Trichoderma* interaction with the plant, SA content failed to differ from that of management plants, even though polysaccharide synthesis locus (psl) infection did increase salicylate concentrations (Shoresh *et al.*, 2005). However, the bio-control activity of the organism was strongly reduced by diethyldithiocarbamic acid (DIECA), general inhibitor of JA production, or silver thiosulfate (STS), and substance of ethylene activity. This knowledge powerfully prompt that each jasmonic acid is needed for the bio-control activity of the fungi.

Bio-control fungi and their mechanism

Bio-control of plant diseases involves use of an organism or organisms to inhibit infectious agent and reduce disease (Cook and Baker, 1983). The basic idea involves a technique for reducing disease incidence or severity by direct or indirect manipulation of microorganisms (Baker and Cook, 1974 and Maloy, 1993). Understanding the mechanisms of biological management of plant diseases through the interactions between bio-control agent and pathogen govern in soil environment to make conditions contributive for successful bio-control or to boost bio-control ways (Fravel, 1988 and Handelsman and Parke, 1989).

Antibiosis

Antibiosis could also be concerned and play a vital role in disease suppression by bound bacterium and fungi. The method has been defined because the interactions that involve a low-molecular-weight compound or an antibiotic made by a being that incorporates a direct result on another being (Handelsman and Parke, 1989 and Weller and Thomashow, 1993). The mechanism of antibiosis in bio-control has been studied by genetic analysis, *e.g.*, mutants

that don't produce antibiotics to demonstrate a correlation between antibiotic productivity and bio-control activity.

Competition

This method is considered to be an indirect interaction whereby pathogens area unit excluded by depletion of a food base or by the physical occupation of the site (Lorito *et al.*, 1994). Generally, nutrient competition has been believed to have a vital role in disease suppression. Bio-control by nutrient competition will occur once the bio-control agent decreases the availability of a specific substance thereby limiting the expansion of the pathogen. Significantly, the bio-control agents have additional economical uptake or utilizing the system for the substance than do the pathogens (Handelsman and Parke, 1989, Harman and Nelson, 1994 and Nelson, 1991). Iron competition in alkaline soils could also be a limiting issue for microorganism growth in such soils (Handelsman and Parke, 1989 and Maloy, 1993).

Mycoparasitism

This method involves the direct utilization of one organism as food by another (Handelsman and Parke, 1989

and Maloy, 1993). Fungi that are parasitic on alternative fungi are considered as mycoparasites (Baker and Cook, 1974). Several mycoparasites occur on fungi and a few of them are proposed to play a vital role in malady management (Adams, 1990, Lo *et al.*, 1996 and Maloy, 1993). *Darluca filum* was described by Saccardo as a parasite of some rust fungi, especially fungus genus and *Uromyces* (Sundheim and Tronsmo, 1988). Weindling in 1932 discovered *Trichoderma lignorum* parasitizing hyphae of *Rhizoctonia solani* and prompt vaccinating soil with *Trichoderma* spores to regulate damping-off of citrus plant (Weindling and Fawcett, 1936).

CONCLUSION

Although general mechanisms concerning plant response to bio-control fungi inoculation will be derived from the studies delineated higher than it's vital to recollect that natural variations do occur. As an example, some *Trichoderma* species induce growth additionally to ISR (Harman *et al.*, 2008), whereas others do not (Alfano *et al.*, 2007). *Trichoderma* strains are conjointly that donot induce resistance or enhance growth despite their endophytic abilities (De Souza *et al.*, 2008). Bailey *et al.*, 2006 have demonstrated that plant gene expression profiles depend upon the *Trichoderma* isolate colonizing the plant. The responses depend not only on the BCF used, however, conjointly on the plant species or cultivar. *Trichoderma*-treated maize mean yield increases five times, however, there are vital varietal differences, with some maize lines giving neutral or perhaps negative growth responses (Harman, 2006). However, yield responses of T22-treated wheat seem to be extraordinarily sturdy within the field (Harman and Shores, 2007). This can give a significant management tool which will afford a reliable assessment of the interaction. It is a tendency to believe that the talents of those fungi to (a) induce resistance to organic phenomenon stresses like illness and abiotic stresses like drought and salinity and (b) increase NUE build them extraordinarily helpful tools with that to extend plant productivity, improve food security and improve the environment.

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Table 1. Mechanisms of specific bio-control agents for controlling plant pathogens

Antibiosis		
Bio-control agent	Antibiotic	Disease
<i>Pseudomonas fluorescens</i>	Phenazine	<i>Gaeumannomyces graminis</i> var <i>tritici</i>
<i>Trichoderma</i> sp.	Trichodermin	<i>Rhizoctonia solani</i>
<i>Bacillus</i> sp.	Bulbiformin	<i>Fusarium udum</i>
Competition		
<i>Peniophora gigantea</i>	Pathogen	
<i>Erwinia herbicola</i>	<i>Heterobasidium annosum</i>	Root rot of pine
<i>Erwinia herbicola</i>	<i>Erwinia amylovora</i>	Fire blight of pear and apple
Mycoparasitism		
<i>Trichoderma viride</i>	Pathogen	
<i>Ampelomyces quisqualis</i>	<i>Rhizoctonia solani</i>	Damping off of seedling
Cross protection	Powdery mildew pathogen	Powdery mildew
Growth promotion		
Mild strain of CTV	Pathogen	
Mild strain of PRSV	CTV (Citrus Tristeza Virus)	
ISR	PRSV (Papaya Ring Spot Virus)	
<i>Pseudomonas fluorescens</i>	ISR against pathogen	
<i>Trichoderma harzianum</i>	Blossom end rot of apple	
<i>Pseudomonas fluorescens</i>	Grey mold of cotton	
<i>Trichoderma harzianum</i>	CMV in tomato	
<i>Aspergillus niger</i>	Crop	Growth promotion effect
<i>Trichoderma harzianum</i>	Cauliflower	Promotes seedling growth and yield
<i>Trichoderma harzianum</i>	Beans	Enhances germination

- of cacao seedlings by endophytic isolates of four *Trichoderma* species. *Planta*, **224**: 1449-1464.
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***In vitro* and *in vivo* evaluation of newer fungicides against *Alternaria brassicicola* caused leaf spot of cabbage**

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ABSTRACT

An experiment on evaluation of five most effective fungicides *viz.*, azoxystrobin 23% SC (Onestar), kasugamycin 3% SL (Kasu-B), flusilazole 40% EC (Cursor), carbendazim 50% WP (Dhanustin) and metiram 55% + pyraclostrobin 5% WG (Carbrio Top) against *A. brassicicola* causing leaf spot in cabbage *in vitro* at 250 and 500 ppm as well as in field in pots receiving two sprays of 0.05 per cent concentration in *rabi* season was conducted. Among them flusilazole 40% EC was highly efficient as it inhibited 100 per cent mycelial growth of *A. brassicicola* at both the concentrations. Per cent disease index was found minimum after application of flusilazole 40% EC. All the fungicides were superior over control in increasing the yield of cabbage per pot. The maximum weight of head (410 g) was recorded after foliar application with flusilazole 40% EC (C). This investigation will be helpful to farmers in managing *Alternaria* leaf spot of cabbage.

Key words: *A. brassicicola*, fungicides, radial growth, inhibition, yield.

The cabbage (*Brassica oleraceae* var. *capitata* L.) crop belongs to family Brassicaceae. Vegetable crops of Brassicaceae family are commonly termed as cole crops. *Alternaria* species cause a widespread destruction in vegetables and other economically important crops. *Alternaria brassicicola* is a destructive pathogen causing significant losses. Most of the studies on *A. brassicicola* are confined to oilseed crops. *Alternaria* leaf spot is a widespread problem on cabbage. However, inadequate information about losses caused by *A. brassicicola* pathogen that often occurs simultaneously with *A. brassicae* is available in cabbage so the present investigation was carried out. Symptoms overlap to some extent and both the pathogens attack simultaneously. Cabbage is affected of all stages of growth. Symptoms appear on leaves, stem of seedlings, adult plants and on siliquae. Irregular, often circular dark brown-black spots of different sizes (0.5 to several cm in diameter) appear on leaves. Dark appearance of the lesions may be due to profuse production of the dark spores of the fungus or may be due to toxins that kill host cells (Pattanamahakul and Strange, 1999). The spots have characteristic concentric lines inside the spots. Sometimes the spots are surrounded by characteristic yellow halo.

One of the most effective measures to control the disease caused by *Alternaria* is through application of fungicides. Since the pathogen is air-borne, foliar sprays are most effective in managing this disease. Many systemic and non-systemic fungicides have been tested against. This Mancozeb, thiram, bavistin, iprodione, chlorothalonil, azoxystrobin,

propineb, copper oxychloride, etc., have been proved effective in managing the pathogen in many crops. Foliar sprays of dithane M-45 (0.25%), kavach (0.1%) or foltof (0.25%) at 10 days interval controlled *A. brassicicola* on cabbage (Neeraj and Verma, 2010). Propiconazole, tebuconazole, hexaconazole, copper oxychloride and mancozeb were found effective against *A. brassicicola* *in vitro* (Kiran *et al.*, 2018). *Alternaria* leaf spot of cabbage is caused by *Alternaria brassicae* (Berk.) Sacc. or *Alternaria brassicicola* (Schwein.) Wiltshire. Both the species have worldwide distribution on cruciferous hosts, but *A. brassicicola* is the predominant species on cabbage.

MATERIALS AND METHODS

In vitro evaluation of fungicides against *A. brassicicola*

The efficacy of five fungicides (Table 1) was evaluated against *A. brassicicola* at 250 and 500 ppm concentrations on potato dextrose agar medium using poisoned food technique of Grover and Moore (1962). First stock solution of 5000 ppm was prepared in 100 ml of distilled water and then by using normality formula desired concentration of the fungicide was prepared.

The poisoned media was prepared by adding required stock solution in the molten sterilized PDA. Following formula was used for making poisoned PDA with concentrations of 250 and 500 ppm and calculations were made accordingly:

$$N_1 V_1 = N_2 V_2$$

Where, N_1 is the normality or the concentration of the stock solution, i.e., 5000 ppm, N_2 is the desired concentration 250 ppm or 500 ppm, V_1 is the volume of stock solution to be used to make desired concentration and V_2 is the volume of PDA that needed to be poisoned.

Fifteen millilitre of poisoned medium was poured in each sterilized petriplates and suitable checks were maintained without addition of fungicides. Five mm of ten days old culture of *A. brassicicola* was placed in the centre of the poisoned medium and incubated at $27 \pm 1^\circ\text{C}$ for twelve days. Three replications were maintained for each treatment. The radial growth of the colony was measured on alternate days after inoculation. Per cent disease inhibition was calculated by using the formula as suggested by Nene and Thapliyal (1993).

Per cent inhibition =

$$\frac{\text{Mycelial growth in control} - \text{Mycelial growth in treatment}}{\text{Mycelial growth in control}} \times 100$$

In vivo evaluation of fungicides against *A. brassicicola*

The 30 days old cabbage plants were artificially inoculated with the pathogen (2×10^4 spores ml^{-1}). The above fungicides at 0.05 per cent were sprayed twice at 10 days interval on cabbage plants after getting symptoms of *Alternaria* leaf spot. Pots with inoculated cabbage plants without spraying fungicides were kept as control. The disease intensity was recorded from 35 to 65 days with an interval of 5 days in each treatment. The observations on severity of *Alternaria* leaf spot were recorded on 10th day after second application of fungicides.

Table 1. List of fungicides used for evaluation to manage leaf spot of cabbage

Common name	Trade name	Active ingredients	Source	Quantity*
Carbribo	Carbribo Top	Metiram 55% + BASF pyraclostrobin 5% WG		1.00 g
Kasugamycin	Kasu-B	Kasugamycin 3% SL	Dhanuka Agritech Ltd.	2.17 ml
Azoxystrobin	One star	Azoxystrobin 23% SC	Dhanuka Agritech Ltd.	16.60 ml
Cursor	Cursor	Flusilazole 40% EC	Dhanuka Agritech Ltd.	0.83 g
Carbendazim	Dhanustin	Carbendazim 50% WP	Dhanuka Agritech Ltd.	1.25 ml

*Amount of fungicides used for making stock solution

The observation on severity of the disease on the foliage was recorded by using 0-5 scale (Mayee and Datar, 1986 and Verma and Saharan, 1994) (Table 2) and per cent disease index (PDI) was calculated by using the formula suggested by Wheeler (1969).

Table 2. Key for the assessment of *Alternaria* disease severity on crucifers

Scale	Description
0	No symptoms on leaf
1	Small round black dots covering 1 per cent or less of the leaf area
3	Grey, circular spots containing concentric rings to cover 1-10 per cent area
5	Lesions enlarge grey circular spots with concentric rings and a black border to cover 11-25 per cent of the leaf area
7	Lesions enlarge and coalesce with each other to cover 26-50 per cent of the leaf area
9	Lesions coalesced with concentric rings and black border to cover 50 per cent or more of leaf area, defoliation occurs

$$\text{PDI} = \frac{\text{Sum of individual disease rating}}{\text{Number of heads/leaves observed}} \times \frac{100}{\text{Maximum disease rating}}$$

RESULTS AND DISCUSSION

In vitro evaluation of fungicides against *A. brassicicola*

Five fungicides viz., azoxystrobin 23% SC, kasugamycin 3% SL, flusilazole 40% EC, carbendazim 50% WP and metiram 55% + pyraclostrobin 5% WG were evaluated for their efficacy to manage *A. brassicicola*. It could be inferred from the observations recorded in the Table 3 that flusilazole 40% EC, metiram 55% + pyraclostrobin 5% WG and kasugamycin 3% SL were comparatively efficient in managing the *Alternaria* leaf spot of cabbage. Flusilazole 40% EC was most efficient chemical resulting in 100 per cent inhibition of the pathogen at both 250 and 500 ppm concentrations. Second best fungicide treatment was metiram 55% + pyraclostrobin 5% WG, which inhibited 68.11 and 77.44 per cent *Alternaria* leaf spot of cabbage at 250 ppm and 500 ppm, respectively.

Least inhibition or 8.11 and 27.77 per cent was obtained in carbendazim 50% WP at 250 and 500 ppm, respectively, which was in confirmation to the study conducted by Khan *et al.* (2007) on *Alternaria* blight of rapeseed-mustard. According to the reports, carbendazim 50% WP inhibited 38.5 per cent disease when used in 500 ppm concentration. Meena *et al.* (2012) also reported that fungicide carbendazim provided least mycelial growth inhibition over control ranged from 2.6 to 86.1 per cent when tested upon various isolates of *A. brassicae*. Azoxystrobin 23% SC was found to inhibit 27.77 and 43 per cent pathogen growth at 250 and 500 ppm, respectively. Similar results were reported by Kiran *et al.* (2018).

Table 3. *In vitro* evaluation of fungicides in different concentration for management of *Alternaria* leaf spot of cabbage

Fungicides	Radial growth (cm)*		% Inhibition	
	At 250 ppm	At 500 ppm	At 250 ppm	At 500 ppm
Kasugamycin 3%SL	4.13	2.77	54.11	69.22
Metiram 55%+ pyraclostrobin 5% WG	2.87	2.03	68.11	77.44
Azoxystrobin 23% SC	6.50	5.13	27.77	43.00
Carbendazim 50% WP	8.27	6.50	8.11	27.77
Flusilazole 40% EC	0.00	0.00	100	100
Control	9.00	9.00	0.00	0.00
CD at 5%	0.126	0.103		
CV	1.379	1.362		

*mean of three replicates

In vivo* evaluation of fungicides against *A.brassicicola

All these fungicides (Table 1) at 0.05 per cent concentration were evaluated against *A.brassicicola*. Per cent disease index (PDI) was calculated based on symptoms observed on head. The disease pressure was created by artificially inoculating the cabbage plants. When disease symptoms like brown necrotic lesions with concentric rings appeared the fungicides were sprayed twice with an interval of 10 days. The observations for the development of *Alternaria* leaf spot of cabbage with per cent leaf area coverage were recorded after fungicide spray after 10 days of 2nd application of the fungicides. Per cent disease index was found to be minimum after application of 0.05 per cent flusilazole 40% EC (Table 4).

After harvesting the weight of fungicide treated cabbage was recorded and compared with untreated control. All the fungicides were superior in increasing the yield of cabbage per pot over control. The maximum weight of head (410 g) was recorded with foliar application of flusilazole 40% EC. It was found that cabbage plants treated with fungicides retained their older leaves and produced normal growth. Lower leaves dropped due to infection in the control pots without fungicide application (Table 5).

Table 4. Per cent disease index after second spray of fungicides

Fungicides	Per cent disease index
Kasugamycin 3%SL	25.90% (30.59)
Metiram 55%+ pyraclostrobin 5% WG	20.03% (26.56)
Azoxystrobin 23% SC	32.03% (34.45)
Carbendazim 50% WP	45.17% (42.19)
Flusilazole 40% EC	8.00% (16.43)
Control	62.48% (52.16)
CD at 5%	1.173
CV	1.954

Figures in parenthesis are arc sine transformed values

Table 5. Weight of cabbage heads after application of fungicides

Fungicide treatment	Weight (kg) Pot ⁻¹ #
Kasugamycin 3% SL	330
Metiram 55%+ pyraclostrobin 5% WG	363.33
Azoxystrobin 23% SC	273.33
Carbendazim 50% WP	260
Flusilazole 40% EC	410
Control	240
CD at 5%	17.862
CV	3.175

#, mean of three replicates

CONCLUSION

It was concluded that among differed fungicides evaluated against cabbage leaf spots causing pathogen, *Aternaria brassicola*, the flusilazol 40 EC (250 and 500 pp) was found most efficient inhibing 100 per cent mycelial growth under *in vitro* conditions. This fungicide sprayed on to cabbage crop with 0.05 per cent concentration twice at 10 days interval also recorded minimum disease index (8.0%) and maximum weighed cabbage head (410 g).

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Ecofriendly management practices to combat mycotoxins contamination in maize

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ABSTRACT

Mycotoxins are toxic secondary metabolites produced by *Aspergillus* and *Fusarium* species are toxic to humans and domestic animals. About seven seed treating fungicides namely captan, carbendazim, azoxystrobin, tebuconazole, trifloxystrobin, mancozeb 50 per cent + carbendazim 25 per cent WS (Sprint) and trifloxystrobin 25 per cent and tebuconazole 50 per cent (Nativo 75 WG) Among the seed treating fungicides tested against the seed-borne *A. flavus* and *F. verticillioides* in growth chamber conditions, seed treated with captan has recorded maximum germination (66.67%), maximum shoot length and shoot weight of 41.00 cm and 4.8 g, respectively. The management results revealed that the minimum per cent infection was noticed in neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *Trichoderma harzianum* at 2.5 kg ha⁻¹ and *Pseudomonas fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 days after sowing (DAS) (4.91) along with maximum yield and benefit cost ratio of 60.59 q ha⁻¹, 3.34 and 57.61 q ha⁻¹, 3.15 in first and second circumstances, respectively.

Key words: *Aspergillus flavus*, Bioagents, *Fusarium verticillioides*, Mycotoxin

Maize (*Zea mays* L., 2n = 20) being C4 plant and important cereal crop belonging to tribe *Maydeae* of the grass family, *Poaceae* with its origin as Central America is considered as one of the oldest food sources. Maize being one of the most important cereal crops in the world agricultural economy is cultivated throughout the world as it has maximum genetic yield potential than any other cereal crops. Hence, it is referred to as “Queen of Cereals” or “Miracle Crop” (Chhetri, 2016). It has myriad end uses as a human food (17%), feed (61%) and industrial products such as corn oil, starch, corn flakes, popcorn and dextrose and corn syrup (22%) (Mehta and Dias, 1999). In the world, it is grown on an area of 180.64 m. ha. with an annual production of 1033.62 million tons of productivity 5722 kg ha⁻¹ (Anon., 2017). In India, maize is the third most important food crop (after rice and wheat) and is cultivated in an area of 9.86 m ha with a production of 26.26 million tons having a productivity of 2664 kg ha⁻¹ (Anon., 2018). The predominant maize growing states that contribute more than 80 per cent of the total maize production are Karnataka (17.2%), Andhra Pradesh (14.9%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%) (Anon., 2019).

Major constraints in the production of maize are pests and diseases. Important diseases which are yield limiting

factors of maize are downy mildew, leaf blight, stalk rot, ear rot and rust in field conditions. In storage condition, mycotoxin contamination is the major problem which affects the quality and sometimes the quantity of the produce throughout the year, thereby it affects exporting prospects of maize. In Karnataka, there is a problem for storage and preservation of maize due to higher production and lack of proper storage units resulting in more chances for mycotoxin contamination (majorly Aflatoxin and Fumonisin). These are toxic secondary metabolites produced by certain group of fungi, such as *Aspergillus* and *Fusarium* species under varied environmental conditions that are toxic to humans and domestic animals associated with food and animal feeds at all stages of the food/feed chain. The occurrence of mycotoxins in food and feed is of great concern as it results in chronic diseases in both humans and animals. According to Indian Council of Medical Research (ICMR), Lucknow, 21 per cent of maize samples in India are unfit for human consumption due to mycotoxin contamination (Reddy *et al.*, 2011). To combat with mycotoxin contamination in maize, an effective, environment friendly integrated (package of chemical and biological) approach should be adopted to reduce the residual toxicity, resistance development by the pathogen against fungicide, high cost *etc.*, associated with the chemical way of managing the mycotoxins.

MATERIAL AND METHODS

Seed level management

The effect of seed treating fungicides on seed-borne *A. flavus* and *F. verticillioides* was assessed in growth chamber conditions for 21 days post sowing. A conidial spore suspension of 1×10^8 cfu ml⁻¹ of both the fungus was prepared with sterile distilled water. Surface sterilized, dried maize seeds were inoculated by placing 15 seeds inside the 125 ml sterile flask containing 50 ml of conidial suspension. Flasks were sealed with aluminium foil and placed onto a rotary shaker set at 110 rpm for 12 hrs, after which inoculated maize seeds were removed, blotted dry onto sterile paper towels and then allowed to dry inside a fume hood.

A total of seven fungicides were selected (Table 1) and their active ingredients in sterile water-based slurries were evaluated with inoculated and uninoculated seeds, where untreated inoculated seeds served as control. Each seed treating fungicide was applied as water based slurry by following the manufacturer's recommended dose to the fungus inoculated maize seeds. Red seed colorant (Becker Underwood®, 0.22 ml kg⁻¹ seed) was added to each fungicide slurry to monitor proper seed coverage. For each treatment, the fungicide slurry and seed samples to be treated were weighed using an analytical scale, poured into a 125 ml flask, sealed with aluminium foil and hand shaken for 5 min until the fungicide was evenly distributed on the maize seed coat. For each fungicide treatment, three replications were maintained with five seeds in each replications were sown in the polythene cover filled with the soil and sand mixture at single seed per cover. The plants were kept inside growth chamber over the course of the experiment and watered twice a week avoiding overflow.

Observations were recorded on number of seedlings survived against total number of seeds sown at 20 days after sowing. Maize seedlings were assessed carefully by removing three seedlings of each treatment from the pots and washed with sterile water to remove the soil and sand from the radical. After washing, primary radical and shoot lengths were measured. The maize seedlings shoot and root systems were separated, observation on weight of shoot and root system were taken. The incidence of fungal growth in the tissues of radical and shoot was estimated as the number of seedlings survived divided by total number of seeds sown.

Effective management measures to combat mycotoxins contamination in maize under field conditions

The field experiment was conducted at Main Agricultural Research Station (MARS), UAS, Raichur in RCBD with three replications. All cultural and pest

management practices were imposed as recommended in package of practices. The crop at silky stage was artificially inoculated by spraying the spore suspension of (1×10^8 cfu ml⁻¹) *A. flavus* and *F. verticillioides*. In this study, isolates of *Trichoderma harzianum* and *Pseudomonas fluorescens* were used as a seed treatment and soil application to determine their effects on population of *A. flavus* and *F. verticillioides* in the geocarposphere and subsequently on the mycotoxin production.

RESULTS AND DISCUSSION

Seed level management

A pot experiment was conducted during 2019 to assess the effect of seed treating fungicides on seed-borne *A. flavus* and *F. verticillioides* in growth chamber conditions till 21 days after sowing at MARS, Raichur and evaluation was done as described in 'Material and Methods'. Observations were recorded on germination (%), shoot and root growth parameters and results are presented here under (Table 2).

Among the different seed treating fungicides, treatment with captan (T₁) recorded maximum germination (66.67%) as compared to inoculated control (13.33%). The next best treatment was seed treatment with carbendazim (T₂) and mancozeb + carbendazim (T₃) with 40 per cent seed germination. The minimum germination of 13.33 per cent was observed with azoxystrobin, tebuconazole and trifloxystrobin treated seeds which are on par to inoculated control (13.33%).

A significant variation has been expressed by the fungicides with regards to shoot and root growth parameters. Among the fungicides, seed treatment with captan has recorded maximum shoot length and shoot weight of 41.00 cm and 4.8 g, respectively which was on par with uninoculated control and significantly superior over all other treatments, which was followed by carbendazim and mancozeb + carbendazim with 35.67 cm, 3.93 g and 35.00 cm, 3.19 g, respectively. Whereas the minimum shoot length was recorded with trifloxystrobin (16.00 cm) and minimum shoot weight was recorded with tebuconazole (2.60 g) as compared to inoculated control (14.67 cm, 1.70 g) and uninoculated control (39.00 cm, 4.82 g).

The effect of different fungicides on root growth parameters also differed significantly and similar trend as of shoot was observed. Seed treatment with captan has recorded maximum root length of 36.33 cm which was on par with uninoculated control (35.67 cm) and significantly superior over other treatments which was followed by mancozeb + carbendazim and trifloxystrobin and tebuconazole with 31.67 cm and 25.00 cm, respectively. The

Table 1. Effect of seed treating fungicides against *A. flavus* and *F. verticillioides* on germination and growth of maize

Tr. No.	Fungicides	No. of seeds sown	No. of seeds germinated	Germination (%)	Shoot length (cm)	Shoot Weight (g)	Root length (cm)	Root Weight (g)
T ₁	Captan	15	10	66.67	41.00 (6.40)*	4.80 (2.19)	36.33 (6.03)	2.73 (1.65)
T ₂	Carbendazim	15	6	40.00	35.67 (5.97)	3.93 (1.98)	27.33 (5.23)	2.53 (1.59)
T ₃	Azoxystrobin	15	2	13.33	22.67 (4.76)	2.74 (1.66)	16.33 (4.04)	2.09 (1.45)
T ₄	Tebuconazole	15	2	13.33	21.67 (4.65)	2.60 (1.61)	16.00 (4.00)	1.80 (1.34)
T ₅	Trifloxystrobin	15	2	13.33	16.00 (4.00)	2.65 (1.63)	20.67 (4.55)	2.44 (1.56)
T ₆	Mancozeb 50% + Carbendazim 25% WS (Sprint)	15	6	40.00	35.0 (5.92)	3.19 (1.79)	31.67 (5.63)	3.04 (1.74)
T ₇	Trifloxystrobin 25% and Tebuconazole 50% (Nativo 75 WG)	15	5	33.33	23.33 (4.83)	3.18 (1.78)	25.00 (5.00)	2.47 (1.57)
T ₈	Inoculated control	15	2	13.33	14.67 (3.83)	1.70 (1.30)	10.67 (3.27)	1.44 (1.20)
T ₉	Uninoculated control	15	15	100.00	39.00 (6.24)	4.82 (2.19)	35.67 (5.97)	3.64 (1.91)
				S. Em. ±	0.81	0.15	0.73	0.09
				C.D. at 5%	2.43	0.44	2.19	0.29

*Figures in the parenthesis are Square Root Transformed Values.

minimum root length was observed with tebuconazole (16.00 cm) which was significantly superior over inoculated control (10.67 cm).

The maximum root weight was perceived by uninoculated control (3.64 g) which was significantly superior over all other treatments followed by mancozeb + carbendazim and captan (3.04 g, 2.73 g, respectively). The lowest root weight was witnessed with tebuconazole (1.80 g) which was significantly superior over inoculated control (1.44 g).

Among the seven seed treating fungicides best germination (66.67%) of maize seed was recorded by captan with maximum shoot length (41.00 cm), shoot weight (4.80 g) with maximum root length (36.33 cm). Maximum root weight was witnessed by mancozeb + carbendazim (3.04 g) followed by captan (2.73 g) which may be attributed to the broad spectrum efficacy against associated fungi.

The research conducted by Falloon (2012) was in accordance with the present work, seed treatment of maize with the fungicides captan, etridiazole or thiram (1.5 g kg⁻¹ seed) or combinations of captan + benodanil, captan + metalaxyl or benomyl + fenaminosulf (0.75 + 0.75 g kg⁻¹) increased seedlings emergence in field trial by 37 to 50 per cent. In a rolled towel test, seedlings were protected from *A. flavus* and *Fusarium* spp. by captan or captafol (0.5 g kg⁻¹

seed), etridiazole (1.0 g kg⁻¹) or thiram (0.5 g kg⁻¹). Similarly, Ibrahim (2015) evaluated seed treating fungicides in soyabean, where carbendazim and captan performed better in inhibiting seed infection by *Aspergillus* and *Fusarium* and improving seed and seedlings vigor of cultivars.

Integrated management of mycotoxin contamination in maize and its economic analysis

Among the different treatments during Kharif 2018 (Table 2 & Fig. 1), plots treated with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) has recorded minimum per cent seed infection (4.15) which was on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1 %) at 60 DAS (T₂) (4.87 %), neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1 %) at 60 DAS (T₃) (5.24%), neem cake application at 250 kg ha⁻¹ + foliar spray with carbendazim (0.1%) at 60 DAS (T₄) (6.38%), neem cake application at 250 kg ha⁻¹ + seed treatment with captan + foliar spray with carbendazim (0.1%) at 60 DAS (T₆) (6.18%) and significantly superior over other treatments and control (11.64 %). Among different treatments, highest per cent seed infection was recorded with neem cake application at 250 kg ha⁻¹ (T₁) (7.23 %).

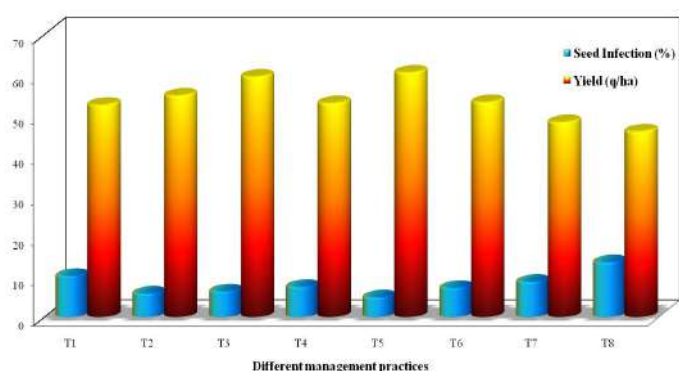


Fig. 1. Effect of management practices on mycotoxigenic fungi contamination and seed yield of maize (Including infected grains)

Significant difference was noticed between different treatments with regard to 100 seeds weight and weight of the cob (Table 2). Among the different treatments, the maximum weight of the 100 seeds and cob was obtained with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) with 35.29 g and 168.7 g, respectively which was on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%)

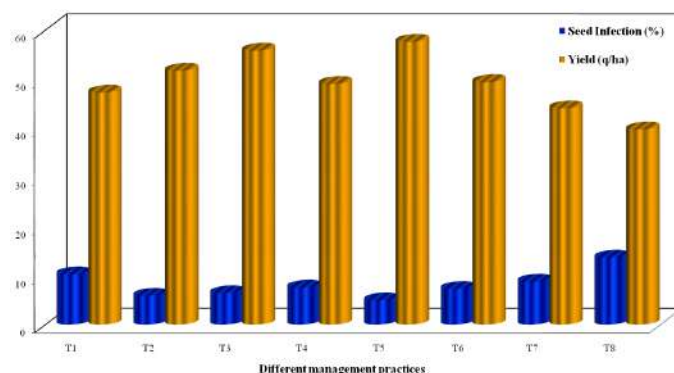


Fig. 2. Effect of management practices on mycotoxigenic fungi contamination and seed yield of maize (Excluding infected grains).

at 60 DAS (T₃) (35.18 g and 166.2 g, respectively) and with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (33.7 g and 155.2 g, respectively). These treatments were significantly superior over other treatments and control (31.61 g and 137.9 g, respectively).

In the experiment the yields of maize were recorded under two circumstances, in the first circumstance the infected grains were included in the yield whereas in the

Table 2. Management practices to reduce the risk of mycotoxin production in maize through integrated approach during Kharif 2018

Tr. No.	Treatment Details	Seed Infection (%)	100 seeds weight (g)	Weight of the cob (g)	Including Infected**		Excluding Infected***		BC Ratio
					Yield (kg plot ⁻¹)	Yield (q ha ⁻¹)	Yield (kg plot ⁻¹)	Yield (q ha ⁻¹)	
T1	Neem cake application @ 250 kg ha ⁻¹	7.23 (15.57)*	32.13	151.3	14.79	56.94	13.73	52.85	3.15
T2	T1 + 250 kg FYM enriched with <i>T. harzianum</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	4.87 (12.71)	33.77	155.2	15.25	58.71	14.51	55.87	3.06
T3	T1 + 250 kg FYM enriched with <i>P. fluorescens</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	5.24 (13.19)	35.18	166.2	16.55	63.71	15.67	60.35	3.33
T4	T1 + Foliar spray with carbendazim (0.1%) at 60 DAS	6.38 (14.59)	32.35	152.4	14.92	57.44	13.97	53.80	3.11
T5	T1 + 250 kg FYM enriched with consortium of <i>T. harzianum</i> @ 2.5 kg ha ⁻¹ and <i>P. fluorescens</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	4.15 (11.71)	35.29	168.7	16.84	64.86	16.14	62.15	3.34
T6	T1 + seed treatment with captan + Foliar spray with carbendazim (0.1%) at 60 DAS	6.18 (14.35)	33.08	152.9	14.97	57.64	14.05	54.11	3.12
T7	Seed treatment with captan	7.11 (15.41)	31.71	141.9	13.67	52.65	12.70	48.91	2.94
T8	Control	11.64 (19.94)	31.61	137.9	13.21	50.86	11.67	44.93	3.19
	S. Em. ±	0.74	1.07	4.93	0.58	2.24	0.56	2.16	
	C. D. at 5%	2.26	3.25	14.95	1.76	6.79	1.71	6.56	

* Figures in the parenthesis are arc sine transferred values. ** Weight of maize was recorded before sorting out the infected grains.

*** Weight of maize was recorded after sorting out the infected grains.

second circumstances the infected grains were excluded based on the visual observations. The result exhibits the similar trend with both the circumstances where the maximum yield was recorded with the treatment of neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) with 16.84 kg plot⁻¹, 64.86 q ha⁻¹ and 16.14 kg plot⁻¹, 62.15 q ha⁻¹ in first and second circumstances, respectively. The results were on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₃) (16.55 kg plot⁻¹, 63.71 q ha⁻¹ and 15.67 kg plot⁻¹, 60.35 q ha⁻¹, respectively) and with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (15.25 kg plot⁻¹, 58.71 q ha⁻¹ in first circumstances) and significantly superior over all other treatments including control (13.21 kg plot⁻¹, 50.86 q ha⁻¹ and 11.67 kg plot⁻¹, 44.93 q ha⁻¹, respectively).

The minimum per cent seed infection during Kharif 201 (Table 3 & Fig 2), was recorded with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) (5.67) which was on par with neem cake application at

250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (6.83%) and significantly superior over all other treatments and control (15.61%). Among the treatments, the highest per cent seed infection was recorded with neem cake application at 250 kg ha⁻¹ (T₁) (13.21%).

The observations on 100 seeds weight and weight of the cob revealed that the maximum weight was obtained with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) with 33.71 g, 150 g, respectively which was on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₃) (33.35g, 148.1 g, respectively) and with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (32.22 g, 138.4 g, respectively). These treatments are significantly superior over other treatments and control (29.08 g, 116.5 g, respectively).

The similar trend was also noticed during 2018 with respect to yield per plot and per hectare. The maximum yield was recorded with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5

Table 3. Management practices to reduce the risk of mycotoxin production in maize through integrated approach during Kharif 2019

Tr. No.	Treatment Details	Seed Infection (%)	100 seeds weight (g)	Weight of the cob (g)	Including Infected**		Excluding Infected***		BC Ratio
					Yield (kg plot ⁻¹)	Yield (q ha ⁻¹)	Yield (kg plot ⁻¹)	Yield (q ha ⁻¹)	
T1	Neem cake application @ 250 kg ha ⁻¹	13.21 (21.28)*	30.82	132.2	12.53	48.25	10.88	41.89	2.73
T2	T1 + 250 kg FYM enriched with <i>T. harzianum</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	6.83 (15.15)	32.22	138.4	13.26	51.06	12.36	47.58	2.85
T3	T1 + 250 kg FYM enriched with <i>P. fluorescens</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	7.52 (15.89)	33.35	148.1	14.41	55.48	13.32	51.29	3.07
T4	T1 + Foliar spray with carbendazim (0.1%) at 60 DAS	8.63 (17.07)	31.22	132.8	12.61	48.54	11.51	44.33	2.84
T5	T1 + 250 kg FYM enriched with consortium of <i>T. harzianum</i> @ 2.5 kg ha ⁻¹ and <i>P. fluorescens</i> @ 2.5 kg ha ⁻¹ + Foliar spray with carbendazim (0.1%) at 60 DAS	5.67 (13.77)	33.71	150.0	14.63	56.33	13.80	53.13	3.15
T6	T1 + seed treatment with captan + Foliar spray with carbendazim (0.1%) at 60 DAS	8.30 (16.73)	31.60	133.5	12.69	48.85	11.63	44.78	2.87
T7	Seed treatment with captan	10.40 (18.78)	29.18	122.6	11.40	43.91	10.21	39.33	2.63
T8	Control	15.61 (23.26)	29.08	116.5	10.68	41.12	9.01	34.69	2.69
	S. Em. ±	0.43	0.89	4.64	0.55	2.11	0.51	1.97	
	C. D. at 5%	1.29	2.71	14.06	1.66	6.39	1.55	5.96	

* Figures in the parenthesis are arc sine transferred values. ** Weight of maize was recorded before sorting out the infected grains.

*** Weight of maize was recorded after sorting out the infected grains.

kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) with 14.63 kg plot⁻¹, 56.33 q ha⁻¹ and 13.80 kg plot⁻¹, 53.13 q ha⁻¹ in first and second circumstances, respectively. The results were on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₃) (14.41 kg plot⁻¹, 55.48 q ha⁻¹ and 13.32 kg plot⁻¹, 51.29 q ha⁻¹, respectively) and with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (13.26 kg plot⁻¹, 51.06 q ha⁻¹ and 12.36 kg plot⁻¹, 47.58 q ha⁻¹, respectively) and significantly superior over all other treatments including control (10.68 kg plot⁻¹, 41.12 q ha⁻¹ and 9.01 kg plot⁻¹, 34.69 q ha⁻¹, respectively).

The pooled analysis of mycotoxin management results revealed that (Table 5), the minimum per cent infection was noticed in neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) (4.91) which was on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *T. harzianum* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₂) (5.85%) and significantly superior over all other treatments and control (13.62%). The maximum per cent seed infection was recorded with neem cake application at 250 kg ha⁻¹ (T₁) (10.22%).

The pooled analysis of yield and benefit cost ratio (BCR) in the mycotoxin management in the two circumstances

revealed that, the maximum yield was observed in neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) with 60.59 q ha⁻¹, 3.34 and 57.61 q ha⁻¹, 3.15 in first and second circumstances, respectively and was on par with neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₃) (59.59 q ha⁻¹, 3.33 and 55.78 q ha⁻¹, 3.07 in first and second circumstances, respectively). The minimum yield and BCR were noticed in seed treatment with captan (T₇) with 48.28 q ha⁻¹, 2.94 and 44.04 q ha⁻¹, 2.63 in first and second circumstances, respectively as compared to control (45.99 q ha⁻¹, 3.19 and 39.73 q ha⁻¹, 2.69 in first and second circumstances, respectively).

The philosophy behind integrated disease management aims at integrating all the existing methods of plant disease management in ecologically sound manner which take into consideration of economic, social and legislative parameters (Kommedahl and Williams, 1983). An appropriate combination of the disease management methods could thus result in improved pathogen control with long term efficacy.

Among the different treatments applied, neem cake application at 250 kg ha⁻¹ + 250 kg FYM enriched with consortium of *T. harzianum* at 2.5 kg ha⁻¹ and *P. fluorescens* at 2.5 kg ha⁻¹ followed by foliar spray with carbendazim (0.1%) at 60 DAS (T₅) that recorded lowest incidence (4.91) with maximum yield and BCR of 60.59 q ha⁻¹, 3.34 and 57.61 q

Table 4. Management practices to reduce the risk of mycotoxin production in maize through integrated approach (Pooled)

Tr. No.	Including infected			Excluding infected		
	Seed Infection (%)	Yield (q ha ⁻¹)	BC Ratio	Seed Infection (%)	Yield (q ha ⁻¹)	BC Ratio
T1	10.22 (18.63)	52.59	3.15	10.22 (18.63)	47.23	2.73
T2	5.85 (13.98)	54.88	3.06	5.85 (13.98)	51.69	2.85
T3	6.38 (14.61)	59.59	3.33	6.38 (14.61)	55.78	3.07
T4	7.51 (15.9)	52.99	3.11	7.51 (15.9)	49.01	2.84
T5	4.91 (12.79)	60.59	3.34	4.91 (12.79)	57.61	3.15
T6	7.24 (15.59)	53.25	3.12	7.24 (15.59)	49.39	2.87
T7	8.75 (17.18)	48.28	2.94	8.75 (17.18)	44.04	2.63
T8	13.62 (21.66)	45.99	3.19	13.62 (21.66)	39.73	2.69
S. Em. ±	0.45	1.9		0.45	1.79	
C. D. at 5%	1.36	5.77		1.36	5.44	

ha⁻¹, 3.15 in first and second circumstances, respectively, as compared to control (45.99 q ha⁻¹, 3.19 and 39.73 q ha⁻¹, 2.69 in first and second circumstances, respectively).

Kumar *et al.* (2008) evaluated an integrated package at ICRISAT, Patancheru, Andhra Pradesh, India during the rainy season during 2001 to demonstrate the effectiveness of improved package *vis-a-vis* farmers' practice. In Integrated package the seed infection by *A. flavus* was very less (2.0 %) compared to farmers' practice (10.0 %). The present findings are in conformity with Kumar *et al.* (2008) and Guruprasad *et al.* (2018) as integrated management is more promising than individual approaches.

Vinodkumar *et al.* (2009) evaluated integrated management practices to prevent pre-harvest aflatoxin contamination in different villages of Junagadh and Amreli districts of Gujarat. The improved practice was effective in reducing the soil population of *A. flavus*, seed infection and colonization and the aflatoxin contamination in comparison with farmers practice.

Fluorescent pseudomonads are the promising inhabitants in the rhizosphere because of their rapid colonization of many crops and considered as effective biocontrol agents against soil borne plant pathogen (Anderson *et al.*, 1988). In addition to antagonistic effect of *Trichoderma* and fluorescent pseudomonads on pathogen they also have an effect such as induced systemic resistance on the plants (Van Loon *et al.*, 1998; Schisler *et al.*, 2002b). Kernel yield of the groundnut was also increased in a considerable way in some treatments. So integration of biocontrol agents with genetic and cultural management can effectively reduce the aflatoxin contamination in groundnut.

Palumbo *et al.* (2007) evaluated maize rhizosphere antagonistic samples for their potential as biological control agents against *A. flavus* and *F. verticillioides*. The most prevalent genera isolated from rhizosphere samples were *Burkholderia* and *Pseudomonas*, which inhibit the incidence of the pathogens to the maize seeds and seedlings.

Pseudomonas strains produce antifungal metabolites and exhibited chitinase and glucanase activity. One distinguishing characteristic of *P. fluorescens* is the production of phenazine-1-carboxamide (PCN), which can be visualized on certain media as a green crystalline precipitate and very much essential for the biocontrol activity of *P. fluorescens* against *Aspergillus* and *Fusarium* strains. Other antifungal metabolites produced by *Pseudomonas* species include phenazine-1-carboxylic acid, 1, 3-diacetylphloroglucinol, pyrrolnitrin, pyoluteorin and hydrogen cyanide (Schisler *et al.*, 2002a and Naik *et al.*, 2013). Identification of the specific strains of *Pseudomonas* producing

antifungal metabolites described in this study will aid in determining the mechanisms involved in their activity against *A. flavus* and *F. verticillioides* and the relative importance of these mechanisms in the interaction of the bacteria with each fungus. In situ studies will be essential for determining the efficacy of selected *Pseudomonas* strains for controlling *A. flavus* and *F. verticillioides* and thus reducing aflatoxin and fumonisin contamination under the field conditions.

Ninety two *Pseudomonas* isolates were isolated from the rhizosphere soil of different crop plants. Among these, 66 isolates produced the characteristic yellow pigmentation and showed fluorescence. Based on the biocontrol parameters the isolates were categorized into four groups based on siderophore production (high, moderate, low and no production) and evaluated for the presence of *pvdA*, *phl* and *plt* genes associated with siderophore production, DAPG and pyoluteorin, respectively. None of them appeared to carry the *pvdA* and *plt* genes (Manjunatha *et al.*, 2012).

The findings of Ranganathswamy *et al.* (2017) were in concurrence with the present study. They evaluated biocontrol agents and natural products against *A. flavus* causing aflatoxin contamination in groundnut. Six biocontrol agents were screened among them *T. harzianum* (IOF) was found promising under *in vitro* studies. Among the nine natural products nimbicidin showed maximum inhibition of *A. flavus* at all the concentrations (1, 5 and 10%).

Reshma *et al.* (2018) reported induction of the induced systemic resistance by six strains of rhizosphere fluorescent *Pseudomonas* possessing 2, 4-diacetyl phloroglucinol (2, 4-DAPG) antibiotic genes against rice sheath blight pathogen *Rhizoctonia solani*. During preliminary screening, isolate EP5 showed 76.5 per cent inhibition against *R. solani*. Paddy grains treated with EP5 upon challenge inoculation with *R. solani* gave higher activity of peroxidase (PO) 2.50 change in absorbance at 470 nm/min/mg protein, polyphenol oxidases (PPO), 2.25 change absorbance at 420 nm/min/mg protein, phenyl alanine ammonia lyase (PAL) and 28.5 nmol transcinamic acid/hr/mg protein. Positive fluorescent *Pseudomonas* strains for 2, 4-DAPG has produced PO, PPO, PAL and 28.5 nmol transcinamic that resulted in ISR against rice sheath blight pathogen *R. solani*.

Trichoderma produces a variety of compounds that induce localized or systemic resistance responses and this explains their lack of pathogenicity to plants. These root-microorganism associations cause substantial changes to the plant proteome and metabolism. Plants are protected from numerous classes of plant pathogen by responses that are similar to systemic acquired resistance and

rhizobacteria-induced systemic resistance. It is well known that trichodermin is a very potent inhibitor of protein synthesis (Shentu *et al.*, 2013). Reports of trichodermin activity against phytopathogens are less common. Inhibitory activity of trichodermin against mycelial growth of plant pathogenic fungi showed that it has potential value in agricultural applications.

In the management trial the yields were recorded under two circumstances *i.e.*, before sorting out the infected grains (including infected) and after sorting out the infected grains (excluding infected). The sorting of infected grains from the healthy grains is possible only through the manual labour and it is laborious and difficult in large scale under farmers' field condition. Hence there is a need to develop machines for mechanical sorting of the infected grains from the healthy grains.

CONCLUSION

The study concludes that the sowing of maize seeds treated with captan could significantly combat *Aspergillus* and *Fusarium* infection and resulted in maximum per cent germination (66.67%), shoot length (41.0 cm) and shoot weight (4.8 gm) under growth chamber condition under field conditions, application of consortium of *Trichoderma harzianum* and *Pseudomonas fluorescens* @ 2.5 kg ha⁻¹ followed by foliar spray of carbendazim (0.1%) at 60 days of sowing registered maximum yield (60.59 g ha⁻¹), 57.61 q ha⁻¹) and benefit cost ratio of 3.34 and 3.15, respectively.

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Antifungal activity of various essential oils “*in vitro*” against *Rhizoctonia solani* causing sheath blight of rice

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ABSTRACT

Several pathogens directly impact rice productivity, in which sheath blight disease, caused by *Rhizoctonia solani* Kuhn, is among the most devastating pathogens causing disease in rice. The present study tested the antifungal activity of ten essential oils against *R. solani* in the 200 to 1000 ppm concentration range by radial assay following the poisoned food technique. The highest inhibitory effect on *R. solani* were recorded after 3 days in a treatment containing *Syzygium aromaticum* at a minimum concentration of 500 ppm, followed by *Zingiber officinale* and *Cymbopogon nardus* (600 ppm) and *Ocimum citriodorum* (700 ppm). Results revealed all the tested essential oils showed inhibitory effects against *R. solani*. This ability was dose-dependent. However, *Pogostemon cablin* and *Chrysopogon zizanioides* oils were less effective against *R. solani* at lower concentrations.

Keywords: Antifungal activity, essential oils, poisoned food technique, sheath blight, *Rhizoctonia solani*, rice

Rice (*Oryza sativa* L.) is an essential source of carbohydrates, protein, and other minerals for billions of people worldwide (Parengam *et al.* 2010). Certain abiotic and biotic factors significantly impact rice production and productivity, resulting in up to 45 per cent (Margani and widadi 2018). The most frequent biotic stress in rice is fungal diseases (Asibi *et al.* 2019). Several pathogens directly impact rice productivity; in which sheath blight (ShB) disease, caused by *Rhizoctonia solani* Kuhn, is among the most devastating pathogens causing disease in rice (Gautam *et al.* 2003) and the world's second most prevalent disease after blast disease (Molla *et al.* 2020). The main symptoms of this disease were an oval or ellipsoidal greenish-grey, water-soaked lesion on the leaf sheath. Later, it develops into a bleached appearance with an irregular purple-brown margin (Singh *et al.* 2016). It causes yield losses ranging from negligible to 50 per cent that have been reported under favourable environmental conditions (Richa *et al.* 2016).

Various techniques have been employed for decades to control ShB. These include resistance breeding, chemical treatment such as seed treatment, soil drenching, foliar spraying, and biological control (Mahmoud *et al.* 2010), and application of plant extracts and essential oils (EOs) (Javaid and Naqvi, 2012).

Essential oils produced from medicinal plants have non-phytotoxic chemicals that may be effective against a variety of microorganisms (Muthukumar *et al.* 2016), including a range of fungal diseases (Hashem *et al.* 2010) that can be transmitted by seed, soil, or foliar contact. Essential oils have long been investigated and recognised (Nguefack *et al.* 2012) for their fungicidal and bactericidal effects due to active components such as alkaloids, phenols, and flavonoids (Alilou *et al.* 2008). The general antifungal activity of various EOs is well documented (Nguefack *et al.* 2012, Amini *et al.* 2012, Khaledi *et al.* 2014, Muthukumar *et al.* 2016, Naveenkumar *et al.* 2017).

This study aims to evaluate the antifungal activity of the ten essential oils against virulent isolate collected from the diseased rice plants. Previous research has shown the antifungal activities of these ten essential oils against clinically tested pathogens to determine the potential of low concentrations of selected EOs, which can affect the fungal growth.

METHODS AND MATERIALS

This study employs an experimental design using a completely randomised block design with three replications. Sheath blight was tested in nine different concentration ranges (200 to 1000 ppm) of the ten essential oils.

Locally available, ten different essential oils known to have some active antifungal properties were collected from Mr Sparsh (Natura Pharmacy Ltd, Varanasi, India). A list of essential oils used in the present study is given in Table 1 and concentration was between 200-1000 ppm. The essential oils have been selected based on local availability and previous reports of their antifungal activity.

The virulent strain of *Rhizoctonia solani* AG-11A (MTCC-12227) isolate was procured from Prof. Vineeta Singh, Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

The inhibitory effect of ten essential oils against *R. solani* was tested by radial assay following the poisoned food technique (Grover and Moore, 1962). The required quantity of EOs was added to potato dextrose agar (PDA) medium to achieve the necessary concentration of active ingredients in each essential oil individually. In each sterilised Petri plate, 20 ml of essential oils amended medium was poured and allowed to solidify. Petri plates without essential oil served as control. Sclerotia were introduced aseptically to the centre of the poisoned medium from a 3 day old *R. solani* culture. For each concentration, three replications were maintained, and all the inoculated plates were incubated at 27±2 °C in an incubator. The colony diameter (mm) of the test pathogen was measured after 72 hrs to determine the Minimum Inhibitory Concentration (MIC) of respective oils compared with control plates (Vincent, 1947). The growth of mycelium was measured using vernier callipers.

Percentage mycelial inhibition was calculated by using the formula:

$$\%inhibition = \frac{C - T}{C} \times 100 \dots\dots\dots (1)$$

Where C was the growth of mycelium in the control set, subtracting the diameter of the inoculum disc, and T was the growth of mycelium in the treatment set, subtracting the diameter of the inoculum disc.

All the experiments were completely randomized design (CRD) and repeated twice. Critical difference (CD) was used for post hoc analysis to determine which treatments were significantly different against isolated pathogen causing sheath blight. All of the statistical analysis was evaluated using OPSTAT software.

Table 1. List of essential oils

Essential oils	Botanical name	Family
Lemongrass	<i>Cymbopogon citrates</i>	Poaceae
Patchouli	<i>Pogostemon cablin</i>	Lamiaceae
Peppermint	<i>Mentha piperata</i>	Lamiaceae
Clove oil	<i>Syzygium aromaticum</i>	Myrtaceae
Citronella	<i>Cymbopogon nardus</i>	Poaceae
Eucalyptus	<i>Eucalyptus sp</i>	Myrtaceae
Lemon Tulsi	<i>Ocimum citriodorum</i>	Lamiaceae
Khus	<i>Chrysopogon zizanioides</i>	Poaceae
Zinger	<i>Zingiber officinale</i>	Zingiberaceae
Thyme	<i>Thymus vulgaris</i>	Lamiaceae

RESULTS AND DISCUSSION

To explore the fungicidal efficacy of some plant extracts and oils were tested against *R. solani*. All essential oils tested at any concentrations were more or less inhibitory to the growth of *R. solani* *in vitro*. This ability was dose-dependent. Significantly, maximum inhibition of mycelial growth was obtained in Clove (73.3%) at 200 ppm concentration, followed by Zinger (64.1%), Eucalyptus (53.3%), Lemon tulsi (45%), and Lemongrass (44.78%). Thyme, Patchouli, Peppermint, Lemongrass, and Khus oils inhibited 27.78, 22.2, 21.11, 16.67 and 4.44 per cent mycelial growth of *R. solani*, respectively

Table 2. Response of the different essential oils in different concentrations and the controls used against Sheath Blight pathogen of rice.

Essential Oil	*Radial growth of pathogen (mm)								
	200	300	400	500	600	700	800	900	1000
Lemon-grass	44.78	64.44	70.56	73.33	80	86.67	100	100	100
Patchouli	22.2	48.89	75.56	78.22	79.11	80.67	82	83.2	83.5
Peppermint	21.11	27.78	41.11	48.89	65.56	70.56	91.11	100	100
Clove	73.33	81.11	84.44	100	100	100	100	100	100
Citronella	16.67	67.78	83.33	93.33	100	100	100	100	100
Eucalyptus	53.33	67.22	68	69.67	77.78	83.33	100	100	100
Lemon-Tulsi	45	65.56	71.11	79	94.44	100	100	100	100
Khus	4.44	23.33	28	42.78	46.89	54.44	58.33	67.78	74.44
Zinger	64.11	68.89	74.44	86.67	100	100	100	100	100
Thyme	27.78	36.67	53.33	60	78.22	87.7	94.4	100	100
Control	0	0	0	0	0	0	0	0	0

*Mean of three replications

Table 3. Inhibition percentage of essential oils against *Rhizoctonia solani* at different concentrations.

Essential oil	*Minimum inhibitory concentration (%)								
	200	300	400	500	600	700	800	900	1000
Lemongrass	4.97(2.23)**	3.2(1.79)	2.65(1.63)	2.4(1.55)	1.8(1.34)	1.2(1.1)	0(0)	0(0)	0(0)
Patchouli	7(2.65)	4.6(2.14)	2.2(1.48)	1.97(1.4)	1.83(1.35)	1.74(1.32)	1.62(1.27)	1.51(1.23)	1.48(1.22)
Peppermint	7.1(2.66)	6.5(2.55)	5.3(2.3)	4.6(2.14)	3.1(1.76)	2.65(1.63)	0.8(0.89)	0(0)	0(0)
Clove	2.4(1.55)	1.7(1.3)	1.4(1.18)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Citronella	7.5(2.74)	2.9(1.7)	1.5(1.22)	0.6(0.77)	0(0)	0(0)	0(0)	0(0)	0(0)
Eucalyptus	4.2(2.05)	2.95(1.72)	2.88(1.7)	2.73(1.65)	2(1.41)	1.5(1.22)	0(0)	0(0)	0(0)
Tulsi	4.95(2.22)	3.1(1.76)	2.6(1.61)	1.89(1.37)	0.5(0.71)	0(0)	0(0)	0(0)	0(0)
Khus	9(3)	7.9(2.81)	6.48(2.55)	5.15(2.27)	4.78(2.19)	4.1(2.02)	3.75(1.94)	2.9(1.7)	2.3(1.52)
Zinger	3.23(1.8)	2.8(1.67)	2.3(1.52)	1.2(1.1)	0(0)	0(0)	0(0)	0(0)	0(0)
Thyme	6.5(2.55)	5.7(2.39)	4.2(2.05)	3.6(1.9)	1.96(1.4)	1.1(1.05)	0.5(0.71)	0(0)	0(0)
Control	9(3)	9(3)	9(3)	9(3)	9(3)	9(3)	9(3)	9(3)	9(3)
SEM	0.63	0.68	0.68	0.73	0.77	0.77	0.79	0.79	0.78
CD	0.61	0.65	0.65	0.7	0.74	0.74	0.76	0.76	0.75

* % of inhibition of mycelium growth = $C-T/C \times 100$; C = Control
SEM- standard error of mean, CD- Critical difference

** In brackets-square root transformed values

(Table 3). We found that each essential oil treatment had a selective inhibitory effect on the frequency of fungal genera.

In the present investigation, all the tested essential oils were statistically significant (Table 2, Table 3) by reducing the mycelial growth of *R. solani*; at 500 ppm cent per cent inhibition of mycelial growth was observed only in Clove. In contrast, Lemongrass (93.33%) and Zinger (86.67%) recorded effective inhibition percentages. At 600 ppm, Clove, Lemongrass, and Zinger recorded a cent per cent inhibition of mycelial growth. Lemon tulsi and lemongrass showed 94.44 and 80 per cent, respectively. Khus oil showed the lowest inhibition with 46.8 per cent. At 700 ppm, Clove, Lemongrass, Zinger, and Lemon tulsi recorded a maximum inhibition percentage of mycelial growth as 100 per cent.

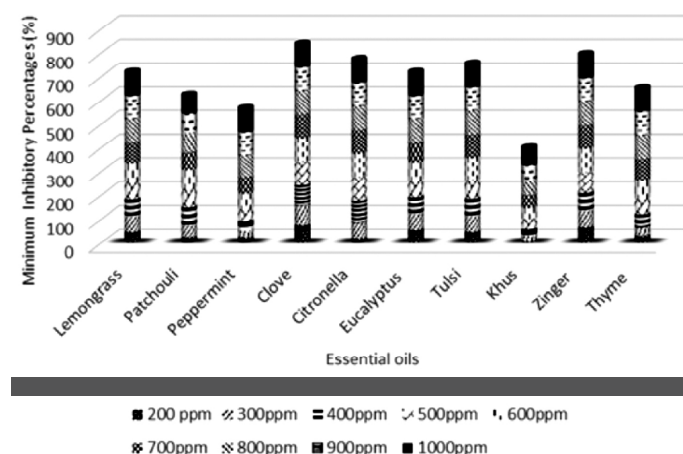


Fig. 1. Inhibition percentage of essential oils against *Rhizoctonia solani* at different concentrations.

However, the rest essential oils are also inhibitory to *R. solani* but comparatively lesser than the above-mentioned essential oils. Moreover, *Thyme* and Lemongrass oils showed complete mycelial inhibition at 800 ppm, and Peppermint showed at 900 ppm. But Patchouli and Khus oils recorded only 80 per cent and 74.4 per cent as the maximum per cent inhibition even at 1000 ppm, which is considered comparatively less significant than the eight mentioned above essential oils (Fig. 1).

Ali *et al.* (2015) evaluated 30 plant-based essential oils at 100 ppm, 200 ppm, 300 ppm, 500 ppm, and 1000 ppm. They reported the fungicidal effect of *W. somnifera* and *M. arvensis* against *R. solani* by using the poisoned food technique *in vitro*. However, it was also noticed that the relative antifungal composition of the essential oils could not be associated with any one ingredient but rather with a combination of these oil components (Hashem *et al.* 2010). It's challenging to establish a link between one molecule and a single target cell because plant extracts include many chemical components. Even small details appear to have a crucial role in antimicrobial activity, and the inhibitory effects appear to be the consequence of their synergistic action (da Cruz Cabral *et al.* 2013).

In a recent study, essential oils derived from *C. citrates*, Lemongrass and *S. aromaticum* were investigated for their antimicrobial properties against a fungal pathogen in a dose-dependent manner (Sowmya *et al.* 2021). Moreover, in a similar study by Naveenkumar *et al.* (2017), essential oils of *C. citratus*, *C. martini* and *P. graveolens* were found to be the most importantly effective, as they exhibited complete inhibition at a concentration of 0.02% against *F. oxysporum f.sp. niveum*.

According to Shrishti *et al.* 2014, substantial inhibition of growth of *R. solani* was depicted in Lemongrass (83.53%) and Lemon tulsi (70.39%). The findings of our study are consistent with those of Sehajpal *et al.* (2009). They reported antimicrobial properties of eight plant oils against the sheath blight pathogen *R. solani*, evaluated by the disc diffusion method. It was found that the mycelial growth is inhibited to the greatest extent by the essential oil of Clove, *i.e.*, 7.5 mm at 1000 ppm.

There are some differences between our results and earlier studies on exhibited levels of antifungal activity of *M. piperata* and *T. vulgaris* EOs (Ali *et al.* 2015; Khaledi *et al.* 2014). It might be due to variations in the fungus species under investigation. It might also be related to the different chemical components present in each plant type from which the oil is extracted. Vaillant *et al.* (2009) described that Lemongrass oil showed 100 per cent mycelial.

CONCLUSION

The present study revealed that among the essential oils tested, Clove, Zinger, and Lemongrass oils were more effective and completely inhibited the mycelial growth of pathogen even at least concentrations of 500 ppm and 600 ppm, respectively. In comparison, other oils were effective at >600 ppm *in vitro*. Due to their natural characteristics, EO'S have minimal toxicity for humans and the environment and a low chance of developing resistance to pathogenic microorganisms. For these reasons and by considering the results, we recommend using plant essential oils to create new and safe fungicides. These oils will be formulated in the coming future and evaluated as natural fungicides under field conditions. To meet this goal, more formulations and field testing are required.

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Antagonistic activity of resident biological agents against wilt and root rot pathogens of pea in different culture media

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ABSTRACT

Antagonistic potential of rhizospheric fungal and bacterial isolates evaluated against wilt and root-rot pathogens of pea exhibited significant effect on radial growth inhibition of pathogens in comparison to control. Two isolates of *Trichoderma* spp., one isolate of *Aspergillus niger*, one isolate of *Penicillium oxalicum* and three isolates of *Pseudomonas* were isolated from rhizosphere of pea and were evaluated for their antagonistic potential against three soil borne plant pathogens viz., *Fusarium oxysporum* f. sp. *pisi*, *Rhizoctonia solani* and *Pythium ultimum* using dual culture technique in different culture media (potato carrot agar, czapek dox agar, rose bengal chloramphenicol and czapek malt agar). Antagonistic potential of fungal and bacterial isolates were found to be significantly influenced in different culture media. All fungal and bacterial isolates preferred potato carrot agar and czapek dox agar media and resulted in maximum reduction in growth of test pathogen on the culture media.

Key words: Biological control, culture medium, fungal and bacterial bioagents, pea

Besides nutritional importance, grain legumes or pulses sustain the productivity of the cropping system through biological nitrogen fixation. Among the pulses, pea (*Pisum sativum* L.) has been known to be very ancient and is cultivated worldwide. Peas are infected by a number of bacterial, fungal, viral, and nematode diseases. These diseases, under the right conditions, significantly decrease both yield and quality. Important groups of organisms causing soilborne diseases on pea include fungi, bacteria and nematodes. In spite of suitable conditions for better cultivation of this crop, many biotic and abiotic constraints limit its yield. Among the biotic stresses, the diseases caused by soil borne pathogens are known to be a major important factor which severely affect the root, stem, leaves, petioles, pods and seeds of this crop and cause significant yield reduction (Kraft *et al.*, 1988). These pathogens are restricted to seed and root system and have been found to infect the crop either alone or as a complex, thereby resulting rots before and after emergence of seedlings, and wilting of plants at ages. Considering the limitations and after effects of chemicals, the focus on the management of plant diseases has been shifted from chemical pesticides to more ecofriendly biopesticides to reduce environmental hazards and to minimize the risk of development of pesticide resistant strains of plant pathogens. Most of the fungi and bacteria have the potential to reduce the crop loss through biocontrol mechanism. Bacteria and fungi isolated from the rhizosphere, called rhizosphere competent, seem to hold more promise as agents for biological control. They multiply in the rhizosphere

and continue to protect the growing root surfaces. Consequently, maximum emphasis for developing biocontrol programmes has invariably gone to fungal and bacterial antagonists/biocontrol agents. Some of the most widely used fungal bio-agents in the world belong to the fungal genus *Trichoderma*. In particular, isolates of *T. harzianum*, *T. virens* and *T. hamatum* are used against seed and soil-borne diseases in a variety of economically important crops (Chet, 1987 and Papavizas, 1985). Strains of trichoderma mechanism include mycoparasitism, antibiosis, competition for nutrient or space, tolerance to stress through enhanced root and plant development, induced resistance, solubilization and sequestration of inorganic nutrients and inactivation of pathogen's enzyme, *etc.* (Harman, 2000). Several scientists have reported the inhibitory effect of volatile and non-volatile compounds produced by trichoderma spp. on several soil borne plant pathogens (Bose *et al.*, 2005). Therefore, present study was carried out to isolate the resident biocontrol agent and to establish their antagonistic potential against three soil borne plant pathogens of pea.

MATERIALS AND METHODS

The investigation was carried out in the Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, U.P. Isolation of pathogens (*Fusarium oxysporum* f. sp. *pisi*, *Rhizoctonia solani* and *Pythium ultimum*) was done in culture media from diseased plant parts collected from field. Pure cultures were obtained by subculturing on potato dextrose agar medium.

The rhizospheric soil was brought to the laboratory in polythene bags for the isolation of naturally occurring rhizospheric fungi and bacteria. One gram of each soil sample was suspended in 9 ml of sterilized water and shaken thoroughly to get the soil particles uniformly dispersed in the suspension. One ml of suspension from the first dilution ($1:10^{-1}$) was aseptically transferred to another tube (10^{-2}) and this procedure further repeated till the dilution of 10^{-6} was obtained. For the isolation of rhizospheric fungi, 0.1 ml of soil suspension from the dilution of 10^{-4} to 10^{-6} was transferred in sterilized petriplates containing potato dextrose agar medium. The rhizobacterium, *Pseudomonas*, was isolated by the method as suggested by Collins and Lyne (1987). One gram of each soil sample was suspended in 9 ml of sterile normal saline solution and shaken vigorously for 10 minutes, thereafter, 0.1 ml aliquot was placed in the petriplate containing selective media of appropriate dilution. These petriplates were incubated at $35\pm 2^{\circ}\text{C}$ for 24 h. After incubation, the suspected bacterial colonies were picked up and sub-cultured for their identification and further use in other studies. Identification of rhizobacterium was made on the basis of their cultural, morphological and biochemical characteristics.

The effect of different culture medium was studied *in-vitro* on the antagonistic activity of promising fungal and bacterial isolates against wilt and root-rot pathogens. The most promising isolates of *Trichoderma harzianum* (Th3 and Th5), *Aspergillus niger* (An1), *Penicillium oxalicum* (Po3) and Fluorescent *Pseudomonas* (PS1, PS2 and PS5) were used for their efficacy in inhibiting the radial growth of wilt and root-rot pathogens at four different culture media potato carrot agar, czapek dox agar, rose bengal chloramphenicol and czapek malt agar.

The efficacy of rhizospheric fungal and bacterial isolates on radial growth inhibition of test pathogens, i.e., *F. oxysporum* f. sp. *pisi*, *R. solani* and *P. ultimum* was studied *in-vitro*, through dual culture technique using 2 isolates of *Trichoderma harzianum* and 3 isolates of Fluorescent *Pseudomonas*, one isolate each of *Penicillium oxalicum* and *Aspergillus niger*.

Mycelial discs having diameter of 5 mm were cut from the young cultures of fungal bioagents and test fungus with the help of a cork borer. These discs were placed in the petriplates containing PDA, maintaining the distance of 4 cm between the discs of test fungus. All the petriplates were incubated for 5 days at $28\pm 1^{\circ}\text{C}$. Each treatment had three replications. Radial growth inhibition of test pathogens was measured at intervals of 24h for 5 days.

The antagonistic potential of *Pseudomonas* on test pathogens was determined by dual culture technique in a

different way. Four discs of the test fungus were placed in the periphery of petriplate at equal distance thereafter, the blotting paper discs having the diameter of 10 mm dipped in bacterial suspension and placed in the centre of petriplates. In check, no blotting paper was placed. These petriplates were incubated at $28\pm 1^{\circ}\text{C}$ for 5 days. Each treatment was replicated thrice. After every 24 h interval the radial growth of the test pathogens was recorded.

The observations were recorded on radial growth and per cent inhibition over control was also calculated. The per cent inhibition over check, noted after 5 days of incubation, was calculated by the following formulae (Vincet, 1947).

$$I = \frac{C - T}{C} \times 100$$

Where, I = Per cent inhibition, C = Colony diameter in check and T = Colony diameter in treated petriplate.

RESULTS AND DISCUSSION

Infected seedlings as well as adult plants of pea showing the symptoms of wilt and root-rot, frequently yielded the growth of *Fusarium oxysporum* f.sp. *pisi*, *Rhizoctonia solani* and *Pythium ultimum* on potato dextrose agar medium. Identification of these causal pathogens was confirmed on the basis of their cultural and morphological characteristics recorded in pure cultures as well as in temporary slides, respectively, and as testified with the literature. The rhizospheric soil of pea collected from 5 different localities, more frequently yielded fungal and bacterial colonies on the medium. Among them, fungal populations included 2 isolates of *Trichoderma harzianum*, 1 isolate each of *Aspergillus niger* and *Penicillium oxalicum* and 3 isolates of *Pseudomonas*. These fungal and bacterial species were identified and confirmed on the basis of their cultural and morphological and biochemical characteristics as documented in the literature. The antagonistic potential of fungal and bacterial isolates against pathogens, was studied using four different culture media viz., potato carrot agar, czapek dox agar, rose bengal chloramphenicol agar and czapek malt agar. The observations thus obtained, are presented in Tables 1, 2 and 3.

It was evident from Table 1 that isolates were significantly influenced in different culture medium, *T. harzianum* isolates Th3 and Th5 preferred potato carrot agar medium followed by czapek dox agar, but exhibited maximum reduction of growth (2.1) of *F. oxysporum* f. sp. *pisi* on potato carrot agar medium in comparison to other fungal isolates and control. The efficacy of these isolates in inhibiting the growth of pathogen, however, was noted to be statistically at par in all four cultures (Table 1). Other fungal

Table 1. *In vitro* effect of culture medium on radial growth inhibition of *Fusarium oxysporum* due to fungal and bacterial bioagents

Fungal and bacterial bioagents	Culture media							
	Potato carrot agar		Czapek dox agar		Rose bengal chloramphenicol		Czapek malt agar	
	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)
Th3	2.1	65.0	2.3	57.5	2.6	50.6	2.2	54.6
Th5	2.1	64.4	2.3	56.9	2.9	42.6	2.4	51.3
An1	2.6	55.5	2.3	57.5	3.0	42.5	2.4	51.3
Po3	3.2	46.1	2.4	55.1	3.6	32.5	2.4	50.6
Ps1	2.5	58.3	3.4	38.1	5.3	0.0	3.3	32.6
Ps2	2.3	61.6	2.6	51.5	5.1	4.3	2.7	46.0
Ps5	2.2	62.7	2.5	54.5	4.5	15.6	2.5	49.3
Control	6.0	0.0	5.5	0.0	5.3	0.5	0.0	0.0
C.D. at p = 0.05	0.36		0.23		0.28		0.16	

*Mean of 3 replicates RG= Radial growth

isolates, namely *A. niger* (An1) and *P. oxalicum* (Po3) exhibited their maximum antagonistic potential against *F. oxysporum* f.sp. *pisi* on czapek dox agar followed by czapek malt agar and found to be statistically at par in their efficacy on these culture media, resulting in reduction of radial growth up to 2.3 to 2.4 and 2.4 cm, respectively. As similar to isolates of *T. harzianum*, *Pseudomonas* isolates also visualized their maximum efficacy on potato carrot agar followed by czapek dox agar. However, its least efficacy was observed in rose bengal chloramphenicol agar. Of the isolates, Ps5 proved to be most effective followed by Ps2 in inhibiting the growth of pathogen showing reduction up to 2.2 to 2.5 and 2.3 to 2.6 cm in radial growth, respectively. The differences in the radial growth inhibition resulted due to isolates Ps5 and Ps2 on potato carrot agar and czapek dox agar, however, were found to be insignificant when compared from one another (Table 1).

The observations presented in Table 2 revealed that the radial growth inhibition of *R. solani* by promising isolates was also significantly influenced on different culture media. Contrary to the observations obtained for *F. oxysporum* f. sp.

pisi on different culture media, the inhibition in growth of *R. solani* due to fungal isolates was found to be significantly maximum on czapek dox agar. Here too, *T. harzianum* Th3 caused maximum reduction in radial growth (1.53 cm) followed by isolate Th5 (1.73 cm) and exhibited non-significant difference from one another. Of remaining isolates, *A. niger* An1 was more effective than *P. oxalicum* Po3 in inhibiting the radial growth upto 1.9 and 2.3 cm, respectively on czapek dox agar medium. Similarly, *Pseudomonas* isolates, exhibited their maximum antagonistic potential on potato carrot agar medium followed by czapek dox agar. Among the isolates, Ps5 revealed maximum reduction (74.8%) in radial growth of pathogen followed by Ps2, (72.6%) against control on potato carrot agar medium. However, the efficacy of these isolates (Ps5 and Ps2) in reducing the growth of pathogen was non-significant when compared from each other on both culture media, i.e., potato carrot agar and czapek dox agar (Table 2).

The data presented in Table 3 indicated that the antagonistic potential of fungal and bacterial isolates against this pathogen also varied significantly on different culture

Table 2. *In vitro* effect of culture medium on radial growth inhibition of *Rhizoctonia solani* due to fungal and bacterial bioagents

Fungal and bacterial bioagents	Culture media							
	Potato carrot agar		Czapek dox agar		Rose bengal chloramphenicol		Czapek malt agar	
	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)
Th3	1.9	67.7	1.5	75.1	2.1	64.2	2.5	54.2
Th5	2.1	65.5	1.7	71.8	2.6	57.1	2.9	46.0
An1	2.2	63.3	1.9	68.1	2.8	53.2	4.0	27.1
Po3	2.5	59.0	2.3	62.7	3.1	49.9	4.3	21.6
Ps1	1.8	69.3	3.6	41.6	5.9	2.1	2.2	5.4
Ps2	1.6	72.6	3.5	42.1	5.6	7.1	4.6	16.8
Ps5	1.5	74.6	3.3	46.4	4.8	19.7	4.1	25.9
Control	6.1	0.0	6.1	0.0	6.0	0.0	5.3	0.0
C.D. at p = 0.05	0.24		0.26		0.34		0.48	

*Mean of 3 replicate RG= Radial growth

media. The efficacy of fungal isolates in growth inhibition of *P. ultimum* on different culture media was found to be similar as recorded for *R. solani*, being maximum on czapek dox agar medium followed by potato carrot agar. Other culture media, however, did not result enhancement in growth inhibition of *P. ultimum*. Among the isolates, Th3 caused significantly maximum reduction (1.6 cm) in growth resulting in 74.8 per cent inhibition in czapek dox agar medium. The efficacy of Th3 and Th5 on one hand and An1 and Po3 on the other, did not differ significantly in inhibiting the radial growth. As similar to the effect of culture media on growth inhibition of *F. oxysporum* f.sp. *lisi* and *R. solani*, *Pseudomonas* isolates once again resulted in their maximum antagonistic activity on potato carrot agar followed by czapek dox agar (Table 3). The isolates of *Pseudomonas* did not vary significantly in their efficacy to inhibit the growth of pathogen on both culture media when compared with one another. Though, maximum reduction in growth of *P. ultimum* was observed on potato carrot agar medium due to Ps5 (1.9 cm) followed by Ps2 (2.1 cm) and Ps1 (2.1 cm).

The results so obtained in this study clearly indicated that growth inhibition of wilt and root-rot pathogens due to fungal and bacterial isolates were significantly influenced by different culture media. Among the promising fungal isolates, Th3 proved to be most effective against the pathogens followed by Th5, An1 and Po3. Though, isolate Ps3 of *Pseudomonas* resulted in their maximum antagonistic potential followed by Ps2 and Ps1 against wilt and root-rot pathogens. *T. harzianum* proved to be most effective against these three pathogens. Besides this, there were several instances where the efficacy of fungal and bacterial bioagents have been studied for their antagonistic potential against these soil borne pathogens (Tronsomo and Dennis, 1978, Elad *et al.*, 1983 a, b, Saikia *et al.*, 1998 and Kredics *et al.*, 2000). Bell *et al.* (1982) observed that the hyphae of *Trichoderma* sp. penetrated the mycelium of pathogen and

grew luxuriantly with it. The pathogenic hyphae were severely ruptured at the points of contact by *Trichoderma* hyphae, ultimately led to hyphal lysis. Elad *et al.* (1983 a, b) and Sharma *et al.* (2005) concluded that the fast growing *Trichoderma* sp. caused more inhibition of the pathogens probably due to mycoparasitism and competition for nutrients. Harman *et al.* (1980, 1989) had suggested that mycoparasitism was the principal mechanism involved in controlling *Pythium* damping off of pea seeds. Hyphal parasitism by *Trichoderma* sp. was also observed *in vitro* by many workers (Dennis and Webster 1971 a, b, Chet and Baker *et al.*, 1981). *Trichoderma* species are known to produce a number of antibiotics, such as trichodermin, trichodermol, harzianum A and harzianolide (Dennis and Webster 1971 a). Besides *Trichoderma* spp., *Aspergillus* spp. are well known for producing various kinds of active compounds including antifungal and antibacterial agents (Buchi *et al.*, 1983). The inhibitory effect exhibited by AN 27 in dual culture and in medium amended with its culture filtrate, persuaded to search for the substance(s) responsible for the action. GC-Mass, IR and NMR spectroscopy analyses of the isolated compound revealed a gamma lactone compound *viz.*, trans and cis-4 (3 acetoxy-6-methoxy-2-hydroxyphenyl)-2-methoxy butanolide. Minimum inhibitory concentration (MIC) bioassay of the compound against *F. oxysporum melonis* established that it inhibits the mycelial growth of the pathogen above 10 ppm concentration and no growth was observed at 150 ppm (Angappan *et al.*, 1996). Kamil *et al.* (2008) evaluated *in vitro* five pathogens *viz.* *Alternaria alternata*, *Curvularia lunata*, *Fusarium oxysporum*, *Helminthosporium oryzae* and *Phoma* sp. for their sensitivity towards the antagonists *Aspergillus niger*. The test pathogens, isolated from soils of different locations, were evaluated against *A. niger* using dual culture methods. *A. niger* proved potential *in vitro* test through inhibiting the mycelial growth of the test pathogens. Boosalis (1956) reported that the

Table 3. *In vitro* effect of culture medium on radial growth inhibition of *Pythium ultimum* due to fungal and bacterial bioagents

Fungal and bacterial bioagents	Culture media							
	Potato carrot agar		Czapek dox agar		Rose bengal chloramphenicol		Czapek malt agar	
	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)	*RG (cm)	Inhibition (%)
Th3	2.1	63.8	1.6	74.8	2.3	60.5	2.5	53.3
Th5	2.5	58.3	1.8	72.3	2.7	55.0	2.7	51.1
An1	2.9	50.5	2.1	67.6	3.0	50.0	3.6	34.5
Po3	3.2	46.6	2.4	63.0	3.3	43.8	3.9	30.3
Ps1	2.1	63.8	3.9	39.4	5.4	10.0	5.3	5.3
Ps2	2.1	65.0	3.7	42.0	4.9	17.2	5.2	7.1
Ps5	1.9	67.2	3.6	43.5	4.6	23.3	4.7	15.4
Control	6.0	0.0	6.5	0.0	6.0	0.0	5.6	0.0
C.D. at p = 0.05	0.34		0.37		0.45		0.21	

*Mean of 3 replicate RG= Radial growth

fungus, *Penicillium* sp. vigorously parasitized the hyphae of *R. solani* and prevented seedling disease of pea in sterile soil. In another study, Gupta *et al.* (1999) successfully used *Pseudomonas fluorescens* *in vitro* against *Macrophomina phaseolina* and *Fusarium oxysporum* and found antifungal activity of the strain. The production of hydrogen cyanic acid and indole acetic acid were also recorded under normal growth conditions.

CONCLUSION

It was concluded that *Trichoderma* and *Pseudomonas* strains could be exploited as biofertilizer and as biocontrol agents to replace the chemical fertilizer and fungicides that impair human health. The fungal and bacterial bioagents could be one of the potential candidates in the development of microbial pesticides to manage wilt and root rot complex in pea diseases, for enhancing crop productivity and raising residue free organic crop, which is the need of the day.

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Evaluation of different substrates on growth and yield of oyster mushroom (*Pleurotus florida*)

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ABSTRACT

An experiment was carried out to investigate the effect of different substrates on growth and yield of oyster mushroom (*Pleurotus florida*). Four different agricultural substrates viz., wheat straw, wheat straw + water hyacinth (1:1), maize straw, maize straw + bajra straw (1:1) were used to evaluate growth period, growth parameters and yield potential of three strains of oyster mushroom (PL-20-204, PL-20-205 and PL-20-206). Maximum average weight of fruiting bodies were recorded in bags where wheat straw+ water hyacinth was used as substrate and it was 19.30 g in case of PL-20-206 followed by 18.03 g and 16.09 g in PL-20-204 and PL-20-205 strains, respectively. Wheat straw + water hyacinth substrate showed best results among all substrates with a total yield of 900.1 kg bag⁻¹ for PL-20-206, 795.1 kg bag⁻¹ for PL-20-204 and 731.9 kg bag⁻¹ for PL-20-205 in three harvests. The results would be useful to mushroom growers in selecting suitable substrate for higher yield.

Keywords: *Pleurotus florida*, substrates, yield potential, strain.

As the population of world is growing at a fast rate, nations are finding it extremely difficult to provide their people with proper and balanced diet causing a threat to global food security. Mushrooms have emerged as a possible solution to this problem because of their high nutritional values and low cost of cultivation. Mushrooms have been used as delicacies by human beings according to earliest records such as Vedas (Wasson, 1971). Mushrooms are excellent source of proteins, vitamins and minerals and have very less amount of carbohydrates and sugar (Ho *et al.*, 2020). Apart from being used as food, mushrooms are also popular for their medicinal properties (Valverde *et al.*, 2015). FAO has identified the importance of mushrooms as a source of protein in countries that depend largely on cereals (Islam *et al.*, 2009). Unlike plants, mushroom cultivation is an indoor activity. It can be grown in any season with minimum requirements.

Different agricultural substrates have been tried to assess growth and yield potential of *Pleurotus florida* (Iqbal *et al.*, 2016 and Ponmurugan *et al.*, 2007). Commercial edible mushroom cultivation converts agricultural, industrial, forestry, and domestic waste into nutrient-dense food. The present investigation was undertaken to evaluate different agricultural waste substrates and best mushroom strain for higher yields.

MATERIALS AND METHODS

Four different substrates viz., wheat straw (WS), wheat straw+water hyacinth (1:1) (WS + WH), maize straw (MS) and maize straw+bajra straw (1:1) (MS + BS) were evaluated for assessment of growth and yield potential of three strains viz., PL-20-204, PL-20-205 and PL-20-206 of *Pleurotus florida* mushroom. All the agricultural wastes used in the study were collected from Agro Farm, B.H.U., Varanasi. The substrates were soaked in water overnight. After removing excess water next day they were steam sterilized at 121°C (15 psi) for 30 minutes. The prepared substrates were well mixed with freshly prepared spawn (18-25 days old) in the room previously fumigated with formaldehyde. Spawn mixed substrate was filled in cylindrical polyethene bags and weighed. Each bag maintained a weight of 2 kg. The mushroom bags were sealed with rubber bands. 8-10 holes were made on the polythene bags for proper aeration. After complete colonization of substrate by mushroom mycelium (spawn run), the polythene bags were cut open with a sharp sterilized blade and removed. The mushroom beds (now in a tray) were regularly sprayed with water to maintain proper moisture level inside the room.

The growth behavior, such as spawn run period, pinhead initiation, harvesting period, growth parameters like average weight of fruiting bodies (g), average length of

stalk (cm), average diameter of stalk and cap (cm) and yield potential were observed and measured at different periods.

RESULTS AND DISCUSSION

Spawn run period

The spawn run period was calculated from the day of spawning to the date of complete colonization of the substrate by mushroom mycelia. Results showed minimum spawn run period in wheat straw+ water hyacinth substrate, which took 16.56 days for PL-20-206 followed by 17.13 days and 18.24 days for PL-20-204 and PL-20-205, respectively (Fig. 1). The maximum spawn run period recorded for maize straw + bajra straw substrate was 20.65 days for PL-20-205 followed by PL-20-204 and PL-20-206 for which spawn run periods were 19.44 days and 19.34 days, respectively.

Pinhead initiation

The initiation of pinhead was fastest in wheat straw+ water hyacinth substrate. It took 20.23 days for PL-20-206

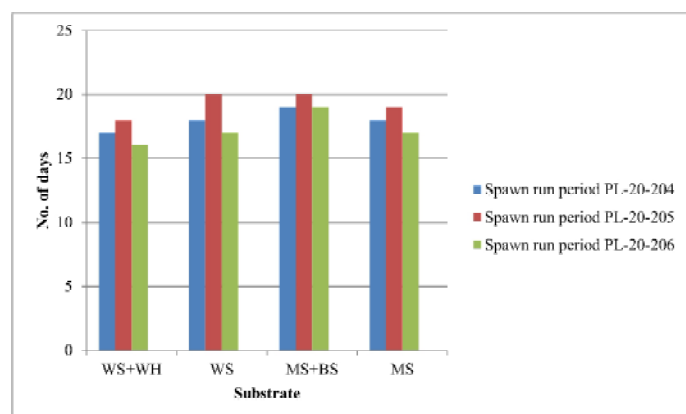


Fig. 1. Effect of different substrates on spawn run period of three strains of oyster mushroom (*Pleurotus florida*)

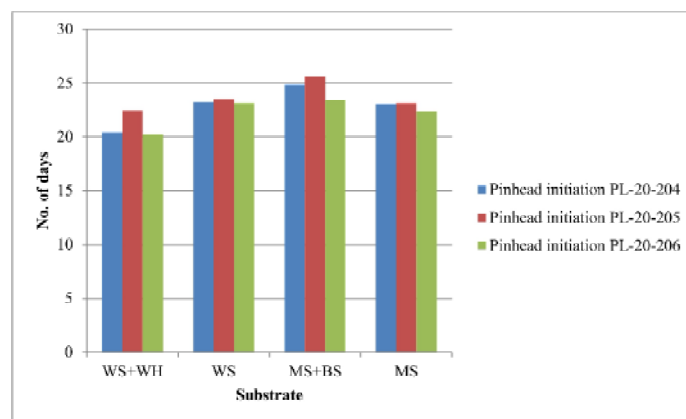


Fig. 2. Effect of different substrates on pinhead initiation of three strains of oyster mushroom (*Pleurotus florida*)

strain followed by 20.44 and 22.24 days for PL-20-204 and PL-20-205 strain, respectively (Fig. 2). The slowest pinhead initiation 25.67, 24.89 and 23.37 days for PL-20-205 PL-20-204 and PL-20-206 strains, respectively was observed in maize straw+ bajra straw substrate.

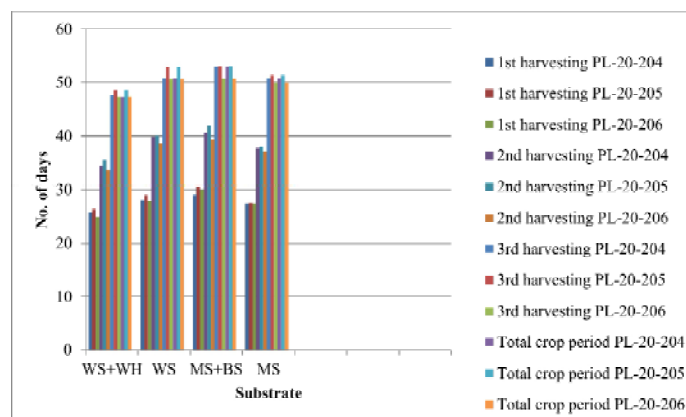


Fig. 3. Effect of different substrates on harvesting period of three strains of oyster mushroom (*Pleurotus florida*)

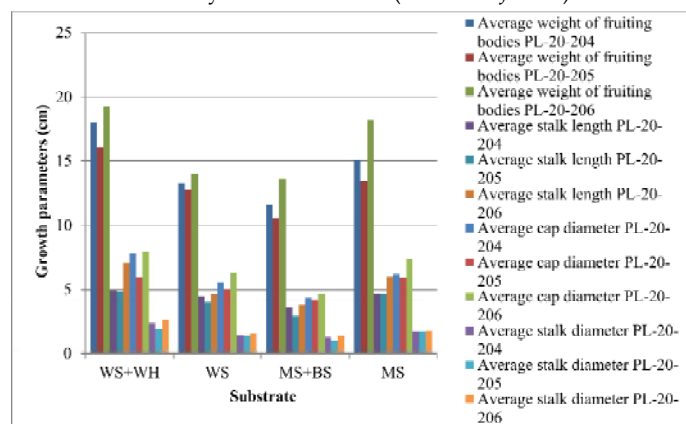


Fig. 4. Effect of different substrates on growth parameters of three strains of oyster mushroom (*Pleurotus florida*)

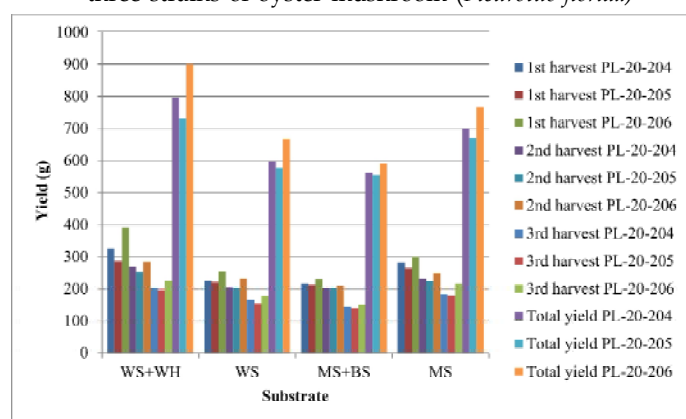


Fig. 5. Effect of different substrates on yield potential of three strains of oyster mushroom (*Pleurotus florida*)

Harvesting and total crop period

A total of three flushes of mushroom fruiting bodies were obtained. Minimum total cropping period was observed in wheat straw+ water hyacinth as substrate (47.54 days in PL-20-204, 48.58 days in PL-20-205 and 47.34 days in PL-20-206) (Fig. 3). Maximum cropping period was obtained where maize straw + bajra straw was used as substrate (52.99 days in PL-20-204, 53.12 days in PL-20-205 and 50.72 days in PL-20-206).

Weight of fruiting bodies

Maximum average weight of mushrooms was recorded in wheat straw+ water hyacinth substrate and it was 19.30 g in PL-20-206 followed by 18.03 g in PL-20-204 and 16.09 g in PL-20-205 strains (Fig. 4). The minimum average weight of fruiting bodies was recorded by PL-20-205 strain (10.61 g) on maize straw+ bajra straw substrate followed by 11.60 g and 13.67 g for PL-20-204 and PL-20-206 strains, respectively.

Stalk length of fruiting bodies

The highest (7.07 cm) average stalk length of fruiting bodies was measured in PL-20-206 strain on wheat straw+ water hyacinth substrate followed by 6.02 cm in PL-20-206 in maize straw. Average weight of fruiting bodies in PL-20-204 and PL-20-205 on wheat straw + water hyacinth was 4.92 and 4.82 cm, respectively (Fig. 4). The minimum average stalk length of fruiting bodies was recorded in PL-20-205 strain (2.94 cm) on maize straw+ bajra straw substrate.

Cap and stalk diameter

The maximum average cap diameter (7.97 cm) was measured in PL-20-206 strain grown on wheat straw + water hyacinth substrate which was followed by 7.84 cm in PL-20-204 grown on wheat straw + water hyacinth and 7.36 cm in PL-20-206 grown on maize straw substrate (Fig. 4). The minimum cap diameter (4.20 cm) was recorded in PL-20-205 strain on maize straw substrate. Average higher stalk diameter (2.61 cm) was measured in PL-20-206 strain on wheat straw+ water hyacinth substrate followed by 2.38 cm in PL-20-204 and 1.89 cm in PL-20-205 strains. The lowest average stalk diameter was recorded in PL-20-205 strain (1.02 cm) on maize straw+ bajra straw substrate followed by 1.30 cm and 1.38 cm for PL-20-204 and PL-20-206 strains, respectively (Fig. 4).

Total yield

Three harvests of the crop were done (Fig. 5). Maximum total yield (900.18 g) was recorded in PL-20-206 strain in grown on wheat straw+ water hyacinth substrate followed by 795.17 g and 731.98 g for PL-20-204 and PL-20-205 strains,

respectively. The lowest yield was recorded for PL-20-205 strain (554.19 g) on maize straw+ bajra straw substrate followed by 561.73 g for PL-20-204 and 590.46 g for PL-20-206 strains.

The results are in conformity with the findings of Neupane *et al.* (2018) who investigated effect of five different substrates *viz.*, banana leaves, rice straw, wheat straw, mixture of rice and wheat straw and saw dust on growth and yield of *Pleurotus florida*. Results are also in accordance with the findings of Iqbal *et al.* (2016) who used different agricultural substrates for growth and yield potential of *Pleurotus florida*.

CONCLUSION

It could be concluded from the present investigation that PL-20-206 strain of *Pleurotus florida* performed best on all substrates. Wheat straw+water hyacinth was best substrate for cultivating oyster mushroom. The above findings also gave an insight that locally available agricultural wastes could be utilized successfully for oyster mushroom cultivation.

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Evaluation of spawn quality and doses on yield and biological efficiency of Blue Oyster Mushroom [*Hypsizygus ulmarius* (Bull.: Fr.) Redhead]

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ABSTRACT

Mushroom cultivation is a cost effective biotechnological approach for converting lignocellulosic wastes into edible proteins. Blue Oyster mushroom is a novel species which has a wide use due to its unique taste, flavor, nutritive and medicinal values. Since, spawn quality is the most important factor of edible mushroom production hence, the study was undertaken to determine the influence of spawn substrate and doses on the yield and biological efficiency of *H. ulmarius* on different agri/industrial wastes. Out of seven different grain substrates evaluated, bajra grains were found as an excellent substrate for spawn production. Growth rate, yield and biological efficiency was also recorded more on bajra grain spawn. Spawning with bajra grain spawn resulted in faster spawn run (13.67 days), first flush (20.33 days), maximum number of sporocarps (38.33), longest stipe length (5.37 cm) and maximum cap diameter (8.57 cm) on wheat straw substrate. Further it can be concluded that 5.0 per cent spawn dose on wheat straw substrate resulted in minimum spawn run period (12.66 days), maximum number of fruit bodies (42.33) and highest yield (661.67 g/0.5 Kg substrate) and maximum biological efficiency (132.33 %) followed by 4.0, 3.0, 2.0 and 1.0 per cent spawn dose respectively spawned with bajra grain spawn. These studies will help in effectively utilization of agri/industrial wastes for production of high quality proteins and crucial to help alleviate the perils of hunger as well as a step forward towards the sustainable environmental conservation.

Keywords: Agri/Industrial waste, Waste management, *Hypsizygus ulmarius*, Spawn, Spawn dose, Yield, Biological efficiency

Hypsizygus ulmarius (Bull.: Fr.) Redhead, usually known as “Elm Oyster” or “blue Oyster” mushroom has higher biological efficiency (Sumi and Geetha, 2017) and larger fruiting bodies in comparison to other species of Oyster mushrooms. Further its spore content is also very low hence it does not cause any respiratory allergy problems as the other species of Oyster (Meera *et al.*, 2011). In India not much work has been done on the cultivation technology of this mushroom, therefore, we evaluated different grain substrates for spawn, spawn doses and fruiting body production of *H. ulmarius*.

MATERIALS AND METHODS

Procurement, maintenance and preservation of culture

The pure culture of Blue Oyster mushroom was procured from ICAR-Directorate of Mushroom Research, Chambhaghat, Solan, Himachal Pradesh, India. The culture, thus obtained was maintained on potato dextrose agar (PDA) medium (sub cultured periodically at an interval of 30-45 days). Full grown culture was stored at 2-4°C in the refrigerator until used further for the entire work.

Preparation of spawn

Seven different cereal grains i.e. wheat, paddy, jowar, bajra, oat, maize and barley were evaluated for spawn production. Healthy grains were cleaned, washed and boiled in tap water for at least 30-35 minutes. Care was taken not to overcook the grains, so that they may not rupture. Excess water was drained off by keeping on a wire mesh for 1-2 h. The substrates were mixed with 2.0 per cent calcium sulphate and 0.5 per cent calcium carbonate on wet weight basis to obtain the desired pH and to avoid the stickiness of the grain substrates. Thereafter, these were filled in graduated glass bottles (1000 ml capacity) plugged with non-absorbent cotton and sterilized at 22 psi for 2 h. After cooling, the bottles were shaken vigorously to restore transparency of glass and were inoculated with uniform sized mycelial bits of *H. ulmarius* under aseptic conditions. These bottles were then incubated at 25±1°C in the BOD incubator, till the grains were fully impregnated with the mycelium of inoculated fungus culture.

Preparation of growing substrates

Seven different agri/industrial wastes viz., wheat straw, maize straw, pine needles (*Pinus roxburghii*), wood chips, saw dust, lantana leaves (*Lantana camara*) and curry leaves (*Murraya koenigii*) were collected from the locality of College of Horticulture and Forestry Neri, Hamirpur, Himachal Pradesh and used as cultivation substrate. The substrates were chopped into small pieces (2-4 cm long) and thereafter soaked separately in water to get completely wet and then treated with a solution of formalin (0.5 %) and carbendazim (0.075 %). After about 18 hours, the straws were taken out and the excess water in the substrate was drained off by placing the substrate on a clean wire mesh (Vijay and Sohi, 1987). After that, all of these chemically treated substrates were thoroughly spawned using 5.0 percent bajra grains spawn. These spawned substrates were then filled in the mushroom growing bags of polythene having 2.0 kg capacity (500 g dry substrate) and later shifted to growing mushroom hut. Standard mushroom growing packages and practices were followed to raise the crop.

Observations recorded

Spawn Preparation: Data were recorded in terms of time taken for spawn run in days and growth characteristics of the mycelium of the test fungus.

Cultivation Studies: Data were recorded in terms of time taken for spawn run in days, time taken for first flush of mushroom in days, number of sporocarps in first flush, Stipe length of the mushroom (cm) and cap diameter (cm).

Yield of mushroom: This is the quantity/weight of mushroom produced per bag of substrate per harvest time. It was weighted by using electronic balance.

Biological efficiency: The biological efficiency (%) was calculated by using formula (Chang *et al.*, 1981) mentioned below:

$$\text{Biological Efficiency (BE) \%} = \frac{\text{Fresh weight of harvested mushroom}}{\text{Dry weight of substrate used}} \times 100$$

Statistical analysis of data recorded

The experiments were conducted in the completely randomized block design with three replications and analyzed by using statistical package of program OPSTAT (Sheoran, 2006).

RESULTS AND DISCUSSION

Effect of different grain substrates for spawn production of *Hypsizygus ulmarius*

Spawn, the vegetative seed material plays a vital role in mushroom cultivation and the substrate on which the

spawn is prepared also affects the mushroom production to a significant extent (Stanley and Awi-waddu, 2010). Grain spawn is of common use because of its ability to ramify the substrate faster and ease of planting (Bahl, 1988). Several authors have tried a variety of grain substrates and agricultural wastes for preparation of spawn based on the easy availability, accessibility and lower cost for different edible mushrooms (Lima *et al.*, 1975; Shah *et al.*, 2004; Stanley, 2010; Oseni *et al.*, 2012; Mijan Hossain, 2017 and Reddy *et al.*, 2020). At present grains like wheat, maize, barley, oat, sorghum, paddy and bajra are commonly used for the commercial spawn production and cultivation of a variety of edible mushrooms (Sharma, 2016).

The time taken in complete spawn run on different grain substrates viz., bajra, jowar, wheat, maize, oat, paddy and barley was significantly different except on paddy and oat grain substrates which took 17 and 17.5 days, respectively. Minimum period for spawn run was recorded in bajra grains (11 days) followed by jowar (13 days), wheat (15 days), maize (60 days), oat (17 days), paddy (17.5 days) and barley (19.0 days) respectively. As far as the growth characteristics of *H. ulmarius* spawn were concerned, it differed greatly with respect to different grain substrates. A white mycelial growth was recorded on all type of grains under study but, it was more conspicuous in bajra, jowar, wheat and maize grains spawn. The mycelia growth was faster, thick, strandy and dense white on bajra grains while, it was observed to be dense to thick in case of jowar, wheat and maize grains. However, comparatively slower, thin and fluffy growth was noticed and grains were also loosely held in oat, paddy and barley grains (Table 1).

The results of present study are in accordance with the findings of Chauhan and Pant (1988); Chaurasia (1997) and Rathod *et al.*, (2002) who have also reported bajra and jowar grains to be superior than other grains for spawn production of different *Pleurotus* spp.

Effect of different grain spawn on yield contributing characters of *Hypsizygus ulmarius*

The data presented in Table 2 revealed that minimum average time taken for spawn run (13.67 days) was recorded in bajra grain spawn, which was statistically at par with jowar (14.33 days), wheat grain (14.33 days) and maize grain spawn (14.67 days) which was further at par with that in oat grain spawn (15.33 days). Minimum time taken for first flush was recorded in bajra grain spawn (20.33 days) which was statistically at par with jowar (20.67 days) and wheat (21.33 days) grain spawn while, maximum time taken for first flush (25.33 days) was recorded in barley grain spawn significantly followed by oat (23.33 days) grain spawn which

did not differ significantly from paddy (23.00 days) grain spawn. Significantly maximum number of sporocarps (38.33) was recorded in bajra grain spawn followed by wheat (34.67) which was statistically at par with jowar (34.00) grain spawn. However, minimum number of sporocarps (28.67) was recorded in barley grain spawn which was statistically at par with number of sporocarps in paddy (29.00), oat (30.33) and maize (31.00) grain spawn. As far as morphometric characteristics of *H. ulmarius* were concerned, longest stipe length (5.37 cm) was recorded in bajra grain spawn which was statistically at par with wheat (5.30 cm), jowar (5.23 cm) and oat (5.07 cm) grain spawn. Paddy grain spawn exhibited the shortest stipe length (4.77 cm) followed by maize (4.83 cm) and barley (4.93 cm) grain spawn which were statistically at par with each other. As far as the cap diameter is concerned, it was recorded to be maximum in bajra grain spawn (8.57 cm) followed by wheat grain spawn (8.50 cm). However, latter two treatments were statistically at par with each other. Minimum cap diameter (7.30 cm) was observed in barley grain spawn which was statistically at par with paddy (7.47 cm) and maize (7.60 cm) grain spawn.

The results are supported by the findings of Sumi and Geetha (2017) who reported complete mycelial colonization with paddy grain spawn in 18.5 days; and also Baghel (2017) on bajra grain spawn took (11.2 days) followed by maize (13.4 days) and wheat grain spawn (14.5 days) for complete mycelia spread. Singh (2019) reported cap diameter ranging from 6.00 to 8.73 cm and stipe length varying between 7.50 cm to 11.17 cm of different substrates while Shendge *et al.*, (2019) recorded cap diameter ranging from 5.80 to 8.16 cm and stipe length varying between 5.53 to 8.66 cm grown on soyabean straw. Our findings are more or less similar to the above workers.

Effect of different spawn doses on different agri/industrial wastes for yield contributing parameters

As per the results obtained under Table 1 and 2, bajra

Table 1. Effect of different grain substrates on spawn production and growth characteristics of *Hypsizygus ulmarius*

Grain substrates	Time taken for spawn run (days)*	Growth characteristics
Bajra	11.00	Thick, strandy and dense white mycelial growth on all grains.
Jowar	13.00	Dense white mycelial growth on all grains but intact with each other.
Wheat	15.00	Thick, strandy white mycelial growth on all grains.
Maize	16.00	Dense, fluffy white mycelial growth on all grains.
Oat	17.00	Thin, fluffy white mycelial normal growth on all grains.
Paddy	17.50	White mycelial growth on all over the grains but not tightly held.
Barley	19.00	White mycelial normal growth on all grains.
CD _{p≥0.05}	0.51	
SE _(d)	0.24	

*Average data of three replications

grain substrate was recorded to be an excellent grain substrate for preparation of quality spawn of *H. ulmarius*. Hence, the further investigations on the effect of different spawn doses of bajra grain spawn were evaluated on yield contributing characters and biological efficiency of *H. ulmarius* on seven different substrates.

It is evident from the results obtained in Table 3, irrespective of the different substrates used, significantly minimum average time taken for spawn run (18.05 days) was recorded in substrates spawned with bajra grain spawn @ 5.0 per cent followed by those spawned at the rate of 4.0 percent (24.90 days) and 3.0 percent (21.47 days). Keeping aside spawn doses used, wheat straw exhibited significantly minimum (18.20 days) time to spawn run followed by maize straw (20.53 days), pine needles (25.69 days), lantana leaves

Table 2. Effect of different grain spawn on production and yield parameters of *Hypsizygus ulmarius*

Grain spawn	Time taken for spawn run (days)*	Time taken for first flush (days)*	Number of sporocarps in first flush*	Stipe length (cm)*	Cap diameter (cm)*
Bajra	13.67	20.33	38.33	5.37	8.57
Jowar	14.33	20.67	34.00	5.23	8.20
Wheat	14.33	21.33	34.67	5.30	8.50
Maize	14.67	21.67	31.00	4.83	7.60
Oat	15.33	23.33	30.33	5.07	7.73
Paddy	17.00	23.00	29.00	4.77	7.47
Barley	18.33	25.33	28.67	4.93	7.30
CD _{p≥0.05}	1.16	1.16	3.36	0.39	0.42
SE _(d)	0.53	0.53	1.55	0.18	0.19

*Average data of three replications

Table 3. Effect of spawn doses on spawn run period of *Hypsizygus ulmarius* in different substrates

Spawn dose (%)	Average time taken for spawn run in different substrates (days)*							Overall Mean
	Wheat straw	Maize straw	Pine needles	Saw dust	Wood chips	Lantana leaves	Curry leaves	
1.0	22.66	24.33	30.66	32.33	34.66	31.66	32.67	29.86
2.0	21.67	23.67	29.33	30.33	33.00	29.33	29.64	28.14
3.0	18.33	21.33	27.00	28.00	29.67	26.67	27.65	25.52
4.0	15.68	17.66	23.00	23.67	26.67	23.00	24.00	21.95
5.0	12.66	15.65	18.33	19.66	21.66	18.33	20.00	18.05
Overall Mean	18.20	20.53	25.69	26.80	29.13	25.80	26.80	
	CD _{p≥0.05}	SE _(d)						
Spawn Dose	0.43	0.22						
Substrate	0.51	0.26						
Interaction	1.15	0.57						

*Average data of three replications.

(25.80 days), saw dust (26.80 days) and wood chips took maximum time (29.17 days) for complete spawn run of *H. ulmarius*. Interaction of spawn doses and substrates used revealed that minimum (12.66 days) time to spawn run was observed in wheat straw @ 5.0 percent which was statistically at par with that of maize straw (15.65 days) spawned at the same rate. The later was further followed by spawn run period (15.68 days) in wheat straw substrate spawned at the rate of 4.0 per cent.

A perusal of the results presented in Table 4 indicates that, average maximum number (26.95) of sporocarps were recorded when the substrates were spawned at the rate of 5.0 per cent significantly followed by those spawned at the rate of 4.0 per cent (24.90). However, average minimum number (18.95) of sporocarps were recorded in substrate spawned with at the rate of 1.0 per cent which was statistically at par with those spawned at the rate of 2.0 per cent (19.81) which was further followed with those spawned at the rate of 3.0 per cent (21.43). Irrespective of the different spawn doses used, significantly maximum (31.80) number of sporocarp was recorded in wheat straw while significantly

minimum (15.20) number of sporocarp was recorded in wood chips substrate. Body of the table revealed that maximum (42.33) number of sporocarp was harvested from wheat straw substrate spawned at the rate of 5.0 per cent which was highly significant with the number of sporocarp was produced on the other substrates spawned at the same rate. Minimum number of sporocarp (12.66) was produced on wood chips spawned at the rate of 2.0 per cent which was statistically at par with the number of sporocarp (13.67) spawned at the rate of 3.0 per cent in the same substrate.

The data presented in the Table 5 indicated that irrespective of substrates used, spawn dose at the rate of 5.0 percent resulted in maximum average yield (493.09 g 0.5 kg⁻¹ substrate) followed by spawn rate of 4.0 percent (447.52 g 0.5 kg⁻¹ substrate, etc. Keeping aside the spawn dose used, wheat straw substrate resulted in maximum (554.27g 0.5 kg⁻¹ substrate) yield followed by maize straw (504.60 g 0.5 kg⁻¹ substrate), lantana leaves (436.13 g 0.5 kg⁻¹ substrate) and pine needles (407.67 g 0.5 kg⁻¹ substrate), respectively. Biological efficiency was recorded maximum (132.33%) in wheat straw substrate spawned at the rate of

Table 4. Effect of spawn doses on fruit body production of *Hypsizygus ulmarius* in different substrates

Spawn dose (%)	Average number of fruit bodies in different substrates*							Overall Mean
	Wheat straw	Maize straw	Pine needles	Saw dust	Wood chips	Lantana leaves	Curry leaves	
1.0	25.33	23.66	17.66	19.33	13.00	19.00	14.66	18.95
2.0	27.66	24.33	18.33	20.00	12.66	20.33	15.33	19.81
3.0	28.00	29.00	20.67	20.33	13.67	21.00	17.33	21.43
4.0	35.67	34.00	23.33	21.00	18.00	22.66	19.67	24.90
5.0	42.33	32.33	26.66	24.00	18.67	24.67	20.00	26.95
Overall Mean	31.80	28.67	21.33	20.93	15.20	21.53	17.40	
	CD _{p≥0.05}	SE _(d)						
Spawn Dose	1.35	0.67						
Substrate	1.60	0.80						
Interaction	3.58	1.79						

*Average data of three replications.

Table 5. Effect of different spawn doses on the yield of *Hypsizygus ulmarius* in different substrates.

Spawn dose (%)	Average yield (g 500 g ⁻¹ substrate) in different substrates*							Overall Mean
	Wheat straw	Maize straw	Pine needles	Saw dust	Wood chips	Lantana leaves	Curry leaves	
1.0	485.67 (97.13)	456.66 (91.33)	338.33 (67.67)	315.67 (63.13)	231.67 (46.33)	396.67 (79.33)	280.00 (56.00)	357.81
2.0	490.00 (98.00)	460.00 (92.00)	361.67 (72.33)	328.33 (65.67)	258.33 (51.67)	410.00 (82.00)	303.33 (60.67)	373.09
3.0	528.33 (105.67)	488.33 (97.67)	410.00 (82.00)	370.00 (74.00)	298.33 (59.67)	445.65 (89.13)	349.00 (69.80)	412.81
4.0	605.66 (121.13)	511.33 (102.27)	440.00 (88.00)	411.67 (82.33)	341.66 (68.33)	443.33 (88.67)	379.00 (75.80)	447.52
5.0	661.67 (132.33)	606.67 (121.33)	488.33 (97.67)	451.66 (90.33)	358.33 (71.67)	485.00 (97.00)	400.00 (80.00)	493.09
Overall Mean	554.27	504.60	407.67	375.47	297.67	436.13	342.26	
	CD _{p=0.05}	SE _(d)						
Spawn Dose	7.49	3.75						
Substrate	8.87	4.43						
Interaction	19.83	9.92						

*Average data of three replications; Figure given in parentheses represents biological efficiency (percentage).

5.0 percent dose followed by maize straw (121.33%) and wheat straw (121.13%) spawned at the rate of 4.0 percent. The results of the present study suggested that blue Oyster mushroom can be cultivated on wheat straw substrate spawned with bajra grains spawn @ 5.0 percent spawn dose for obtaining higher yield and maximum biological efficiency.

In the present study, the mean number of days taken for spawn run of *H. ulmarius* from the date of spawning exhibited significant difference among different spawn rates. These results are in agreement with the findings of Tewari (1991); Biswas and Kuiry (2013); Sharma (1999); Royse (2002); Ram and Pant (2004); Chandravanshi (2007); Dasmesh (2013); Chauhan (2013); Shazia *et al.*, (2017) and Shendge (2018) who reported earlier spawn run and higher yield with increasing rate of spawning. These results are also in agreement with the findings of Pal *et al.*, (2017) and Pardeep *et al.*, (2018) who reported higher yield biological efficiency with the increased rate of spawning. Increased spawning rate shortens mycelial colonization, time to primordia formation, the time to the first mushroom crop and narrows the gap of opportunity for competitor invasion (Stamets, 2000). The increased nutrient level available in spawn at higher rates would provide more energy for mycelial growth and development (Royse *et al.*, 2004).

CONCLUSIONS

Waste management is the need of the hour, the global food and nutritional security of growing population is a great challenge which looks for a new crop as a source of food and nutrition. Cultivation of highly nutritional and medicinal

mushrooms on agri/industrial wastes is one of such efforts which can provide nutritional, employment, environmental security and it would be eco-friendly sustainable strategy for alleviate hunger.

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Design of solar tray tomato drier

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ABSTRACT

Drying is one of the oldest, cheapest and most common methods of preservation and storing agricultural products. Open air sun drying of agricultural products is the traditional method employed in most of the developing countries. Sun drying is used to denote the exposure of a commodity to direct solar radiation and the convective power of the natural wind. Many of our food crops have 80 to 90 per cent moisture content and most of these need to be removed for long term storage. In practice, most of the dryers used have an operating efficiency of 50-60 per cent and this indicates that significant amounts of energy are used in the post-harvest activity. A small scale village level solar dryer for tomato was designed in Mainefhi subzone using locally available materials. The theoretical design of the solar dryer was composed of the solar collector, blower, drying chamber and chimney. Designing a solar collector parts which include solar collector area, absorber surface area, selection of suitable blower with the recommended capacity, designing solar drying chamber area and sizing of drying chamber and chimney were the specific aim of the study. The results on the basis of calculations and assumptions with the recommended value were obtained. The solar dryer with collector area of 2.26 m² and drying capacity of 5kg was designed to dry tomato from 90 per cent to 8 per cent moisture content wet bulb during the sunshine hours, 8.21 hrs per batch. After drying, 5kg of tomato was reduced to 0.544kg of tomato.

Key words: Solar, tray, tomato, dryer, collector

Vegetable drying is one of the most accessible and widely spread processing technologies. Sun drying of vegetables is still practiced largely unchanged from ancient times. Traditional sun drying takes place by storing the product under direct sunlight. Sun drying is only possible in areas where weather allows food to be dried immediately after harvest. However, since sun drying depends on uncontrolled factors, production of uniform and standard products is not expected. As a result of these factors, the demand of solar dryer is crucial.

Solar drying of agricultural product is essential and most viable solution to the world's food problem as it involves reducing the food loss, which occurs due to various reasons such as lack of suitable technology, improper cultivation and fertilization, lack of marketing channels, improper transportation, high post-harvest losses, etc., causing a food loss from 10 to 40 per cent (Reyes *et al.*, 2015). Solar dryer is specialized device that control the drying process and protect the agricultural product from damage by insect pests, dust and rain. In comparison to natural sun drying, solar dryer generates higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to mechanical

drying methods. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and mechanical drying. Various types of solar dryers had been designed to overcome this problem. The type of dryer depends on the product and the drying process required for that particular type of product. However, this project concentrates on solar tomato dryer.

Tomato (*Solanum lycopersicum* L.) is one of the most universally known, widely consumed, nutritious, and widely grown stable vegetable in the world. Tomato is a good source of vitamin A, B and excellent source of vitamin C. It also contains α -carotene and lycopene one of the most powerful natural antioxidants (Hernández-Suárez *et al.*, 2007 and Javanmardi, and Kubota, 2006). In Eritrea, tomato is the most popular vegetable, used daily, mixed with sauce, soup, and salad, making the stable food more delicious. It is placed among the four priority vegetable crops along with onion, potato and pepper. Even though fresh tomatoes are very refreshing and appetizing, it cannot be stored for long periods.

The approach used in this study aimed to design a solar tomato dryer with the aim that it could easily be adopted and designed locally.

MATERIALS AND METHODS

Fundamental design considerations

The size of the dryer was determined as a function of the drying area needed per kilogram of tomato. The drying temperature was established as a function of maximum limit of temperature that might support. From the climatic data of study area, the mean average day temperature was 16.56 °C and relative humidity was 50.59 per cent. Hence, from the psychometric chart the initial humidity ratio was 0.006 kg kg⁻¹, final humidity ratio was 0.0145 kg kg⁻¹. The maximum allowable drying temperature of tomato without compromising its quality was maintained at 50°C and final moisture content of tomato for safe storage was 3 to 15 per cent for 3 to 5 mm sliced thickness (Aduet *et al.*, 2012).

To carry out design calculations and size of the dryer, the design conditions applicable to the study area were considered. Information regarding the type of crop to be dried, loading densities acceptable, the crop characteristics and the quantity per batch were needed with data concerning the geographical location of the dryer and climatic conditions during the harvest period. The conditions, assumptions and relationships summarized in Table 3 were used to calculate the design parameters of the solar tomato dryer.

Solar collector: A solar thermal collector collects heat by absorbing sunlight or solar radiation. Air heated through a solar collector and then passed over a medium to be dried and provide an efficient means by which to reduce the moisture content of the product. The materials used in the solar collector were wood, glass, paint, nails and screws.

Drying chamber: Drying chamber is a rectangular shape which is used for holding of the product that is going to be dried. The materials used to construct the drying chamber were metal sheet and mesh.

Insulation materials: Insulation materials are used for covering the side walls of the air solar heater, the walls of drying chamber, the door of the drying chamber and for the connecting tubes, to prevent heat lost to the surrounding during drying process. They were polystyrene and/or thermocole type.

Solar collector area: From the total useful heat energy required to evaporate moisture and the net radiation received by the collector, the solar drying system collector area A_c (m²) can be calculated from the following equation (Youcef-Ali *et al.*, 2001):

$$A_c IT\eta_c = E = ma (h_f - h_i) t_d$$

Therefore, area of the solar collector: $A_c = E / IT\eta_c$

Quantity of heat required to evaporate the water (E)

E [kJ] was calculated using the following equation $E = ma (h_f - h_i) t_d$

Mass of air needed for drying

It was calculated using the following equation: $ma = m_w / t_d(w_f - w_i)$

Drying rate (DR): It was calculated using the following equation: $DR = m_w / t_d$

Amount of moisture to be removed $m_w = m_p(m_i - m_f) / (100 - m_f)$

The collector efficiency: The efficiency of flat plate collector is influenced by many factors such as the size of collector, geographical location, velocity, humidity, the temperature of the surrounding air etc. The thermal efficiency for solar collector was determined by the following equation: $\eta_c = maC_p(t_f - t_i) / A_c I_t$

Five kilogram of tomatoes cut into 5 mm thick slices, placed on 4 trays in dryer were dried for 8.21 hrs to get a moisture level of 8 per cent.

RESULTS AND DISCUSSION

Design specifications drying process

The drying process of heat and mass transfer of the tomato is inside the drying chamber of the drier. The process consisted removal of moisture from the product by heat usually in the presence of a controlled flow of air. Initially the tomatoes were manually chosen, having average dimensions of 4.0 ± 0.3 cm diameter and 9.0 ± 0.3 cm length. The tomatoes were washed, sliced longitudinally in quarters or eighths, and prepared (if necessary), then placed at the trays inside the drying chamber. This was necessary because the tomatoes skin is a barrier to moisture removal, and a higher exposure of the tomatoes flesh improved water diffusion, thus shortening the drying process. The solar insolation entered into solar collector through the double glass cover material and converted into heat energy, raising the inside temperature. The blower blew air to the collector. Then the heated air moved to the drying chamber where the tomato was to be dried. The heated product gave out water vapour and dried up. Gradually the heated moist air went up and left the drying chamber through the chimney (air outlet) at the top end of the dryer. The efficiency of the solar drier was influenced by relative humidity in the air, the moisture content of the materials to be dried on the drying chamber, etc. The solar radiation intensity on the material varied with season, time of the day, length of exposure,

ambient air temperature and wind speed, which were important factors (Reyes *et al.*, 2015).

Desired design calculation of the solar collector

It consisted of an insulating box made of popular wood (*Liriodendron tulipifera*) and deodar (*Cedrus deodara*). These wood could be used for the preparation of the insulating box because they are good insulators, cheap, easily available in the local market, having a high melting point and low weight. It was insulated inside with the help of packing material or polystyrene foam. The absorber was V corrugated (50mm thick) and black painted steel sheet fixed in the middle of the insulating chamber. The glazing broad glass sheet (5mm thickness), which has the same size as the absorber, was placed at the top of the insulating chamber. Glass was used for covering the absorber so that it could be protected from air currents and allow long as well as short wave length solar radiation to reach the absorber. The air passed through the free space (30 to 50 mm height) between the glass sheet and the V corrugated steel sheet (Reyes *et al.*, 2015).

According to the above data:

Amount of moisture removed (m_w)

It was calculated from equation as:

$$m_w = 5 \times (90 - 8) / (100 - 8) = 4.456 \text{ kg.}$$

The amount of moisture was removed from the initial mass product $5 \text{ kg} - 4.456 \text{ kg} = 0.544 \text{ kg}$.

Drying rate (DR)

It was calculated from the equation: $DR = 4.456 \text{ kg} / 8.21 \text{ hr} = 0.555 \text{ kg/hr}$

Mass of air needed for drying (m_a)

It was calculated from equation as:

$$m_a = 4.456 \text{ kg} / 8.21 \times [0.0145 - 0.006] = 63.853 \text{ kg/hr} = 0.0177 \text{ kg/s}$$

Quantity of heat required to evaporate water (E)

It was calculated from equation as:

$$E = 63.853 \times (67.5 - 30.25) \times 8.21 = 19.527 \text{ MJ}$$

Solar collector area (A_c): It was calculated from equation as:

$$A_c = 19.527 / 21.6 \times 0.4 = 2.26 \text{ m}^2$$

Selection of blower

Discharge of air (m^3/s)

It was calculated from equation as:

$$Q_v = (63.853 \text{ kg/hr}) / (1.2 \text{ kg/m}^3) = 53.21 \text{ m}^3/\text{hr} = 0.0147 \text{ m}^3/\text{s}$$

Volume of drying air (m^3)

It was calculated from equation as: $V_a = 53.21 \text{ m}^3/\text{hr} \times 8.21 \text{ hr} = 436.854 \text{ m}^3$

Determination of size and power of the fan

Diameter of fan (D)

It was calculated from equation as follows. The speed of the fan in m/s was calculated from the Renolds number and the Nussult number:

$$A = (53.21) / (23.96 \text{ m/s})$$

$$= 6.135 \times 10^{-4} \text{ m}^2$$

Then the diameter of the fam was:

$$D = 27.948 \text{ mm}$$

Speed of the fan (rpm)

It was calculated from equation as:

$$W = (23.96 \text{ m/s}) / (0.0139 \text{ m})$$

$$= 1714.612 \text{ radian}$$

$$\text{rpm} = 272.88$$

Power of the motor for the fan

It was calculated from equation as:

$$p = 0.5 (0.0177 \text{ kg/s}) \times (23.96 \text{ m/s})^2 = 5.08 \text{ w}$$

CONCLUSION

Five kg of fresh tomatoes were dried to 0.544 kg by reducing the moisture from 90 to 8 per cent in 8.21 hrs in the solar dryer fabricated and used in the study. For effective drying 0.0177 kg/s mass flow rate of air and 436.854 m^3 volume of air were needed. The diameter 27.948 mm of fan which rotated in 272.88 rpm was sufficient to suck the required volume of air for drying and the power used was 5.08 w. A 27 mm diameter of pipe with 31cm length was sufficient to convey the right volume of air from the collector to the drying chamber for effective drying.

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Microbial degradation of chlorpyrifos and carbosulfan in sterile soil under laboratory conditions

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ABSTRACT

Bacterial degradation of chlorpyrifos and carbosulfan in sterile soil under laboratory condition has been investigated at different concentrations (100, 200 and 300 $\mu\text{g g}^{-1}$ of soil for chlorpyrifos and 100 and 400 $\mu\text{g g}^{-1}$ of soil for carbosulfan). HPLC data of chlorpyrifos after 60 days of sampling revealed that the insecticide has degraded to 98.48, 98.22 and 95.19 per cent from its initial concentrations of 100, 200 and 300 $\mu\text{g g}^{-1}$ in sterile soil. Whereas, the degradation percentages were 29.58, 37.16 and 28.40 after 60 days from the control samples without microbial consortium. Similarly, 100 per cent degradation for carbosulfan in sterile soil by microbial consortium was achieved at 30 days after treatment for 100 $\mu\text{g g}^{-1}$ and at 60 days for 400 $\mu\text{g g}^{-1}$ compared to control. Faster degradation by bacterial consortium was recorded for both the insecticides which followed pseudo first order rate kinetics. The study confirmed that microbial consortium could effectively be utilized for faster bioremediation of these insecticides in sterile soil under laboratory conditions. This consortium can also be used for effective biodegradation of two insecticides in mango orchard soil under field conditions.

Key words: Chlorpyrifos, carbosulfan, bacterial degradation, sterile soil, laboratory conditions

Chlorpyrifos (an organophosphorothionate insecticide) and carbosulfan (a carbamate insecticide) are used in mango ecosystem to reduce the population of mealy bug and leaf webber, respectively. Chlorpyrifos is a contact insecticide and its dust formulation is used as soil application to check the movement of mealy bug nymph. However, carbosulfan is a systemic insecticide and used as foliar application to control leaf webber in mango tree (Bhattacharjee, 2013). Chlorpyrifos is a moderately persistent insecticide in soil and its persistence in different kinds of soil under different crop cultivation ranged between 30-300 days with half-life of 10-120 days (Castro *et al.*, 2002; Bhattacharjee *et al.*, 2017). Similarly, carbosulfan can persist in different kinds of soil for 60-75 days with half-life of 11-15 days (Rajeswaran *et al.*, 2005). Both chlorpyrifos and carbosulfan are comparatively less persistent than imidacloprid, another insecticide heavily used in mango, which can persist in soil for more than four years with half-life ranging from 18-1230 days depending on soil type (Bhattacharjee *et al.*, 2019). The degradation of a particular insecticide in soil depends on various factors like soil pH, soil temperature, soil moisture, soil type, presence of active microbial groups in soil, etc. Faster degradation of persistent insecticides in soil can reduce the load of that particular insecticide in water environment by preventing its entry into groundwater through leaching and subsequently reduce the

risk of its toxicity to human being by preventing its entry into food chain.

Though, physical, chemical and microbial approaches can be undertaken to degrade a pesticide in soil, microbial degradation has been found an environment-friendly, economically viable and most effective approach. Several microorganisms (mostly bacteria) were isolated from different kinds of soil and tested for degradation of chlorpyrifos and carbosulfan in soil and in liquid medium. For biodegradation of chlorpyrifos some isolated and identified bacteria as reported were *Enterobacter asburiae* strain B-14 from Australian soil (Singh *et al.*, 2004), *Sphingobacterium* sp. strain JAS3 from Indian soil (Abraham and Silambarasan, 2013), *Bacillus safensis* strain FO-36b, *Bacillus subtilis* subsp. *inaquosorum* strain KCTC13429, *Bacillus cereus* strain ATCC14579 from pesticide polluted Sudanese soil (Ishag *et al.*, 2016), *Achromobacter xylosoxidans* strain JCP4 and *Ochrobactrum* sp. strain FCP1 from agricultural soil in Pakistan (Akbar and Sultan, 2016), *Xanthomonas* sp. strain 4R3-M1, *Pseudomonas* sp. strain 4H1-M3 and *Rhizobium* sp. strain 4H1-M1 from sugarcane farm soil in Australia (Rayu *et al.*, 2017), *Pseudomonas stutzeri* strain CHL3 from pesticide contaminated soil in Thailand (Phumkhachorn and Rattanachaikunsopon, 2020), *Klebsiella pneumoniae* strain M-11 from subtropical agricultural land in India (Kumar *et al.*,

2021), *Bacillus cereus* Ct3 from cotton growing soil in Pakistan (Farhan *et al.*, 2021), etc. Similarly, for carbosulfan degradation in soil, eight different bacterial isolates from Pakistan (Mujeeb *et al.*, 2011), *Pseudomonas* sp. from brinjal cultivated soil in Bangladesh (Sharif and Mollick, 2013), *Pseudomonas* sp. strain CISH C-1 from mango orchard soil in India (Garg *et al.*, 2018), unidentified bacterial isolates Sp.1 and Sp.6 from Sumatera (Naibaho *et al.*, 2020), etc. were isolated. Many bacterial strains were identified from chlorpyrifos bioremediation in soil under various crops, but not much research has been conducted to isolate and characterize the same from mango orchard soil. Also not much work has been done regarding isolation and identification of carbosulfan degrading bacteria from mango orchard soil. Therefore, the present experiment aims at isolation and identification of chlorpyrifos and carbosulfan degrading bacteria from mango orchard soil and their effect on insecticide degradation in sterile soil under laboratory conditions.

MATERIALS AND METHODS

Analytical grade standards of chlorpyrifos (99.0% pure) and carbosulfan (98.0% pure) were purchased from Sigma-Aldrich India branch, Mumbai. HPLC grade solvents and other analytical reagents were procured locally. Bergey's manual was followed to prepare the culture media for microbes. Soil samples were taken from mango (cv. Dashehari) field using aseptic technique for preventing any contamination. Soil samples were air-dried, sieved and autoclaved at 121°C for 15 min at 15 psi before use. In Petriplates, 5 g soil sample in triplicate was fortified with three concentrations of chlorpyrifos (100, 200 and 300 µg g⁻¹) and two concentrations of carbosulfan (100 and 400 µg g⁻¹) and preserved at room temperature up to 60 days along with control (with pesticides but no microbes). Sample collection was done at 15 days interval for chlorpyrifos and 10 days interval for carbosulfan and their residues were analyzed by HPLC. Degradation of carbosulfan by bacterial consortium in mineral salt media (MSM) was also studied under laboratory conditions. MSM consists of dipotassium hydrogen phosphate (K₂HPO₄, 1.73 g), potassium dihydrogen phosphate (KH₂PO₄, 0.68 g), magnesium sulphate heptahydrate (MgSO₄·7H₂O, 0.1 g), sodium chloride (NaCl, 4 g), ferrous sulphate heptahydrate (FeSO₄·7H₂O, 0.03 g), ammonium nitrate (NH₄NO₃, 1.0 g), calcium chloride (CaCl₂·2H₂O, 0.02 g) and glucose (C₆H₁₂O₆, 5 g) dissolved in 1 L of distilled water. MSM was fortified with 10 µg ml⁻¹ of analytical grade carbosulfan, bacterial consortium was added to it and test tubes were kept for 30 days at room temperature. Samples were withdrawn at 0, 15 and 30 days after treatment.

Culture enrichment technique was used for the isolation of chlorpyrifos and carbosulfan degrading bacteria from contaminated soil. Total 4 no. bacteria from chlorpyrifos contaminated soil and 2 bacteria from carbosulfan contaminated soil were isolated. All these bacteria were found gram negative. Identification of 4 bacteria (2 from chlorpyrifos and 2 from carbosulfan), based on their plant growth promoting (PGPR) and enzymatic activities was done using 16S ribosomal RNA gene partial sequencing method. Briefly, after extraction and amplification of DNA in PCR, enzymatic purification and bi-directional DNA sequencing was conducted using 8F and 1492R primers. BLAST alignment search using 16S rDNA sequence at NCBI Gene bank database helped in identification of specific genus, species and strain (Altschul *et al.*, 1997). Compatibility study for all isolated bacteria has been conducted to verify their compatibility with each other before use in consortium.

For chlorpyrifos, soil samples were extracted with 25 mL of hexane: acetone (1:1, v/v, 3 times) by passing through a glass column (30 x 1.5 cm i.d.) filled with 5.0 g Florisil + 0.5 g Carbotrap sandwiched between two layers of anhydrous sodium sulphate. Similar extraction method was followed for carbosulfan also except eluate used was 25 ml of acetonitrile (3 times). Carbosulfan from MSM was also extracted with acetonitrile (same as soil). For both the insecticides, the eluate was completely evaporated in a rotary vacuum evaporator and the residues were dissolved in 5 mL of HPLC grade acetonitrile. Shimadzu (Japan) make HPLC model LC20 AVP was employed for chromatographic analysis of both the insecticides. Reverse-phase C-18 Enable column (250 x 4.6 mm i.d., 5 µ film thickness, 100Å porosity) was used as stationary phase along with PDA detector for both chlorpyrifos and carbosulfan. Mobile phase, detector wavelength and flow-rate were acetonitrile: water: glacial acetic acid (82.5: 17:0.5, v/v), 254 nm and 1.0 ml min⁻¹ for chlorpyrifos and acetonitrile: water (90:10, v/v), 210 nm and 1.0 mL/min for carbosulfan, respectively. All the samples were filtered through a nylon membrane filter (Axiva, 0.45 mm thickness and 13 mm diameter) held firmly in a filter holder attached to a glass syringe.

RESULTS AND DISCUSSION

Identification of bacteria

Among the 4 bacteria isolated from chlorpyrifos contaminated soil, two were identified as *P. aeruginosa* strain NG4 (NCBI accession no. MN238694) and *P. plecoglossicida* strain PSG1 (NCBI accession no. MN258925). However, *P. aeruginosa* strain NG4 was found incompatible with other three bacteria and so it was not used in consortium for chlorpyrifos degradation in sterile soil. In case of carbosulfan,

the identified bacteria were *P. aeruginosa* strain NG22 (NCBI accession no. MN340034) and *B. cereus* strain NG23 (NCBI accession no. MN365109) and both were found compatible to each other and used in consortium.

Six chlorpyrifos-degrading bacteria were isolated from an Australian soil and one strain (B-14) was identified as *E. asburiae* having ability to mineralize chlorpyrifos (Singh *et al.*, 2004). Lu *et al.* (2012) have isolated and characterized a bacterium *Cupriavidus* sp. strain DT-1 from Chinese soil having ability to degrade chlorpyrifos and its metabolite 3,5,6-trichloro-2-pyridinol (TCP) using these compounds as sole carbon source. Abraham and Silambarasan (2013) have isolated a bacterial strain, *Sphingobacterium* sp. JAS3 from Indian soil which can degrade chlorpyrifos and TCP in aqueous medium as well as in soil. This strain was identified using 16S rRNA gene sequence analysis. 16S rRNA gene sequence analysis was also used to identify two more bacterial strains, *A. xylosoxidans* strain JcP4 and *Ochrobactrum* sp. strain FCp1, isolated from pesticide contaminated agricultural fields with chlorpyrifos degradation potential (Akbar and Sultan, 2016). In Sudan, *B. safensis* strain FO-36b, *B. subtilis* subsp. *inaquosorum* strain KCTC13429 and *B. cereus* strain ATCC14579 were isolated from pesticide polluted soil (Ishag *et al.*, 2016). Rayu *et al.* (2017) have isolated *Xanthomonas* sp. strain 4R3-M1, *Pseudomonas* sp. strain 4H1-M3 and *Rhizobium* sp. strain 4H1-M1 from sugarcane farm soil exhibiting degradation potential of both chlorpyrifos and TCP. *B. cereus* strain Ct3, recently isolated from contaminated cotton field in Pakistan and identified through 16S rRNA sequence technique, is found capable of degrading both chlorpyrifos and TCP (Farhan *et al.*, 2021). In India, Kumar *et al.* (2021) have isolated and identified a rhizobacterium, *K. pneumoniae* strain M11, from subtropical agricultural field for biodegradation of chlorpyrifos using the same 16S rRNA gene sequencing method. In case of carbosulfan, a bacterial strain of *Pseudomonas* sp. CISH C-1 was tentatively isolated and identified from contaminated mango orchard soil which could degrade carbosulfan both in soil and in liquid medium (Garg *et al.*, 2018). From brinjal cultivated soil in Bangladesh, a carbosulfan-degrading bacterial strain of *Pseudomonas* sp. has been isolated by Sharif and Mollick (2013). Eight different bacterial strains (BCTL 202-209), belonging to genus *Planococcus*, *Marinococcus*, *Sporosarcina*, *Bacillus*, *Enterococcus* and *Micrococcus*, were isolated from different areas of Punjab, Pakistan having specific ability to degrade and utilize carbosulfan for their growth (Mujeeb *et al.*, 2011).

Degradation of chlorpyrifos in sterile soil

Bacterial degradation of chlorpyrifos using a consortium in sterile (autoclaved) soil was investigated at

room temperature under laboratory conditions. *Pseudomonas plecoglossicida* strain PSG1 and two unidentified bacteria were used in consortium, which were found compatible to each other. Chlorpyrifos degraded from 93.16, 186.74 and 280.73 $\mu\text{g g}^{-1}$ at 0 day to 20.36, 49.14 and 56.33 $\mu\text{g g}^{-1}$ at 30 days after treatment for 100, 200 and 300 $\mu\text{g g}^{-1}$ concentrations, respectively, which further degraded to 1.41, 3.33 and 13.49 $\mu\text{g g}^{-1}$ after 60 days of treatment (Table 1). The degradation was 78.14, 73.68 and 79.93 per cent after 30 days under laboratory conditions which was further enhanced to 98.48, 98.22 and 95.19 per cent after the end of the experiment (60 days) in case of 100, 200 and 300 $\mu\text{g g}^{-1}$ concentrations, respectively. Slightly faster degradation was observed for lower concentrations. However, in case of control samples the degradation was much slower during the same period. After 60 days of experiment, only 29.58, 37.16 and 28.40 per cent chlorpyrifos was degraded in 100, 200 and 300 $\mu\text{g g}^{-1}$ concentrations, respectively, which confirmed its high persistence in soil (Table 1). For control samples, slightly higher degradation was recorded in 200 $\mu\text{g g}^{-1}$ concentration compared to 100 and 300 $\mu\text{g g}^{-1}$ concentrations. The rate of degradation of chlorpyrifos in treated soil samples followed pseudo first-order kinetics – the rate was steeper up to 30 days but comparatively much slower during later period of experiment. Whereas in control soil samples, the rate of degradation followed first-order kinetics throughout the study period. All the three concentrations of this organophosphate insecticide were found susceptible to bacterial degradation at room temperature under *in vitro* conditions indicating that this consortium can be utilized under field conditions also for faster removal of chlorpyrifos residues from mango orchard soil.

Degradation of carbosulfan in sterile soil

In vitro degradation of carbosulfan in sterile soil was studied under laboratory conditions by microbial consortium

Table 1. Degradation of chlorpyrifos by microbial consortium in sterile soil under laboratory conditions

Days after treatment	Residues of chlorpyrifos ($\mu\text{g g}^{-1}$)					
	T1 (100 $\mu\text{g g}^{-1}$)	Control (100 $\mu\text{g g}^{-1}$)	T2 (200 $\mu\text{g g}^{-1}$)	Control (200 $\mu\text{g g}^{-1}$)	T3 (300 $\mu\text{g g}^{-1}$)	Control (300 $\mu\text{g g}^{-1}$)
0	93.16	93.16	186.74	186.74	280.73	280.73
15	64.05	83.68	109.45	165.35	206.02	283.44
30	20.36	77.55	49.14	153.65	56.33	254.33
45	8.86	75.4	15.26	127.86	21.47	243.64
60	1.41	65.6	3.33	117.34	13.49	201.01
Degradation after 60 days (%)	98.48	29.58	98.22	37.16	95.19	28.40

(combination of *Bacillus cereus* strain NG23 and *Pseudomonas aeruginosa* strain NG22). Sampling was done at 10 days interval up to 60 days. For lower concentration ($100 \mu\text{g g}^{-1}$), carbosulfan persisted only up to 20 days (from $27.90 \mu\text{g g}^{-1}$ at 0 day to $1.80 \mu\text{g g}^{-1}$ after 20 days – 93.50% degradation) and completely degraded at 30 days after application. Whereas for higher concentration ($400 \mu\text{g g}^{-1}$), it persisted up to 50 days (residues degraded from $110.47 \mu\text{g g}^{-1}$ at 0 day to $1.33 \mu\text{g g}^{-1}$ at 50 days after application – 98.80% degradation) and degraded completely within 60 days (Table 2). In case of control soil samples, complete degradation of carbosulfan was observed after 50 days of application for $100 \mu\text{g g}^{-1}$ concentration, while for $400 \mu\text{g g}^{-1}$ concentration, the insecticide persisted up to 60 days in sterile soil under laboratory conditions with degradation percentage of 96.02 (Table 2). The rate of degradation of carbosulfan followed first-order kinetics at lower concentration (both treated and control) and pseudo first-order kinetics for higher concentration (both control and treated). The study indicated that lower concentration of insecticide could easily be degraded by bacterial consortium under laboratory conditions whereas higher concentration was resistant to degradation up to the study period. This bacterial consortium can also be applied in mango orchard soil for quicker removal of carbosulfan residues under field conditions.

Table 2. Degradation of carbosulfan by microbial consortium in sterile soil under laboratory conditions

Days after application	Residues of carbosulfan ($\mu\text{g g}^{-1}$)			
	Control ($100 \mu\text{g g}^{-1}$)	T1 ($100 \mu\text{g g}^{-1}$)	Control ($400 \mu\text{g g}^{-1}$)	T2 ($400 \mu\text{g g}^{-1}$)
0	27.90	27.90	110.47	110.47
10	12.83	11.73	52.83	16.73
20	3.33	1.80	16.20	11.73
30	2.70	ND	9.83	3.17
40	1.03	ND	8.33	2.53
50	ND	ND	5.53	1.33
60	ND	ND	4.40	ND
Degradation after 60 days (%)	100	100	96.02	100

ND = Not detected

Degradation of carbosulfan in MSM

Degradation of carbosulfan by bacterial consortium in MSM was studied under laboratory conditions. MSM was fortified with analytical grade carbosulfan ($10 \mu\text{g ml}^{-1}$), bacterial consortium was added to it and tubes were kept for 30 days at room temperature. Samples were withdrawn at 0,

15 and 30 days after treatment. Carbosulfan residues in MSM dissipated from 3.54 mg ml^{-1} at 0 day to 0.44 mg ml^{-1} within 30 days of treatment resulting in 87.57 per cent degradation, whereas only 9.47 per cent degradation of carbosulfan (from 3.59 mg ml^{-1} at 0 day to 3.25 mg ml^{-1} after 30 days of treatment) was recorded in control sample.

Lower persistence of chlorpyrifos and carbosulfan residues in sterile soil treated with bacterial consortium might be due to the higher degradation potential of study bacteria without any interference by other microbes after sterilization of soil. Results indicated that bacterial isolates were capable of utilizing chlorpyrifos and carbosulfan as sole carbon and nitrogen source in soil during the study period. Chlorpyrifos is a widely used insecticide and therefore, many authors have reported its microbial degradation in soil and liquid media. Getzin (1981) has reported that faster breakdown of ^{14}C -ring-labeled chlorpyrifos in autoclaved Chehalis clay loam soil (half-life 28 days) was due to microbial degradation compared to autoclaved Sultan silt loam soil where the half-life was 84 days. Degradation of chlorpyrifos in inoculated soil samples proceeded more rapidly under flooded conditions than under non-flooded conditions. Thus, chlorpyrifos disappeared totally within 15 days under flooded conditions and within 28 days under non-flooded conditions in soil inoculated with the *Flavobacterium* sp. strain ATCC27551. In soil inoculated with *Arthrobacter* sp., it took less than 28 days under flooded conditions and more than 28 days under non-flooded conditions for complete loss of chlorpyrifos (Mallick *et al.*, 1999). *E. asburiae* strain B-14, when inoculated in soil treated with 35 mg/kg chlorpyrifos, resulted in higher degradation compared to uninoculated soil confirming its potential to be used in bioremediation process (Singh *et al.*, 2004). A consortium of four bacteria namely *P. putida* (NII 1117), *Klebsiella* sp. (NII 1118), *P. stutzeri* (NII 1119) and *P. aeruginosa* (NII 1120) was found capable of degrading 500 mg L^{-1} chlorpyrifos in soil at pH 7.0 and temperature 37°C (Sasikala *et al.*, 2012). Inoculation of chlorpyrifos-contaminated soil with *Cupriavidus* sp. strain DT-1 resulted in 100 and 94.3 per cent degradation of chlorpyrifos and its metabolite TCP, respectively, as compared to 28.2 and 19.9 per cent degradation in uninoculated soil (Lu *et al.*, 2012). Akbar and Sultan (2016) have observed that two bacterial isolates *Achromobacter xylosoxidans* (strain JCp4) and *Ochrobactrum* sp. (strain FCp1) were able to degrade 84.4 and 78.6 per cent of the 100 mg L^{-1} concentration of chlorpyrifos within 10 days and 93-100 per cent of 200 mg kg^{-1} concentration of chlorpyrifos in sterilized as well as non-sterilized soils within 42 days. This result is in sync with the present finding where 91.83 per cent of $200 \mu\text{g g}^{-1}$ of chlorpyrifos was degraded by bacterial

consortium within 45 days in sterilized soil. *P. stutzeri* strain CHL3, isolated from pesticide contaminated soil in Thailand, was found tolerant to chlorpyrifos as high as 2000 ppm in minimal salt medium which meant this bacterium strain could degrade 2000 ppm concentration of chlorpyrifos (Phumkhachorn and Rattanachaikunsopon, 2020). *B. cereus* strain Ct3, isolated from cotton growing soil, could degrade 88 per cent of 125 mg L⁻¹ chlorpyrifos in 8 days at pH 8.0 and 30–40°C temperature (Farhan *et al.*, 2021). Recently Kumar *et al.* (2021) have reported that *K. pneumoniae* M11 was able to degrade 70.25 per cent of 100 mg L⁻¹ of chlorpyrifos in sterile soil after 30 days of incubation, which is similar to our result where 78.14 per cent of 100 µg g⁻¹ of chlorpyrifos was degraded by bacterial consortium in sterile soil after 30 days.

As carbosulfan is not a widely used insecticide, literature on microbial degradation of this insecticide in soil is very scanty. Sahoo *et al.* (1990) have concluded that microorganisms are responsible for the hydrolysis of carbosulfan in nonsterilized laterite soil after 12 days as degradation has been observed in nonsterilized soil only. In an earlier study it has been observed that a *Pseudomonas* strain CISH C-1, isolated from mango orchard soil of subtropical India, was able to degrade 91.00 per cent of carbosulfan in inoculated sterilized soil after 28 days of incubation under laboratory conditions (Garg *et al.*, 2018), which is at par with the present findings where 100 per cent of 100 µg g⁻¹ of carbosulfan was degraded after 30 days. Two unidentified bacterial isolates of Sp.1 and Sp.6 were found capable of complete degradation of carbosulfan after 21 days of incubation (Naibaho *et al.*, 2020). Recently, a study by Bhattacharjee *et al.* (2022) has mentioned that microbial consortium was able to degrade imidacloprid, a neonicotinoid insecticide, in both sterile and non-sterile soil where insecticide degradation was around 73.00 per cent in sterile soil under laboratory conditions and around 52.00 per cent in non-sterile soil under the same conditions after 50 days of treatment for 5 and 10 µg g⁻¹ of imidacloprid, respectively. The authors have suggested that higher degradation of imidacloprid in sterile soil than in non-sterile soil might be due to the proper utilization of degradation potential of study microbes without the interference of other microorganisms in sterile condition, which may be the case in the present investigation also. Garg *et al.* (2021) have also reported that degradation of imidacloprid in soil under field condition was highly influenced by microbial community present in the soil.

CONCLUSION

It can be concluded from the present investigation that bacterial consortia comprising of compatible bacteria is capable of degrading chlorpyrifos and carbosulfan in sterile

soil as well as in MSM at room temperature under laboratory conditions. Carbosulfan degraded faster than chlorpyrifos because of its low persistence in soil. These consortia can be utilized under field conditions for bioremediation of soil from pesticide contamination.

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Utilization of raw mango peel waste for instant soup preparation

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ABSTRACT

During processing of raw mango fruits, peel is generally removed and thrown as waste though it contains fair amounts of nutritive elements apart characteristic aroma and taste. Raw mango peel is a good source of fibre, pectin, acid, minerals, phenolics and pigments like chlorophylls and carotenoids. In order to utilize such nutritionally rich waste, an attempt was made to develop a value added product out of it in the form of instant soup. The peel powder was added with spices and other ingredients and packed in laminated aluminum pouches. The product was stored at room temperature (20-30 °C) and analyzed up to 6 months for various biochemical and sensory parameters. The soup powder was found to have 5.7 per cent titratable acidity, 52.6 mg per 100 g vitamin-C and 944 mg per 100 g total phenolics. Decreasing trends were observed in the contents of acid, vitamin-C and total phenolics during storage. Organoleptically, soup was found to be acceptable till the end of storage, obtaining 7 or above sensory score out of 9. Raw mango peel soup may find good acceptability among market consumers. The protocol may also serve a good mean to utilize huge quantity of raw mango peel which otherwise is thrown as waste.

Keywords: Raw mango, peel, waste, soup, vitamin-C, total phenolics

Mango is the choicest fruit for preparing a number of processed products, viz. puree, squash, juice, nectar, bar, cubes, etc. (Kumar *et al.*, 2014; Kumar *et al.*, 2016). Raw mango is green, fairly acidic in taste with characteristic sour mouth appealing flavor. It is generally used in varieties of processed products like dry slices, powder (*amchoor*), pickles, sweet and sour chutneys, bar, spiced beverage (*panna*), etc. During preparation of most of the raw mango products, peel is removed and thrown away as waste or used as cattle feed. However, raw mango peel is nutritionally rich in many health benefiting materials like pectin, fibre, acid, phenolics and pigments. According to Ajila *et al.* (2007), raw mango peel of Raspuri and Badami cultivars of mango contains 66.0 & 70.2 per cent moisture, 3.80 & 3.28 per cent crude fibre, 26.5 & 21.5 per cent carbohydrate, 1.76 & 1.45 per cent protein, 109.7 & 90.2 mg g⁻¹ total phenolics, 493 & 365 µg g⁻¹ total carotenoids, 188 & 315 µg g⁻¹ vitamin-C and 44.7 and 64.1 per cent total dietary fibre on dry weight basis. From time-to-time, scientists worked on mango peel waste to develop some value added products from it. Tandon and Kalra (1991) extracted pectin and fibre from dry peel of immature and ripe mangoes. Kumar *et al.* (2012) worked on production of pectinase enzyme from mango peel using *Aspergillusfoetidus*. Garg *et al.* (2021) produced pectinase, cellulase and amylase enzymes from fruit and vegetable

wastes using *Lactobacillus plantarum*. Reddy *et al.* (2011) produced ethanol from mango peel using *Saccharomyces cerevisiae*. The potential of using mango (var. Totapuri) peels and stones for the production of vinegar was investigated by Ethiraj and Suresh (1992). Larrauri *et al.* (1996) developed technology for jam manufactured from mango peel.

India is the leading mango producing country in the world. However, northern part of India suffers with huge loss of mango every year in the form of immature fruits due to heavy wind storms that come in early summer season. A big quantum of immature fruits fall resulting into situation of glut. These are sold at very low and uneconomical price, resulting into big loss to growers. Except for pickles, processing of these fruits results into huge generation of peel waste. Hence, some technologies are needed to utilize such waste in to value added products. The astringent materials like mango peel, aonla processing wastes, etc., containing rich amounts of phenolics seem to be quite suitable for preparation of spiced products like chutney, spiced beverages, soups, etc. Garg *et al.* (2021) developed spicy flavored beverages from sugar syrup waste of aonla processing industry. In the present investigation, an instant soup was prepared from raw mango peel and evaluated for its sensory acceptability and storage life.

MATERIAL AND METHODS

Raw material

Raw mango fruits were collected from the Institute's orchard, washed thoroughly with tap water and peeled manually with stainless steel knife. The peel was dried in a cabinet dehydrator at 60 °C. It was ground in a mixie-grinder and filtered through a muslin cloth to obtain fine powder.

Preparation and storage of soup powder

The powder was mixed with desired amounts of sugar, salt, mint powder, cumin seed powder, black pepper powder and citric acid. Fine pieces of dried carrot was also added to mixture. The instant soup powder was packed in small laminated aluminum pouches and sealed. The product was stored at room temperature (20-30 °C) for six months and analyzed at every two month intervals for various biochemical and sensory parameters. For preparation of soup from instant powder, the content of the pouch was mixed with water and boiled for 2 minutes. It was served hot.

Biochemical quality analysis

The total soluble solids (TSS) of instant raw mango powder was recorded by using hand refractometer (Erma, Japan). The moisture content and acidity of powder were determined as per the method described by Ranganna (2000). Moisture content was estimated by drying the instant raw mango soup powder in an oven at 70 °C up to a constant dry weight and then calculating moisture loss. Titratable acidity of the samples was estimated by titration of sample solution against 0.1N NaOH solution using phenolphthalein as indicator. The vitamin-C content of powder was measured by titrating samples against 2, 6-dichloro phenol indophenol dye solution as done by Garg *et al.* (2021) in peach products. The total phenolics content was estimated spectrophotometrically using method of Folin and Ciocalteu (1927).

Sensory and microbial quality analysis

The sensory evaluation of products was carried out by a panel of semi-skilled judges on composite scoring (Amerine *et al.*, 1965) based on colour, consistency, aroma and taste of prepared soup samples. The coded samples were given to evaluators along with score card format based on hedonic scale to score out of maximum 9 score. The microbial counts for bacteria, yeast and mould were observed as per Speck (1985) method.

RESULTS AND DISCUSSION

The moisture content of instant powder was found to be 2.50 per cent which remained almost unchanged during

whole storage period. Agustini (2018) reported 2.37-2.94 per cent moisture in mango peel powder dried at different temperatures. The samples were found to be free from any microbial contamination at all stages of storage. The total soluble solids (TSS) of the sample was initially 75 °B which did not change till the end of storage. The titratable acidity of the product was 5.7 per cent at zero day which declined to 5.2 per cent up to four months (Fig. 1). There was a sharp decrease after 4 months and value came to 3.8 per cent. The soup had a initial vitamin-C content of 52.6 mg/100 g, which decreased regularly during storage to reach at 26.3 mg/100 g after 6 months (Fig. 2). Ferrari *et al.* (2021) also reported reduction in vitamin-C content of mango peel powder during storage. According to Steskova *et al.* (2006) vitamin C is first oxidized in to dehydroascorbic acid and then to diketogulonic, oxalic, and threonic acids. The total phenolic content of instant powder was 944 mg/100 g at zero day which declined regularly during storage to reach a final value

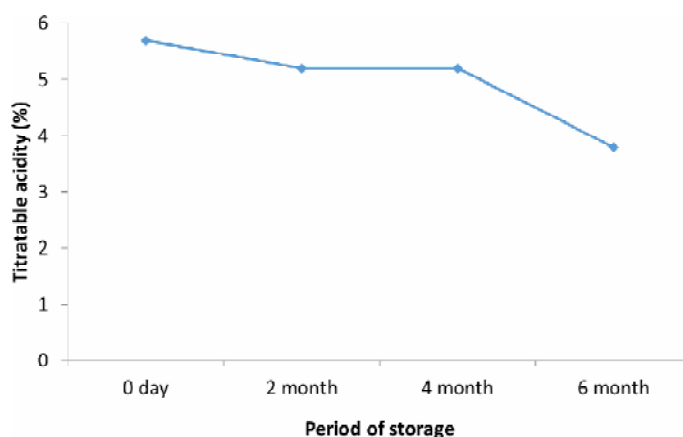


Fig. 1: Changes in Titratable acidity of raw mango peel soup during storage

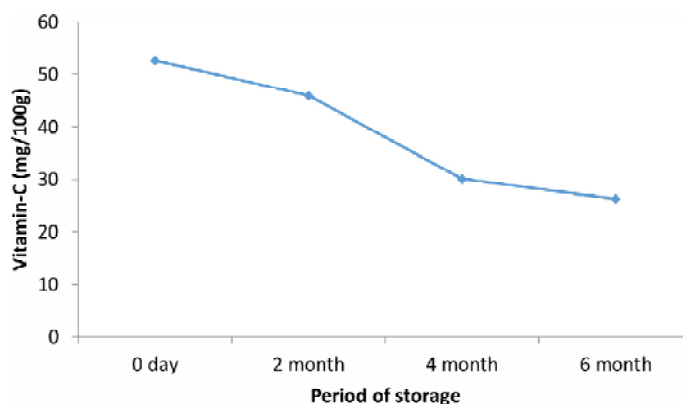


Fig. 2: Changes in vitamin-C of raw mango peel soup during storage

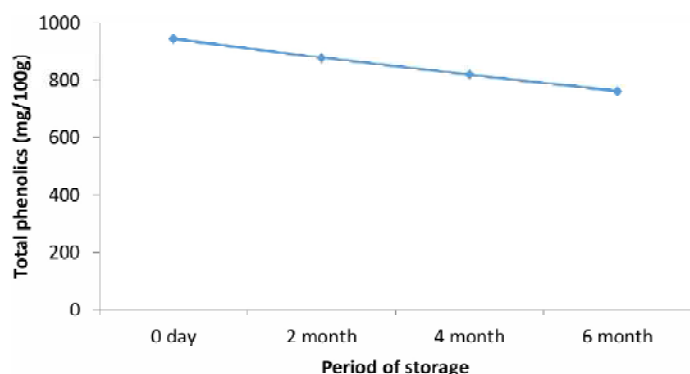


Fig. 3: Changes in total phenolics of raw mango peel soup during storage

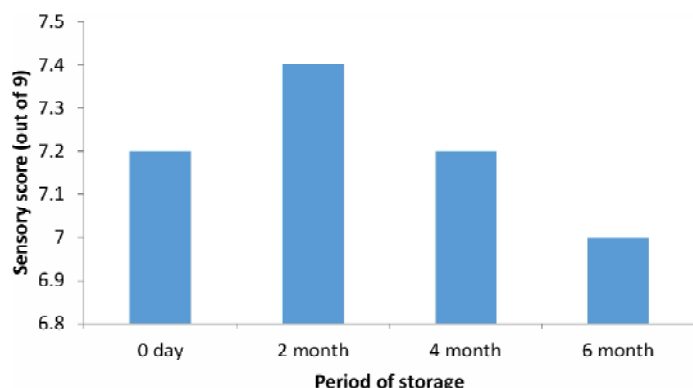


Fig. 4: Changes in sensory score of raw mango peel soup during storage

of 761 mg/100⁻¹ after 6 months of storage (Fig. 3). Pareek and Kaushik (2012) also observed decrease in phenolic content of aonla powder during storage. Moldovan *et al.* (2015) attributed degradation of phenolic compounds responsible for reduction of these compounds during storage. During sensory evaluation, the prepared soup was found to be acceptable on the basis of colour, consistency, flavour and taste. It obtained a sensory score of 7.2 out of 9.0 at zero day. The score remained almost same with 0.2 plus/minus flexibility in the values during storage up to 6 months (Fig. 4).

CONCLUSION

The raw mango instant soup powder is a novel product with good nutritional and sensory qualities. It could be stored for 6 months without much deterioration in the biochemical and sensory qualities. The product may go well in the market and has good potential to utilize raw mango peel waste. It may give fair economic return out of waste and save environment by safe mean of waste disposal through value addition.

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Effect of blending traditional herbs on physico-chemical changes in bottle gourd nectar

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ABSTRACT

The present investigation was carried out with the objective to study the changes in quality of bottle gourd based herbal nectar during storage period. Varied percentages of bottle gourd (75 to 100%), mint (5 to 20%), basil (5 to 20%) and lemon juice (5%) were blended to form nine treatment combination. Prepared nectar was packed in 250 ml glass bottles and stored under ambient conditions. Quality of nectar was assessed for physico-chemical changes at 30 days interval until 90 days. The highest mean L* (48.34), a* (-0.62) and b* (18.86) values, total soluble solids (15.51°B), total sugars (12.93%) and reducing sugars (2.83%) were recorded in T₁ (control). Treatment T₉ (75:20:5::BGJ:BLJ:LJ) recorded maximum crude protein (1.07%), whereas maximum titratable acidity (0.487%) and ascorbic acid (12.41 mg/100 ml) were recorded in treatment T₅ (75:20:5::BGJ:MLJ:LJ).

Keywords: Basil, bottle gourd, lemon, mint, nectar, storage

Nectar is one the refreshing beverage enriched with vitamins and minerals (Bal *et al.*, 2014). The beverage prepared by adding water with or without addition of sugar, honey, syrups and/or sweeteners to vegetables juice or concentrated vegetable juice, or their mixture is recognized as vegetable nectar. Products could be prepared from a single vegetable or from vegetable blends. According to Indian Food Laws, class II preservatives such as benzoic acid or sulfur dioxide are not allowed in fruit nectar. As per FSSAI standards fruit nectar should contain at least 20 per cent fruit juice, 15 per cent total soluble solids and 1.5 per cent of acid (Majumder *et al.*, 2017).

Mentha piperita (mint) is a herbal plant which belongs to family Lamiaceae. Leaves of mint plant add flavour and aroma to the food. Basil (*Ocimum sanctum* L.) is cultivated throughout India. In preparation of many Ayurvedic medicines, the leaves, seeds and roots of basil are utilized. Basil plant possess numerous properties like analgesic, cardio protective, anticancer, antidiabetic, antifertility, antifungal, antimicrobial, antiparasitic and adaptogenic action. Eugenol (1-hydroxy-2-methoxy-4-allylbenzene) is an important component responsible for therapeutic applications of basil (Buddhadev *et al.*, 2014). Lemon (*Citrus limon*) is small evergreen tree native to South Asia. Its juice consists of 5 to 6 per cent citric acid and pH of about 2.2. Lemon has variable biological applications, such as, antiallergic, antimutagenic, antioxidative, anticarcinogenic,

antiinflammatory, antiviral and antiproliferative. The present investigation of blended vegetable herbal nectar was undertaken to assess the quality during 3 months of storage under ambient conditions.

MATERIALS AND METHODS

Fresh and tender bottle gourd fruits were selected for the experiment. The bottle gourd fruits were washed keenly under running tap water to remove surface adhering and other extraneous material. The fruits were then peeled, top 20 mm and bottom 15 mm of bottle gourd was cut and removed. The fruits were sliced and then blanched at 80°C for about 3-4 min. to deactivate enzymes and avoid browning. After blanching, juice was extracted using a mechanical juicer, filtered through two layers of muslin cloth and utilized for further processing. The mint and basil leaves were separated from stalk, cleaned, chopped, blanched (2 min.) and the juice was extracted by mechanical juicer separately followed by filtration. Lemon juice was extracted by cutting the lemon into two halves, removing the seeds and then juice was extracted by squeezing and strained through muslin cloth.

The bottle gourd juice was blended with mint, basil and lemon juice in varied concentrations of T₁ (control), T₂ (90:5:5::bottle gourd:mint:lemon juice), T₃ (85:10:5::bottle gourd:mint:lemon juice), T₄ (80:15:5::bottle gourd:mint:lemon juice), T₅ (75:20:5::bottle gourd:mint:lemon juice), T₆

(90:5:5::bottle gourd:basil:lemon juice), T₇ (85:10:5::bottle gourd:basil:lemon juice), T₈ (80:15:5::bottle gourd:basil:lemon juice) and T₉ (75:20:5::bottle gourd:basil:lemon juice) to form highly nutritious and delightful nectar. Total soluble solids and acidity of the nectar were adjusted to 15°Brix and 0.3 per cent by using sugar and lemon/citric acid, followed by heating at 85°C for 10 minutes. Afterwards, the nectar was filled into pre-sterilized glass bottles of 250 ml capacity, keeping 1.5-2 cm head space and crown corked. The bottles were pasteurized for 15 min. at 85°C cooled labeled and stored under ambient conditions.

The nectar was analysed for various traits at 0, 30, 60 and 90 days. Colour analysis of the sample was performed using Hunter Lab Colorimeter (Hunter Lab Colour Flex Reston VA, USA) as per method of Vargas *et al.* (2009). Total soluble solids (TSS) were determined by using hand refractometer (0-32°B), and the results were expressed as degree brix (°B). Titratable acidity was estimated by titrating a known quantity of sample (10 ml) against standard solution of 0.1 N sodium hydroxide to a light pink colour using few drops of phenolphthalein as an indicator (AOAC, 2012). Vitamin C was estimated using 2, 6 dichlorophenol indophenol as dye (Ranganna, 2014). Sugars were determined as per methods described by Ranganna (2014). The crude protein content was determined by micro Kjeldhal method (Sadasivam and Manickam, 2008). The results obtained were statistically analyzed (Gomez and Gomez, 1984) using factorial completely randomized design (CRD) for interpretation of results through analysis of variance. The nutritive value of the ingredients is presented in Table 1.

RESULTS AND DISCUSSION

Effect on colour (L*, a* and b*) value

The colour value of bottle gourd based herbal nectar was measured in terms of Hunter L* (lightness), a* (greenness) and b* (yellowness). Among control and mint treatments, 39.01, 254.84 and 10.60 per cent decline was recorded in L*, a* and b* value, respectively, (Table 2) whereas among control and basil treatments the decrease was 12.60, 112.90 and 4.98 per cent, respectively. Our results were in line with Kaur and Aggarwal (2014) who studied blending of bottle gourd juice with preservatives. The mean colour value, L* and b* showed 4.88 and 3.65 per cent reduction, respectively, whereas, a* value showed 14.29 per cent increase this might be due to increased rate of pigment degradation with storage and formation of brown pigments by maillard reaction (Rahman, 2021). Similar results were reported by Bhargawa *et al.* (2014) in kinnow nectar supplemented with aloe juice and by Rahman (2021) in mulberry-aloe vera blended nectar.

Effect on TSS

The mean TSS among control and mint treatments showed a declination of 1.68 and 2.19 per cent (Table 3) declination was observed in control and basil treatments. The TSS of blended nectar decreased with the addition of mint and basil juice which might be due to lower concentration of TSS in fresh mint and basil (Baljeet *et al.*, 2013 and Madhuri *et al.*, 2021). The TSS of bottle gourd based herbal nectar recorded 3.80 per cent inclination with progression in storage period. The increase in TSS of nectar with storage could be due to conversion of polysaccharides

Table 1: Physico-chemical composition of raw materials

Parameters	Bottle Gourd	Mint	Basil	Lemon
Hunter colour values				
L* (Lightness)	52.31±1.37	32.57±0.32	32.81±1.78	66.29±0.20
a* (greenness)	3.08±0.09	-4.81±0.15	-9.17±0.41	0.38±0.12
b* (yellowness)	21.45±0.17	9.28±0.05	17.98±0.20	19.89±1.13
Moisture (%)	94.25±0.29	81.22±0.21	83.46±2.78	88.30±0.09
TSS (°B)	4.15±0.30	1.83±0.43	1.27±0.09	7.19±0.16
Titratable acidity (%)	0.050±0.01	0.441±0.22	0.357±0.04	5.740±0.07
Ascorbic acid (mg/100g)	12.72±2.44	20.31±0.13	17.62±0.96	24.05±0.24
Reducing sugar (%)	1.27±0.15	0.25±0.07	0.03±0.02	1.54±0.80
Total sugar (%)	2.18±0.12	0.61±0.11	0.19±0.05	2.61±0.09
Crude protein (%)	1.13±0.04	2.39±0.06	3.17±1.47	0.94±0.05
Ash (%)	0.52±0.06	1.42±0.35	1.36±0.06	0.32±0.01
Calcium (mg/100g)	23.69±0.66	196.13±1.82	24.27±2.10	24.61±0.03
Phosphorous (mg/100g)	11.52±1.32	327.68±3.13	284.61±0.19	14.89±1.04
Total phenol (mg GAE/100g)	123.64±0.19	334.89±0.67	364.52±4.81	73.45±0.32
Antioxidant activity (%)	83.61±1.34	85.13±1.10	80.38±0.16	78.64±2.63

Table 2: Effect of treatment and storage period on Colour value (L*, a* and b*) of blended herbal nectar

Treatment		Storage period (Days)				Mean (Treatment)
		0	30	60	90	
T ₁ (Control)	L*	49.04	48.63	48.20	47.51	48.34
	a*	-0.71	-0.65	-0.59	-0.52	-0.62
	b*	19.17	18.99	18.74	18.53	18.86
T ₂ (90:5:5::BGJ:MLJ:LJ)	L*	35.82	35.11	34.58	33.67	34.80
	a*	-1.13	-1.08	-0.98	-0.94	-1.03
	b*	18.65	18.46	18.28	18.02	18.35
T ₃ (85:10:5::BGJ:MLJ:LJ)	L*	34.65	33.47	32.69	31.35	33.04
	a*	-1.49	-1.42	-1.34	-1.28	-1.38
	b*	18.16	17.93	17.54	17.30	17.73
T ₄ (80:15:5::BGJ:MLJ:LJ)	L*	32.47	32.13	31.22	30.73	31.64
	a*	-1.74	-1.70	-1.63	-1.57	-1.66
	b*	17.70	17.51	17.32	17.17	17.42
T ₅ (75:20:5::BGJ:MLJ:LJ)	L*	30.19	29.65	29.21	28.87	29.48
	a*	-2.29	-2.23	-2.16	-2.10	-2.20
	b*	17.18	16.97	16.75	16.52	16.86
T ₆ (90:5:5::BGJ:BLJ:LJ)	L*	45.91	45.87	45.18	44.82	45.44
	a*	-0.89	-0.82	-0.77	-0.69	-0.79
	b*	18.97	18.76	18.49	18.24	18.61
T ₇ (85:10:5::BGJ:BLJ:LJ)	L*	45.25	44.61	43.91	43.07	44.21
	a*	-1.03	-0.96	-0.91	-0.85	-0.94
	b*	18.71	18.58	18.34	18.11	18.43
T ₈ (80:15:5::BGJ:BLJ:LJ)	L*	44.83	43.77	43.18	42.95	43.68
	a*	-1.25	-1.19	-1.11	-1.06	-1.15
	b*	18.55	18.39	18.19	17.83	18.24
T ₉ (75:20:5::BGJ:BLJ:LJ)	L*	43.62	42.41	41.79	41.16	42.25
	a*	-1.41	-1.36	-1.29	-1.23	-1.32
	b*	18.26	18.06	17.79	17.57	17.92
Mean (Storage)	L*	40.20	39.52	38.88	38.24	
	a*	-1.33	-1.27	-1.20	-1.14	
	b*	18.37	18.18	17.94	17.70	
Effects		C.D. (p≤0.05)				
	L*	a*	b*	BGJ	Bottle Gourd Juice	
Treatment (T)	0.02	0.01	0.03	MLJ	Mint Leaf Juice	
Storage (S)	0.01	0.01	0.02	BLJ	Basil Leaf Juice	
T x S	0.03	0.02	0.07	LJ	Lemon Juice	

into soluble sugar and formation of water soluble pectin from protopectin as reported by Bal *et al.* (2014). According to Singh and Gaikwad (2012) hydrolysis of polysaccharide into monosaccharides and oligosaccharides might be responsible for major increase in TSS during storage. Similar results were observed by Rani and Babu (2015) who worked on acceptability and storage studies of guava-aloe nectar blends.

Effect on Titratable acidity

The mint juice blended samples observed higher titratable acidity as compared to basil blended samples which might be due to higher acidity in fresh mint. In control and mint treatment 32.70 per cent increase was recorded and in control and basil treatments 25.89 per cent increase was recorded (Table 3). Similar results were recorded by Yadav *et*

al. (2010) in whey-based banana herbal beverage and Hirdyani (2015) in RTS beverage made from Indian medicinal plants. Significant increase of 89.33 per cent in mean titratable acidity was recorded during 90 days of storage period. The increase in titratable acidity might be possibly due to rapid conversion of proteins into amino acids (Singh *et al.*, 2018). The findings were in close conformity with the findings of Jain *et al.* (2007) in aonla nectar, Choudhary *et al.* (2008) in guava beverage and Shukla *et al.* (2006) in pineapple RTS, who observed an increasing trend in titratable acidity with the advancement in storage period.

Effect on Ascorbic acid

There was significant difference among the treatments with respect to ascorbic acid which might be due to variation

Table 3: Effect of treatment and storage period on TSS (°B) and Titratable acidity (%) of blended herbal nectar

Treatment		Total Soluble Solids (°B)				Mean (Treatment)	Titratable acidity (%)				Mean (Treatment)
		Storage period (Days)					Storage period (Days)				
		0	30	60	90		0	30	60	90	
T ₁ (Control)		15.00	15.47	15.66	15.93	15.51	0.300	0.323	0.365	0.481	0.367
T ₂ (90:5:5::BGJ:MLJ:LJ)		15.00	15.36	15.57	15.75	15.42	0.300	0.359	0.402	0.527	0.397
T ₃ (85:10:5::BGJ:MLJ:LJ)		15.00	15.32	15.45	15.62	15.35	0.300	0.377	0.436	0.563	0.419
T ₄ (80:15:5::BGJ:MLJ:LJ)		15.00	15.29	15.41	15.57	15.32	0.300	0.402	0.457	0.618	0.444
T ₅ (75:20:5::BGJ:MLJ:LJ)		15.00	15.20	15.33	15.46	15.25	0.300	0.445	0.520	0.683	0.487
T ₆ (90:5:5::BGJ:BLJ:LJ)		15.00	15.27	15.39	15.53	15.30	0.300	0.342	0.381	0.495	0.380
T ₇ (85:10:5::BGJ:BLJ:LJ)		15.00	15.24	15.36	15.49	15.27	0.300	0.361	0.425	0.537	0.406
T ₈ (80:15:5::BGJ:BLJ:LJ)		15.00	15.17	15.29	15.43	15.22	0.300	0.383	0.442	0.586	0.428
T ₉ (75:20:5::BGJ:BLJ:LJ)		15.00	15.11	15.20	15.36	15.17	0.300	0.428	0.495	0.624	0.462
Mean (Storage)		15.00	15.27	15.40	15.57		0.300	0.380	0.436	0.568	
Effects		C.D. (p≤0.05)						BGJ	Bottle Gourd Juice		
	TSS	Titratable acidity						MLJ	Mint Leaf Juice		
Treatment (T)	0.04	0.029						BLJ	Basil Leaf Juice		
Storage (S)	0.03	0.020						LJ	Lemon Juice		
T x S	0.08	0.059									

in composition of raw materials added. Among control and mint treatments increase of 24.35 per cent was recorded in ascorbic acid content (Table 4), whereas, among control and basil treatments an increase of 19.64 per cent was recorded in ascorbic acid content of herbal nectar. Ascorbic acid content of herbal nectar increased with the incorporation of mint and basil juice as compared to T₁ (control) which might be due to lower ascorbic acid content in bottle gourd. Similar results were reported in whey based pineapple and bottle gourd mixed herbal beverage by Baljeet *et al.* (2013) and mint and basil leaves incorporated ice cream by Singh (2014). During storage of 90 days, 3.95 per cent decrease was observed in ascorbic acid content which might be because of

oxidation of ascorbic acid into dehydro-ascorbic acid by oxygen (Ahmad *et al.*, 2016). The reduction could also be due to destruction of ascorbic acid during processing and subsequently during the storage period due to its oxidation (Baljeet *et al.*, 2013). Almost similar observations for ascorbic acid were reported by Vaghashiya *et al.* (2016) in health drink prepared using aloe vera, bitter gourd, aonla and guava and by Byanna and Gowda (2012) who studied the quality changes in nectar prepared from sweet orange during storability of six months.

Effect on Crude protein

Among control and mint treatments increase of 68.97%

Table 4: Effect of treatment and storage period on Ascorbic acid (mg/100ml) and Crude Protein (%) of blended herbal nectar

Treatment	Ascorbic acid (mg 100 ml ⁻¹)				Mean (Treatment)	Crude protein (%)				Mean (Treatment)
	Storage period (Days)					Storage period (Days)				
	0	30	60	90		0	30	60	90	
T ₁ (Control)	10.19	10.06	9.91	9.77	9.98	0.63	0.61	0.57	0.51	0.58
T ₂ (90:5:5::BGJ:MLJ:LJ)	11.28	11.12	10.97	10.83	11.05	0.75	0.72	0.66	0.60	0.68
T ₃ (85:10:5::BGJ:MLJ:LJ)	11.79	11.63	11.46	11.31	11.55	0.83	0.78	0.73	0.67	0.75
T ₄ (80:15:5::BGJ:MLJ:LJ)	12.20	12.06	11.90	11.76	11.98	0.90	0.87	0.82	0.76	0.84
T ₅ (75:20:5::BGJ:MLJ:LJ)	12.63	12.48	12.35	12.19	12.41	1.07	1.03	0.95	0.88	0.98
T ₆ (90:5:5::BGJ:BLJ:LJ)	11.17	11.01	10.85	10.70	10.93	0.79	0.75	0.69	0.63	0.71
T ₇ (85:10:5::BGJ:BLJ:LJ)	11.42	11.29	11.13	10.95	11.20	0.86	0.82	0.77	0.71	0.79
T ₈ (80:15:5::BGJ:BLJ:LJ)	11.89	11.74	11.57	11.42	11.66	1.03	0.99	0.92	0.85	0.95
T ₉ (75:20:5::BGJ:BLJ:LJ)	12.16	12.03	11.88	11.71	11.94	1.14	1.11	1.05	0.98	1.07
Mean (Storage)	11.64	11.49	11.34	11.18		0.89	0.85	0.80	0.73	
Effects	C.D. (p≤0.05)						BGJ	Bottle Gourd Juice		
	Ascorbic acid	Crude protein				MLJ	Mint Leaf Juice			
Treatment (T)	0.01	0.01				BLJ	Basil Leaf Juice			
Storage (S)	0.01	0.01				LJ	Lemon Juice			
T x S	0.02	0.02								

Table 5: Effect of treatment and storage period on Total sugar (%) and Reducing sugar (%) of blended herbal nectar

Treatment	Reducing Sugar (%)				Mean (Treatment)	Total Sugar (%)				Mean (Treatment)
	Storage period (Days)					Storage period (Days)				
	0	30	60	90		0	30	60	90	
T ₁ (Control)	2.43	2.66	2.94	3.28	2.83	12.56	12.79	13.01	13.34	12.93
T ₂ (90:5:5::BGJ:MLJ:LJ)	2.29	2.53	2.76	3.12	2.68	11.48	11.71	11.96	12.25	11.85
T ₃ (85:10:5::BGJ:MLJ:LJ)	2.18	2.44	2.68	2.97	2.56	10.90	11.12	11.35	11.63	11.25
T ₄ (80:15:5::BGJ:MLJ:LJ)	2.10	2.32	2.57	2.89	2.47	10.28	10.45	10.68	10.93	10.59
T ₅ (75:20:5::BGJ:MLJ:LJ)	1.96	2.16	2.41	2.82	2.34	9.65	9.87	10.12	10.48	10.03
T ₆ (90:5:5::BGJ:BLJ:LJ)	2.21	2.49	2.70	3.01	2.60	11.43	11.66	11.91	12.20	11.80
T ₇ (85:10:5::BGJ:BLJ:LJ)	2.14	2.37	2.59	2.92	2.51	10.85	11.07	11.28	11.57	11.19
T ₈ (80:15:5::BGJ:BLJ:LJ)	2.02	2.25	2.51	2.84	2.40	10.21	10.39	10.61	10.88	10.52
T ₉ (75:20:5::BGJ:BLJ:LJ)	1.86	2.08	2.35	2.78	2.27	9.59	9.82	10.07	10.41	9.97
Mean (Storage)	2.13	2.37	2.61	2.96		10.77	10.98	11.22	11.52	
Effects	C.D. (p≤0.05)						BGJ	Bottle Gourd Juice		
	Reducing Sugar	Total Sugar					MLJ	Mint Leaf Juice		
Treatment (T)	0.03	0.03					BLJ	Basil Leaf Juice		
Storage (S)	0.02	0.02					LJ	Lemon Juice		
T x S	0.05	0.06								

was recorded in crude protein content, whereas, among control and basil treatments an increase of 84.48 per cent was recorded in crude protein content of herbal nectar (Table 4). The crude protein content of nectar increased with increasing per cent of basil and mint among treatments which might be due to variation in crude protein content in raw materials. According to Agarwal and Kumar (2017) protein content decreases with storage due to the increase in time and temperature in bottle gourd based RTS beverage. The crude protein of bottle gourd based herbal nectar showed a significant decrease of 17.98 per cent. The decrease in amount of protein during storage could be due to hydrolysis of peptide bond with protease enzyme which ultimately results in splitting of protein molecules (Kumar, 2015). Similar decrease in protein content was observed by Singh *et al.* (2014) in whey guava beverage and Kumar (2015) in whey based herbal fruit beverage.

Effect on Reducing sugar

In control and mint treatments, 17.31 per cent decrease was observed whereas, in control and basil treatments, 19.79 per cent decrease was observed in reducing sugar content (Table 5) of the nectar, respectively. With the incorporation of mint and basil juice in the bottle gourd based herbal nectar, reducing sugar content decreased which might be due to lower concentration of reducing sugar in the raw materials used. Similar studies were observed by Yadav *et al.* (2010) in whey-based banana herbal beverage. Significant increase of 38.97 per cent in reducing sugar content was observed in herbal nectar during storage period. The increase in reducing sugar might be due to inversion of sucrose into glucose and fructose under the acidic conditions (Elbandy *et al.*, 2014)

and also due to hydrolysis of polysaccharides and inversion of non-reducing sugar during processing and storage (Singh *et al.*, 2018). The results are in accordance with the findings of Mall and Tandon (2007) in guava-aonla blended beverage and Singh *et al.* (2018) in aloe vera fortified mango RTS.

Effect on Total sugar

Total sugar content showed 22.43 per cent declination among control and mint treatments whereas, in control and basil treatments, 22.89 per cent declination was observed (Table 5). The total sugar per cent decreased with the addition of mint and basil juice. The results are in line with Kesharwani *et al.* (2015) in blended jamun RTS, Tiwari and Deen (2015) in blended RTS from bael and aloe vera and in mulberry-aloe vera blended nectar by Rahman (2021). The mean value of total sugars during 90 days storage, showed an increase of 6.96 per cent. The increase in total sugar content was attributed to the conversion of insoluble compounds and inversion of non-reducing sugars to reducing sugars by heating (Hamid *et al.*, 2014). Sharma *et al.* (2013) also reported an increasing trend in total sugar of guava-jamun blended RTS and squash during storage period of three months, which might possibly be due to hydrolysis of polysaccharides like starch, pectin etc. into simple sugars.

CONCLUSION

The a* value, TSS, titratable acidity, reducing and total sugars increased, while L* value, b* value, ascorbic acid and crude protein decreased significantly during 90 days of storage in beverages. The nectar formulated from blends of vegetable and herbs could be a good substitute with high nutritional value.

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