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(Doctor's Agricultural and Horticultural Development Society)

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Main office : A-601, Indira Nagar, Lucknow-226 016, India
: www.ecoagrijournal.com
: info@ecoagrijournal.com

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMER

सत्यमेव जयते

कृषि एवं किसान कल्याण,
ग्रामीण विकास तथा पंचायती राज मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
MINISTER OF AGRICULTURE & FARMERS' WELFARE,
RURAL DEVELOPMENT AND PANCHAYATI RAJ
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI

MESSAGE

It gives me immense pleasure to know that Doctor's Krishi Evam Bagwani Vikas Sanstha (Doctor's Agricultural and Horticultural Development Society), Lucknow, dedicated towards cultivation of horticultural and agricultural crops by eco-friendly ways, has been publishing bi-annual **"Journal of Eco-friendly Agriculture"** since 2006 and the Journal is going to celebrate its 15th anniversary this year.

The role of eco-friendly approaches in Agri-Horti systems has assumed greater importance with the current thrust on environmental sustainability and organic farming. In recent years, Indian farmers have started using biopesticides, bioagents, biofertilizers and other eco-friendly components in management of Agricultural and Horticultural crops. However, there is a need to increase focus on multi-dimensional research for achieving optimum enhancement in farm-production with sustainable organic Agri-Horti systems.

I am happy to mention that Ministry of Agriculture, Government of India, through its various initiatives and programmes, has been constantly encouraging farmers to adopt new technologies and advancements to get better farm-produce. Because of the key initiatives and hard work of the farming community, the country has witnessed record food production in the recent times. It is high time that the farming community must take advantage of the one of the strongest national agricultural research systems which the country has.

I congratulate Doctor's Agricultural and Horticultural Development Society for their endeavour and convey my best wishes for successful publication of the Journal of Eco-friendly Agriculture.

(Narendra Singh Tomer)

Office: 'G' Wing, Ground Floor, Krishi Bhawan, New Delhi- 110001, Tel.: 011-23782373, 23782327 Fax: 011-23385876
Resi.: 3 Krishna Menon Marg, New Delhi-110001, Ph.: 011-23794697/98, Fax: 011-23794696

United States Department of Agriculture
Research, Education and Economics

MESSAGE

The rapid changes in the agro system leaves a snag in the establishment of harmony, for at least five to six decades mankind has made unprecedented progress in terms of agriculture production by usage of strong pesticides, insecticides & fungicides resulting in decline in human immune system. It is now the world is witnessing the side effects, rather to be more precise actually paying cost of our achievements.

In today's fast changing agriculture scenario globally, it becomes mandatory for us that we look back to our ancient farming techniques and redesign our GAP (Good Agricultural Practices) methodology and hence the scientific research including use of bio-pesticides, bio-fungicides and bio-fertilizers to enable a healthy future for generations to come.

I feel proud to be a part of advisory board of this very reputed international scientific journal '***Journal of Eco-friendly Agriculture***' being published from India since 2006. The journals focus area to compile & publish research articles aimed on eco-friendly techniques of doing agriculture and horticulture crops.

I wish Doctors Krishi Evam Baghvani Vikas Sanstha (Doctors Agricultural and Horticultural Development Society) who is behind this extraordinary journal and wish them success in their mission.

Sincerely,

Gadi V.P. Reddy, Ph.D.
Research Leader

Southeast Area
Jamie Whitten Delta State Research Center
Southern Insect Management Research Unit
141 Experiment Station Road P. O. Box 346 Stoneville, MS 38776-0346 USA
Voice: 662-686-5319 Fax: 662-686-5421
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Doctor's Krishi Evam Bagwani Vikas Sanstha

(Doctor's Agricultural & Horticultural Society)

Registered under society Registration Act 21, 1860 R.No. 1-131380

A-601, Indira Nagar, Lucknow – 226016 (U.P), INDIA

:+91-522-2351389, ecofriendly.agriculture@gmail.com www.ecoagrijournal.com

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PREFACE

I feel extremely proud to introduce ***'Journal of Eco-friendly Agriculture'*** completing its fifteen years long & successful journey.

The society at the initial stages started working on farmer's training programs & demonstration trials on adopting good agricultural practices under eco-friendly system. This was around year 2000. Later in 2006 our team decided to launch an International level '*Journal of Eco-friendly Agriculture*' from the society platform to consolidate the research work done in our country and abroad in field of eco-friendly agriculture. The scientists across world working on this subject share their thoughts (in form of articles) and get benefitted. The idea was to collect all the data and distribute. Hence our first bi-annual journal Vol.1, Issue-1 got published in Jan 2006 and thereafter journey continues.

I wish the journal all the very best in its future endeavour.

(Dr. R. P. Srivastava)

General Secretary

and Former Director, ICAR-CISH, Lucknow

E-mail: ecofriendly.agriculture@gmail.com

Cell: +91-9305836798

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Review Article

Non-Chemical Approaches for the Management of Insect Pests in Agri-Horti Crops and Storage

R.A. Balikai, Madhurima Vinod and Soumya Desai[1]

Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India
[1]University of Agricultural Sciences, Raichur-584 104, Karnataka, India
E-mail: rabalikai@gmail.com

ABSTRACT

Insects are the largest group of hexapod invertebrates belonging to the Phylum Arthropoda. They are the major enemies of our crops in field and stored products. On one side are the beneficial entomofauna, which positively works for human welfare, whereas, the other side comprises of insect pests which cause a huge negative impact on human and his belongings. Unfortunately, nearly one-sixth of all crops grown worldwide are lost to herbivorous insects and the plant diseases they transmit. In addition to this, due to climate change coupled with intensification in agriculture, there has been a paradigm shift in infestation of insect pests both in time and space. Moreover, over the decade, food security at global level has also emerged as a concern at an alarming rate. The farmers use pesticides as first line of defence and frequently resort to indiscriminate and non-judicious use of pesticides for managing the insect pests. However, these lead to several problems, such as environmental pollution, pesticide residue in the harvested products, development of resistance/resurgence of pests, emergence of new pests, destruction of natural enemies and pollinators, and ultimately, increased cost of production. In this background, a paradigm shift in pest management approaches is urgently required. Such management strategies could be A) Mechanical methods, B) Physical methods, C) Legislative methods, and D) Cultural methods. The literature on these components is being focused in the present review.

Key words: Eco-friendly, Non-chemical methods, Organic, Pest management

It is most important to adopt alternative management strategies, which are blessed with preserving the environment, while maintaining satisfactory levels of agricultural productivity. Non-chemical strategies form the basis of organic pest management programs, because only a limited range of pest management tactics are available to organic growers. Effective deployment of these strategies requires knowledge of pest-crop interactions and about natural enemies of pests. It is usually the case that implementation of any single pest management strategy alone will not be effective. The challenge for organic farmers (and researchers) has been to identify sets of site and crop-specific practices that in combination are effective in preventing economic damage by the pests.

Nearly one-sixth of all crops grown worldwide are being lost due to herbivorous insects and the plant diseases transmitted by them. In addition, due to climate change coupled with intensive agriculture, there has been a paradigm shift in infestation of insect pests in time and space. Moreover, over the decade, global food security has also emerged as an alarming issue. The farmers use pesticides as first line of defence and frequently resort to indiscriminate and non-judicious use of pesticides for managing the insect pests. However, these lead to several problems, such as environmental pollution, pesticide residue in the harvested products, development of resistance, resurgence of pests, emergence of new pests, destruction of beneficial insects, and increased cost of production. In this background, a paradigm shift in pest management approaches is urgently required, wherein it is most important to adopt alternative management strategies, which are blessed with preserving the environment, while maintaining satisfactory levels of agricultural productivity. Such management strategies include A) Mechanical methods, B) Physical methods, C) Legislative methods, and D) Cultural methods.

A) Mechanical Control

Use of manual forces or the mechanical devices for the destruction or exclusion of pests is known as mechanical method of pest management. These are very useful on small scale and particularly, during initial stages of pest infestations. These include 1) Hand picking, 2) Burning, 3) Trapping and 4) Preventive barriers.

1. Handpicking: When the pest is conspicuous, the infestation is low and labour is cheap, the pest stages can be easily destroyed by mechanical means. Hand picking and destroying the insects at their different growth stages, like egg, larva, cocoon and adult insect have proven to be an effective control method. Examples: Pod borers and blister beetle on pulses (Widanapathirana, 1983). Eggs of grasshoppers can be destroyed by hand. Locust nymphs, which are congregating can be beaten by sticks and brooms. European corn borer in the stalk can be killed by running the corn stalks through the stalk shredder. Handpicking of sugarcane borer eggs, cabbage butterfly eggs, sawfly larvae on mustard, *Papilio* larvae from citrus plants and stages of *Epilachna* beetle in vegetables is very effective, especially in small areas. Collection and destruction of egg masses and early instar larvae of *Spodoptera litura* Fab. in groundnut and *Spilarctia obliqua* Walker in sunflower is feasible. Collection and destruction of caterpillars in case of red headed hairy caterpillar (RHHC) in groundnut and *Mythimna separata* (Walker) in maize and sorghum can be followed. Clipping of the tips of leaves / seedlings before transplanting is done to eliminate egg masses of paddy yellow stem borer. At 70-90 DAS, detopping of cotton shoot tips is recommended to remove bollworm egg load. The destruction of insect affected crop habitat, such as leaf webs of okra, fruits affected by borer, cucurbit fruits damaged by fruit fly and twigs of citrus infested by leaf miner also form some examples of mechanical control. With greater pest densities, however, a sweep net has to be employed to catch the insects and destroy them thereafter.

Hand picking of stem girdler beetles in grapevine yards is possible. During the day time, the adults hide on the lower side of the leaves or under the forking of the bunches, but actively move out at night avoiding the light. Such beetles should be handpicked (at night with the help of torch light) and killed as and when noticed. Whenever grapevine flea beetles (*Scelodonta strigicollis* M.) are disturbed they feign death. Thus, exploiting this behavior, putting bundles of dry shreads of banana on the pruned end of the vines in the evening, beetles which take shelter at night can be shaken and collected in the morning and destroyed.

Alternatively, shake the vines on a sheet of cloth spread below the vines to dislodge the beetles. Otherwise use open umbrella in reverse direction and shake the vines to dislodge the beetles. Later put them into trays containing kerosenized water and destroy.

2. Burning: Controlled burning is sometimes recommended to control certain pests. Weedy fallows harbouring European corn borers are burnt to destroy overwintering pest stages. To eradicate the pink bollworm dried cotton stalks are piled and burnt. Trash and garbage, weeds, *etc*. are collected and burnt to destroy different pest stages. Flame throwers are used to burn locust hoppers and adults that are congregating and marching.

3. Trapping: Trapping is popular method to lure insects to bait, light, *etc*. to kill them. *Examples*: Light trap, sticky trap, food trap, pheromone trap, poison bait, sound trap (to scare birds), *etc*. Traps usually fail to give adequate crop protection but prove useful to know population build up and are convenient to collect insect samples. Many trap designs have been developed from time to time to suit different insect enemies.

Yellow-pan traps: These traps containing water and few drops of oil have proved useful in killing hopper adults in paddy, sugarcane and wheat crops.

Sticky traps: These traps are boards of yellow colour smeared with sticky substance, which trap and kill the flying insects that are attracted to and try to rest on it. *Eg*: whitefly, aphids, thrips, *etc*. Install 4-5 yellow coloured sticky traps per acre to monitor thrips population.

Pitfall traps: Pitfall traps are pan-like containers bearing insecticide and embedded below the ground level. Crawling and fast-running insects often fall into them and die.

Light traps: Light traps attract night-flying insects, which fall into a container having insecticide, water or oil, or hit an electric grid. Light source emitting UV light is most attractive to insects. The white light trap is the most effective for attracting the insects. White light trap operated from 6 pm to 6 am everyday accounted peak moth (*Helicoverpa armigera* Hub.) catch during 14th standard week of April and moth population catch in light trap were positively correlated with larval counts of *H. armigera* on tomato in the field (Kumar *et al*., 2006).

Pheromone traps: These are particularly effective against the lepidopterous pests. Use of pheromone traps was found to be very effective in catching adult moths and also to know the population build-up of the pest. Females release specific pheromone to which males are attracted from considerable distance. Pheromones are produced by females in most of the cases except in cotton boll weevil (*Anthonomus grandis* (Boheman), where males produce the pheromone. The list of different companies manufacturing mechanical traps in India are provided in Table 1. The list of different companies manufacturing pheromone lures in India are furnished in Table 2. Sex pheromone lures and the type of trap to be used are furnished in Table 3.

The red traps were the most effective in trapping male moths of *Helicoverpa armigera* (Hub.), *Earias insulana* (Boisd.) and diamondback moth (DBM), *Plutella xylostella* (Linn.). The red and pink traps were found to be on par in trapping the male moths of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guen. Yellow pheromone traps attracted maximum moths of *Spodoptera litura* Fab. However, differences in numbers of moths trapped were statistically

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non-significant. Laboratory evaluation of lures placed in red, pink and yellow traps showed that lures in red traps were the most attractive to the male moths of the five pest species. The studies have concluded that beside other factors, trap colour also plays an important role in attracting moths of these five lepidopterous pest species (Prasannakumar *et al*., 2009).

Uses of Sex Pheromones in IPM

i) **Monitoring:** Helps to detect population and level of infestation. Developing traps baited with sex pheromones on a large-scale can be deployed for monitoring of insect pest population.

ii) **Mass trapping:** A large number of pheromone traps can be used to capture more number of adult moths and thus reduce the number of males for mating.

iii) **Mating disruption:** Confusing insects to find their sexual counterparts for mating. The natural sex pheromone emanating from the female is masked, thereby, confusing males in locating females, which ultimately results in laying of unfertilized eggs and

Table 1. List of different companies manufacturing mechanical traps in India

Sl. No.	Name of trap	Name of the company and place
1	Barrix Control Pheromone trap	Sumukha Farm Products Private Limited- Hosur, Karnataka
2	Macphill Pheromone trap	Green Revolution - Kohlapur, Maharashtra
3	Barrix Catch Fruit fly trap	Grosure Seeds - Hosur, Karnataka
4	Barrix Catch Vegetable fly trap	Sumukha Farm Products Private Limited-Bengaluru, Karnataka
5	Pheromone Funnel trap	Elevon Enterprise India - Vadodara
6	Pheromone Funnel trap	Agri Phero Solutionz - Hyderabad
7	Giant fly glue trap with attractant	Arbuda agrochemicals Privare Limited, Mumbai
8	Phero Sensor – BP trap	Pheromone chemicals - Hyderabad
9	Insect Sticky and pheromone traps	Ishita International – Nagpur, Maharashtra.
10	Pheromone lure traps for insects	Reliable Corporation- Chennai
11	Pheromone trap	Rescholar Equipment- Ambala Industrial State
12	IPM trap	Rev Agro Services - Nashik, Mumbai
13	Pheromone trap	V. J. Agro - Rajkot
14	Pheromone fly trap	Divine trap Industries -Kolkata
15	Pheroglo traps	Harmony Ecotech Pvt. Ltd. - Hyderabad
16	Plastic pheromone trap	Kabali Plastic Corporation - Bengaluru, Karnataka
17	Funnel trap	S. K Agrotech - Pune, Maharshtra
18	Pheromone trap	K. K Plastics - Ahmedabad, Gujarat
19	Bucket traps	Sanjay Trading and Industrial Services- Mumbai, Maharashtra
20	Nomate lifetime pheromone traps	Shubh Traders- Lucknow, Uttar Pradesh

Table 2. List of different companies manufacturing pheromone lures in India

Sl. No.	Name of lure	Name of the company and place
1	Fruit fly Lure	Mangalam Agrotech - Pune, Maharashtra
2	Pheromate Lure LO	Innovac Bioscience Private Limited- Vadodara
3	Pheromone Lure	Stick Line Organics - Nashik, Mumbai
4	Bee Pheromone Lure	Green Life Pheromone Systems- Malkajgiri,
5	Pheromone Lures	Innovative Agro System - Pune, Maharashtra
6	Pheromone Lures for *Scirpophaga incertulas* Fab.	Pheromone Chemicals - Hyderabad
7	Pink Boll-Worm Pheromone Lure	Green Revolution - Kohlapur, Maharashtra
8	Fruit fly Pheromone Lure	Agri Phero Solutionz - Hyderabad
9	Pheromone Lure HA	Innovac Bioscience Private Limited- Vadodara
10	Pheromone Crop Lures	Harmony Ecotech Pvt. Ltd. - Hyderabad
11	Pheromone Traps and Lures	Bio Organic Industries - Maharashtra
12	Pheromone Lures and Traps	Pest Control of India - Haryana
13	Barrix Catch Vegetable fly lure	Sumukha Farm Products Private Limited-Bengaluru, Karnataka
14	Barrix Catch Fruit fly lure	Sumukha Farm Products Private Limited-Bengaluru, Karnataka
15	Diamondback moth lure	
16	Red flour beetle lure	
17	*Earias insulana* (Boisd.) lure	ATGC Biotech Private Limited - Hyderabad
18	*Maruca vitrata* Geyer lure	
19	*Helicoverpa armigera* Hub. lure	

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subsequent suppression of pest population. *Example*: Cotton Pink bollworm – parapheromone (Hexalure) is more active than natural pheromone.

Replace lures after every 21 days. Place the Traps at a height of at least 1-2 feet above crop level. Whenever, five moths per day per trap for three consecutive days are noticed, then initiate control measures in case of *H. armigera*. Similarly, whenever more than 25 moths per day per trap for three consecutive days are noticed, then initiate control measures in case of *S. litura*. In others, whenever 5-10 adults per day per trap for three consecutive days are noticed, then initiate control measures.

Table 3. Sex pheromone lures and the type of trap to be used

Lure Name	Male Insect trapped	Type of Trap to be used
Leucinlure	*Leucinodes orbonalis* Guen.	Water trap
Spodolure	*Spodoptera litura* Fab.	Sleeve type trap/ ICRISAT Trap
Helilure	*Heliothis armigera* Hub.	Sleeve type trap/ ICRISAT Trap
Pectinolure	*Pectinophora gossypiella* (Saunders)	Delta Trap
Bador lure	*Bactrocera (=Dacus) dorsalis* Hendel	Methyl Eugenol Trap
DBM Lure	*Plutella xylostella* (L.)	Delta Trap
Inblure	*Chilo sacchariphagus* (Bojer)	Water trap
ESB Lure	*Chilo infuscatellus* Snell.	Water trap
RB Lure	*Oryctes rhinoceros* L.	Bucket Trap
RPW Lure	*Rhyncophorus ferrugenus* F.	Bucket trap

4. Preventive Barriers: In certain instances, barriers may prevent insects from infesting the crop. *Examples*: Trenches with water, insecticidal bands, oil bands around tree fruits, polythene bags for fruits. Cloth screens over seedbeds protect the younger plants from insects, like flea beetles, hoppers, armyworms, *etc*. Metal collars around young plants protect them from cutworms. Trench barriers are used to stop chinch bugs, armyworms, locusts, *etc*. Metal or concrete barriers are used against termites. Sticky bands applied around mango tree-trunks during December-January prevent the upward movement of crawlers of mango mealy bugs and mango scale insects [*Hemilecanium imbricans* (Green)], which upon hatching begin to crawl up the trunk to reach the leaves. Similarly, protecting the seedlings in nursery with nylon net (200 mesh) for 25-30 days is recommended against white flies in tomato and thrips in chilli (Rai *et al*., 2014). At Indian Institute of Horticultural Research, Bengaluru and Indian Institute of Vegetable Research, Varanasi, use of nylon net as a barrier along with infested shoot clipping for the control of brinjal shoot and fruit borer has reduced the borer incidence by 16 per cent.

Nylon fish nets are being used to cover the entire pomegranate orchards to protect from fruit sucking moths [*Eudocima* (=*Othreis) fullonia* (Clerk); *E. materna* (Linn.); *E. homaena* Hub. and *E. cajeta* Cramer] and fruit borer [*Deudorix* (=*Virachola*) *isocrates* F.]. Soon after putting nylon mesh over the crop, take up one spray with insecticide to control the existing population inside the net.

In case of grape mealy bugs [*Maconellicoccus hirsutus* (Green)], debarking and rubbing the vine stems with a stiff cloth soon after pruning followed by application of a sticky band like "Track trap" or "Bird Tangle foot" on the arms or on main stem before the appearance of mealy bugs on vines or bunches is practiced to prevent the crawlers reaching the bunch.

B) Physical methods

Modification of physical factors in the environment to minimize or prevent pest problems and use of physical forces like temperature, light, moisture, *etc*. in managing the insect pests is known as physical control. In other words, use of devices that either affect the pests physically or alter their physical environment. The physical methods include 1) Temperature control, 2) Drying, 3) Radiation, 4) Ultrasonic vibrations, and 5) Use of inert dusts.

1. **Temperature control:** Temperature extremes are fatal to insects. This method is used against stored grain pests. Temperature ranging from 20 to 40°C accelerates the development of insects but above 42°C and below 15°C retards reproduction and development, while, prolonged temperature above 45°C and below 10°C may kill the insects. Heating of grains to 50°C is lethal to insects but it is not advisable, because the grains are affected and lose the viability. Low temperatures are utilized for the control of insects in flourmills and warehouses. Exposure to sub-zero temperature for 24 hours is lethal to most of the insects. Heat therapy of the cuttings can be done to prevent spread of nematodes to newer soils through infested rooted cuttings. Immersion of rooted cuttings in hot water at a temperature of 47.7°C for 30 min, or 48.8°C for 10 minutes is effective in killing the nematodes present in roots.
2. **Drying:** Insects infesting stored grains require certain amount of moisture to develop. Neither the rice weevils nor the granary weevils (*Sitophilus granaries* L.) can survive moisture contents as low as 8 per cent (except khapra beetle). Drying the grains either in the sun or by heat blowers reduces infestation of majority of stored grain insects.
3. **Radiation:** Gamma radiation kills all stages of the pests under storage conditions. This is a common method

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employed to kill insect stages during export or imports of huge quantities of grains, fruits and vegetables. Employment of gamma rays in doses lethal or in doses, which sterilize the irradiated insects, help in pest management. In 1937 E.F. Knipling used Male Sterile insect technique (SIT) to eradicate the pests.

4. **Ultrasonic vibrations:** Moths are often sensitive to bat's ultrasonic signals and quickly escape from the area. Imitation of the bat's echolocation system helps in scaring away the lepidopterous insect pests from the area.

5. **Use of inert dusts:** This method is used by many farmers in villages. The inert dusts used are sand, clay, ash, *etc.* Mixing of such dusts with the grain makes the entry of insects in grains a difficult task and cause physical injuries; block mouth parts and lodges in joints of the insects. Some of the dusts made from Silica aerosols, activated carbons operate by abrasive action on waxy layer over the insect cuticle, resulting in desiccation and death of the insect. Food grains stored with inert dust are to be cleaned and washed before consumption. *Examples*: Kaoline clay, fine dust and talc, which are used against stored pests, adhere to insect body and absorbs moisture and thus the insects get killed.

C) Legal methods

Putting legal restrictions on the movement of plants/ seeds/commodities, *etc.* infested with insects. The following four types of legal methods could be imposed.

i) Legislation to prevent entry of new pests from foreign country.

ii) Legislation to prevent the spread of already established pest.

iii) Legislation to take effective management measure against established pest.

iv) Legislation to regulate activities of men engaged in pest control operations

D) Cultural Methods

The cultivation practices of crops could be modified without affecting the productivity, in order to bring down pest population below the economic injury level. Also, the different cultural practices help create a micro-environment conducive to better crop growth; they do not demand supplementary input materials other than a few more labour hours. Cultural methods of pest management include preventative practices to minimize the insect pests on crops or make the environment less favourable for their survival, growth and reproduction. These are the oldest methods that have been used to manage pest populations. They may only partially control insect pests because these are preventive rather than curative and are dependent on long-range planning. Also, because they are dependent on detailed knowledge of the bio-ecology of the crop pests, most of which, in the past were poorly understood. Today, the situation is very different from those early days of pest control. We have much better understanding of the bio-ecological relationships within crop systems. With this knowledge, cultural practices, to be effective, must be tailored to specific pests and performed before pests appear. Some important cultural methods of pest and disease control are a) Use of resistant varieties, b) Sanitation, (c) Crop rotation, (d) Catch Crop, (e) Time of Planting/sowing, (f) Selection of Crops / Varieties, (g) Plant Spacing and planting density, (h) Manures and fertilizer practices, (i) Soil and irrigation management, (j) Mixed cropping, (k) Intercropping (l) Tillage practices, and (m) Trap crops.

(a) Use of Resistant Varieties

The selection and breeding of crop varieties resistant to insect pests and diseases have demonstrated the enormous potential of this method in the reduction of pests and diseases. In certain cases, there are no effective methods of control of certain plant diseases, particularly those caused by viruses; here the only available alternative would be the cultivation of resistant varieties. The varieties resistant to various insect pests and diseases in different crops are listed in Tables 4 and 5.

Screening studies conducted by Patel (1996) with different early and mid-late sugarcane varieties for reaction to the root borer in southern Gujarat revealed that Co 6808 was the least susceptible. In Karnataka, the varietal reaction and loss estimation studies indicated that varieties *viz.*, SNK 09293 (0.00%), which was absolutely free from root borer infestation and emerged as promising variety to root borer attack followed by SNK 07360 (0.00%) and SNK 088789 (0.00%) and yielded significantly higher cane yield (Patil, 2017).

Arabjafari and Jalali (2007) studied 26 popular varieties of maize in Karnataka state (India) for resistance to *Chilo partellus* Swinhoe. In field trial, varieties CM 132, CM 137 and PMZ 103 showed the highest level of resistance.

Screening of 40 maize germplasm including seven hybrids (KH-510, KH-517, Hybrid Maize-47, GS-2, K-26, Apna Makka and HM-4640) was done against *C. partellus.* All the seven hybrids and five other entries (VL-90, Harsha Composite, Surya, Ageti FS and VL Makka-16) had no infestation of stem borer (Khan and Monobrullah, 2003).

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Table 4. Examples of resistant varieties in major crops

Crop	Pest	Resistant varieties
Paddy	Brown planthopper (BPH)	IET 7575, IET 5375, Jyothi, PY 3, CO 42, IR 36, IR 64
	Gall midge	Vikram, Phalguna, GMR-16
	Yellow stem borer	IR-20, IR-36, IET-2815, Ratna, TKN 6, Paiyur 1
	Green leaf hopper (GLH)	IR-20, IR-26, Vani, IR 50, Ptb 2, CO 46
Sorghum	Earhead midge	DJ 6514 (DSV-3), ICSV-197, ICSV- 745
	Earhead bug	K tall
Cotton	American bollworm	Abhadita
	Spotted bollworm	Deltapine
	Stem weevil	MCU 3, Supriya
	Leaf hopper	MCU 5, K 7, K 8
Sugarcane	Early shoot borer (ESB)	CO 853, CO 987, CO 1007, CO 312, CO 421, CO 661
	Internode borer	CO 975, CO 7304
	Top shoot borer	CO 745, CO 6515
	White woolly aphid	NNK 044 for Karnataka and SNK 049 for Peninsular Zone
Groundnut	Late leaf spot and rust	Dh-245, Dh-232
Soybean	Highly resistant to rust	DSb 28-3 (JS 93-05 x EC 241778)
Cowpea	Resistant to rust and Cowpea mosaic virus	DC16
Jasmine	Eriophyid mite	Pari Mullai

Table 5. Examples of development of crop cultivars for resistance to insect pests and diseases at ICRISAT

Crop	Trait	Screening techniques	Resistance source/ Released cultivar
Sorghum	Midge	Infester rows /Cage technique	DJ 6514, ICSV 745
Pearl millet	Downy mildew	Infector rows/ Greenhouse inoculation	ICML 12, WC-C 75
Chickpea	Wilt	Sick-plot, Indicator rows	ICC 2682, ICCV 2
Pigeonpea	*Helicoverpa*	Field screening	ICP 7203-1, ICPL 332*
Groundnut	Late leaf spot	Inoculant spray	ICGV 86699 FDRS 10**

One example cited from each ICRISAT mandate crop. * = Low levels of resistance.
** = Also less susceptible to *Helicoverpa*/*Spodoptera*, and leaf miner.

Out of 10 varieties tested, two varieties *viz*., DSb-1 and KHSb-2 recorded zero egg masses of *S. litura* per meter row length and thus proving best among the genotypes (Natikar *et al*., 2015). Out of ten released varieties screened for resistance to pod borer [Cydia ptychora (Meyrick)], varieties DSb 21, RKS 18, DSb 23-2 and MACS 1394 were classified as moderately resistant (Madhurima, 2015).

Groundnut varieties AK-159, CO-1, GG-2, GG-3, GG-5, Girnar-1, ICG-FDRS-10, ICGV 86590, O9-52-1 and S4-84 were found resistant to thrips by recording <2.5 thrips per meter row (Prasad *et al*., 2012). Eight varieties *viz.,* Dh-103, DH-86, DH86-15Kr-18-1,DH-2000-1, DTG-17 X ICGV-86699-5, ICGV-86699TAN, Dh-330, TAG-24 recorded damage score of 3 (>20 % and <30% leaf damage) and hence belonged to moderately resistant category (Gadad *et al*., 2014).

Cowpea genotypes C-152 and DC-15 were categorized as moderately resistant and DC 47-1, GC-3, RC-101 and PGCP-6 as intermediate to pod borers. Based on mean infestation index the genotypes C-152, GC-3 and DC-15 were regarded as highly resistant, whereas DC-47-1 regarded as moderately resistant to aphids. While, the genotypes RC-101 and PGCP-6 were regarded as highly susceptible to aphids. Less population of sucking pests (leafhoppers, thrips and bugs) were noticed on C-152, GC-3 and DC-15 genotypes of cowpea (Anusha *et al*., 2013).

b) Sanitation

Pest infested plants, fruits, crop residue, *etc*. would serve as a potential source of re-infestation. Collecting and destroying them and in general, the maintenance of a good sanitary standard in crop production would bring down the pest population enough to avoid re-infestation. Collection and destruction of stubbles helps reduce carryover of pest in many crops. Removal of grasses in and around paddy fields is recommended, since they also breed on number of grasses such as *Paspalum scrobiculatum* L., *Panicum* sp., *Cynodon dactylon* (Linnaeus) Persoon *etc*.

This method is used to reduce pest infestation through the removal of breeding and also hibernating sites. Sanitation has broad applicability; to be most effective, it requires knowledge of the habitats of the pest species and careful timing. It involves: i) Eradication of harmful weed hosts or alternate hosts, ii) Timely destruction of crop residues, iii)

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Cleaning of field borders having alternate hosts, and removal of scrub or shelter in which pests might hide, e.g., in orchards, destruction of dropped fruits and pupation sites for codling moth and apple maggot, *etc*.

Sanitation in Storage pest management

a. Threshing floor/yard should be clean, free from insect infestation and away from the vicinity of villages/ granaries/godowns.

b. Clean the harvesting and threshing machines before their use.

c. Trucks, trolleys or bullock carts, which are used for transportation of food grains should be made free from insect infestation.

d. Clean and sanitize the storage structure/godowns before storage of newly harvested crop.

e. All dirt, rubbish, sweepings and webbings should be removed from the stores and disposed/destroyed.

f. All the cracks, crevices, holes existing in the floors, walls, ceiling should be plastered with cement permanently.

(c) Crop Rotation

Repeated cultivation of any single crop results in the progressive build-up of soil-borne insect pests and pathogens that are especially injurious to that crop. Furthermore, certain pests are associated with specific crops, which feed voraciously and multiply rapidly with the presence of the same crop. In addition, the progressive cultivation of the same crop favours the increase in un-controllable growth of weeds, which could be checked by the adoption of a different crops in the successive season. Hence, crop rotation would be an effective and profitable method of reducing insect pests, diseases and even some of the weeds.

An effective rotation is one in which a crop of one plant family is followed by one from a different family that is not a host crop of the pest to be controlled. Most common rotations include grasses, legumes and root crops. Rotations are effective against pests that have a limited host-plant range and depressiveness and/or that cannot survive for more than one or two seasons without suitable host crops. Pests subjected to this type of control are poorly mobile, soil-inhabiting species with a restricted host range and a life cycle of one year or longer (Stuart, 1989). Two important factors influencing the impact of a particular rotation on an insect are the host range of the insect and its degree of mobility.

Crop rotation is useful for insects which have narrow range of host crops, *eg*. BPH in paddy–rotate with other cereals or pulses. Sorghum shoot fly–rotate with cotton or bajra.

(d) Catch Crop

Insect pests are not attracted towards some crop varieties and when those crops are cultivated together with another crop, which is readily susceptible to a particular pest, the overall incidence of pest attack has been found to be low. This technique has a very good application in reducing pest populations in multiple cropping programmes.

(e) Time of Planting

The rapid development and multiplication of pests is majorly influenced by time of cultivation of the crops. For example, some insect pests multiply swiftly and reach very high levels during certain seasons, while the pest population is less throughout the rest of the season. The time of planting can, therefore, be adjusted in such a way to plant the crop, when the pest population is low. By the time the pest number increases, either the crop may be ready to harvest or may not be there in the field, thus ensuring the protection of crop from pest attack (Widanapathirana, 1983).

Manipulation of sowing time can be used to allow young plants to establish to a tolerant stage before attack occurs. It reduces the susceptible period of attack, to mature the crop before a pest becomes abundant, to allow it to compensate for damage and to fill gaps where plants have been damaged or killed, and to avoid the egg-laying period of a particular pest. Optimum time of sowing aims at avoiding invasion by migrants, oviposition period of particular pests, introduction of diseases in the crop by insect vectors and also synchronising the pest attack with its natural enemies or weather conditions that are adverse for the pest (Stuart, 1989).

Time of planting or sowing is helpful largely to:

i) avoid invasion by migrants or the oviposition period of particular pests and the introduction of disease in the crop by insect vectors;

ii) to synchronize the pest attack with its natural enemies, with weather conditions that are adverse for the pest or with the abundance of an alternative host;

iii) to make it possible to destroy the crop before the pest enters diapause.

Varying the time of planting causes asynchrony between crop and pest phonologies, resulting in reduced colonisation by insect pests. By manipulating time of planting, pest and its damage can be avoided by three ways

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viz., early planting, late planting and optimum planting time that results in injury-free periods during crop growth and development (Teetes, 1981). Several studies have quoted evidences for reduction in pest abundance and damage due to early planting in India. For instance, early planting of barley resulted in reduced population density of *Rhopalosiphum maidis* (Fitch). Similarly, early planting of corn, rice, wheat and sorghum resulted in reduced damage by *Atherigona naquvi* (Steyskal), *Nilaparvata lugens* (Stal.), *Mythimna separata* (Walker) and *Atherigona soccata* (Rondani), respectively, whereas, late planting recorded increased abundance of all these pests. However, there are also reports of late planting of sorghum crop having reduced incidence of *Chilo partellus* (Swinhoe) and *Stenodiplosis* (=*Contarinia*) *sorghicola* (Coq.) (Balikai, 2002) (Table 6). Similar findings were reported by Ameta and Sumeria (2004), where the infestation of shoot fly and stem borer increased, when sorghum sowing was delayed and had adverse impacts on plant height, weight and length of earhead, number of primaries and spikelets and grain and stover yield, whereas, early sown (July 14) crop had a reduced incidence of these pests.

Table 6: Effect of planting times on insect abundance and/or potential damage in India (Balikai, 2002)

Crop	Insects	Planting Time	
		Early	Late
Cereals			
Barley	*Rhopalosiphum maidis* (Fitch)	-	+
Common millet	*Atherigona* spp.	+	-
Corn	*Atherigona naquvi* (Steyskal)	-	+
Rice	*Cnaphalocrocis medinalis* (Guen.)	-	+
	Nilaparvata lugens (Stal.)	-	+
	Orseolia oryzae (Wood-Mason)	-	+
Wheat	*Mythimna separata* (Walker)	-	+
Sorghum	*Chilo partellus* (Swinhoe)	+	-
	Stenodiplosis (=*Contarinia*) *sorghicola* (Coq.)	+	-
	Atherigona soccata (Rondani),	-	+
Commercial Crop			
Sugarcane	*Chilo infuscatellus* Snell.	-	+
Oilseeds			
Linseed	*Dasyneura lini* (Barnes)	-	+
Rapeseed & mustard	*Lipaphis erysimi* (Kalt.)	-	+
Safflower	*Uroleucon carthemi* (H.R.L.)	-	+
	Uroleucon compositae (Theobald)	-	+
Soybean	*Rivula* sp.	+	-
	Obereopsis brevis (Swedenbord)	+	-
Peanut	*Holotrichia serrata* (Fab.)	-	+
Sesame	*Antigastra catalaunalis* (Duponchel)	-	+
Pulses			
Chickpea	*Helicoverpa armigera* (Hubner)	-	+
Cowpea	*Maruca testulalis* (Geyer)	-	+
	Cydia ptychora (Meyrick)	-	+
Pigeonpea	*Helicoverpa armigera* (Hubner)	-	+

Note: + increase in population density or damage, - decrease in population density or damage

In case of soybean, *Obereopsis brevis* incidence was reduced due to late planting while early planting had an increased abundance and damage by the pest (Balikai, 2002). On the contrary, there are also reports of reduced pest incidence due to early sowing in soybean. For example, investigations on soybean crop sown in three different dates indicated that early sown crop (June 16th) suffered less pest damage compared to late sown crop. The lowest incidence of *S. litura* was noticed on early sown crop (5.37 and 3.98 l/mrl, respectively) compared to the late sown crop (8.44 and 6.03 l/mrl, respectively). Even the pod borer incidence in terms of per cent pod damage was significantly lower in early sown crop (38.82%), whereas, highest pod damage was recorded in case of late sown crop (58.77%) (Santhosh, 2008). Influence of different dates of sowing on the incidence of pink pod borer, *Cydia ptychora* (Meyrick) on soybean was reported. It was observed that the crop sown on 21st meteorological standard week (MSW) during the first week of June recorded the minimum larval population of 9.10 larvae per plant. However, the peak incidence of 30.40 larvae per plant was recorded in the crop sown on 29th MSW during the last week of July. Similarly, the lowest pod and seed damage was observed in the crop sown during the first week of June with 5.26 and 3.19 per cent, respectively, whereas, the highest pod and seed damage of 42.70 and 40.96 per cent, respectively, was recorded in the crop sown during the last week of July (Madhurima and Patil, 2017). Similar findings on soybean were also reported by Adimani (1976); Kumar (1978) and Amarnath (2000).

An early planted (October) chick pea crop escapes with the least damage of pod borer, whereas, late planted ones (December-January), which matured during late March to April suffered heavy damage (Rathore and Nwanze, 1993). The activity of two sucking pests *viz.*, thrips and mites in chilli as reported by Gayatridevi and Giraddi (2009) revealed that July 15 and July 30 planting dates emerged as better planting time. Significantly lower pest population were recorded in July 15 planted crop (0.14 and 0.37 numbers per leaf, respectively), followed by July 30 planting as evident by the lowest activity of thrips and mites (0.35 and 0.39 numbers per leaf, respectively). These findings were also in confirmation with reports of Sujay and Giraddi (2014) who recorded significantly lower level of sucking pest and leaf curl index on July 15 planted chilli crop when spaced at 90x60 cm.

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The effect of dates of sowing on incidence of insect pests on castor genotypes was evaluated. Results revealed that infestation of *Achaea janata* Linnaeus was observed when castor was sown either early or late, however, there was a decrease in larval incidence when the crop was sown late during the month of August as compared to that during July. Maximum of 2.73 larvae were observed when sown early, which was reduced to 1.07 with late sowing. Early sown crop was more prone to incidence of *S. litura* than late sown crop (Laxman and Maheswari, 2017).

In a similar trend, an increased population of *Bemisia tabaci* Gennadius nymphs were recorded in late sown cucumber crop. During the first planting date (March 15th) cucumber leaves harboured the lowest seasonal mean count of *B. tabaci* 6.94 nymphs/inch^2. On the contrary, the later date (May 15th) recorded the highest population 20.46 nymphs/inch^2 (Mohamed, 2012).

(f) Selection of Crops/Varieties

Some of the crops when planted in an area where the environmental factors are optimum for its development grow rapidly and give an early harvest. On the other hand, when the same crop is planted on the land where the factors of crop growth are below the optimum requirement, the growing period is substantially lengthened and as a result the incidence of pest attack may be high. Still other crops are more susceptible to particular pest and disease attacks, when planted in an area where the incidence of attack is reported to be high. Similarly, short-aged crops are preferred to long-aged crops; in the latter case the period of crop exposure to natural calamities such as pest and disease outbreaks, is high, since it is subjected to a greater risk of pest attack. Therefore, the selection of crops with particular reference to the climate of the area, where it is expected to be planted, is a good strategy to minimise pest outbreaks. The short duration varieties escape from the attack by the pests occurring in the later stage of the crop. *eg*. Short duration varieties of pigeon pea escape from pod fly damage.

(g) Plant Spacing and Planting density

Plant spacing directly influences the soil moisture extraction, light interception, humidity and wind movement (Heitholt *et al*., 1992), which in-turn influences plant height, branches development, fruit location and size, crop maturity and ultimately yield. Plant spacing significantly affects health, growth and development of the crop as well as microclimatic condition of the crop ecosystem on multiplication of the pest (Jain and Bhargava, 2007). Hence, manipulating the plant spacing has an immense influence on the growth and reproduction of some the pests which can be effectively utilised as an easier and much safer management strategy against target pests.

The primary objective of this cultural method is to maximize yield per unit area without reducing crop quality, so that yield advantages override pest incidence reduction. It can also be used to reduce pest numbers and damage. Spacing may affect the relative rate of growth of the plant and its pest population per unit of time, and the behaviour of the insect pest in searching for food or for an oviposition site. It is based on the following observations:

i) Close spacing may add to the effectiveness of natural enemies and result in greater control of pest population;

ii) Some insect pests are attracted by low density planting because they are silhouetted against bare ground, e.g., at low density brassicas attract more aphids;

iii) Some populations of pests can increase on high density crops. Because of the variety of existing responses to crop spacing, a detailed knowledge of the pest's biology is of extreme importance.

Plant spacing is also used to promote vigorous and strong plants, which in itself can be a good cultural control measure, e.g., a good protection for corn against corn stalk borer. Plant spacing that encourages rapid crop maturation could also provide a means of encouraging early fruiting and harvesting of crops of indeterminate flowering plants. This has been used in the south against boll weevils and pink bollworms.

It has now been suggested that the devastating incidence of Brown Plant Hopper attack is partly attributed to the high paddy plant density. Thus, for BPH management, alley farming (Rogue space planting) is followed. After every 2 m of planting, space is given for aeration and to reduce relative humidity. Experience also indicates a positive relationship between the paddy plant density and the occurrence of diseases of fungal origin. Wider spacing in sugarcane reduces sugarcane woolly aphid due to aeration.

It is a well-known fact that as the spacing between the plants decreases, the pest population increases. This might be due to the fact that narrow spacing provides higher plant density which in turn may alter the microclimatic condition of the field in favour of the pests. There are some research findings in confirmation to this. The adjustment of plant spacing to the recommended level should therefore, be employed in order to lower pest and disease attack. The population of aphids in *Bt* cotton decreased as plant to plant distance was increased. The aphid population decreased significantly with 5.20 per leaf on *Bt* cotton raised at 150 × 60 cm, wider plant spacing. The *Bt* cotton cultivated at a spacing of 120 × 60 cm (12.25/leaf) and 150 × 45 cm (9.89/

leaf) significantly differed with each other and recorded medium population of aphid. The *Bt* cotton raised at wider spacing of 150 × 60 cm recorded lower activity of major sucking pests *viz*., aphid, leafhopper and whitefly (Patel *et al*., 2015). As the spacing increased, the population of sucking pests decreased and *vice versa*. Such findings were also reported by Mohite and Uthamasamy (1997), Muhammad *et al.* (2006), Kalaichelvi (2008) and Shwetha *et al.* (2009) in *Bt* cotton.

Avasthy and Varma (1979) and Sunil Kumar *et al*. (2007) reported that wider spacing would tend to decrease early shoot borer damage in sugarcane. Malik *et al.* (2003) deduced an inverse relation between increased line spacing and thrips population in onion. The mustard aphid, *Lipaphis erysimi* (Kalt.) population increased significantly as the inter row spacing decreased (Sarwar, 2008).

Significantly least aphid population (47.80 aphids/ twig) was registered in dodi, *Leptadenia reticulata* (Retz.) crop, which is a medicinal crop grown for pharmaceutical drugs, planted at wider spacing (60 x 120 cm) over other spacing. Likewise, significantly least (9.05) number of infested leaves due to leaf roller *Psylla* were registered in the crop planted at wider (60 x 120 cm) spacing than the crop planted at other spacing.

(h) Manures and Fertilizer Practices

Plant nutrition can influence the feeding, longevity and fecundity of phytophagous pests. The common fertilizer elements (nitrogen, phosphorous and potassium) can have direct and indirect effects on pest suppression. In general, nitrogen in high concentrations has the reputation of increasing pest incidence, particularly of sucking pests such as mites and aphids. On the other hand, phosphorous and potassium additions are known to reduce the incidence of certain pests, *e.g.*, in low phosphorous soils wireworm populations often tend to increase.

Fertilization promotes rapid growth and shortens the susceptible stages. It gives better tolerance to, and opportunity to compensate for, pest damage. Trace mineral and plant hormones sprays (*e.g*., from seaweed extracts) have been found to reduce damage by certain pests, particularly sucking pests such as some aphids and mites.

When all required nutrients are available in a balanced form, it has been observed that crop growth is more steady, while pest and disease attacks are also at minimum. On the other hand, indiscriminate use of one plant nutrient over others, for example excess nitrogen, favours a luxurious growth of plants causing an increase in the degree of susceptibility to insect pests and diseases, *e.g*., High incidence of Rice Blast disease associated with more nitrogenous fertilizer and the greater degree of paddy leaf folder attack with unbalanced nitrogen fertilization.

Nutrition of crop plants influences its resistance or susceptibility to infesting herbivore. Source, quantity and timing of nutrient application either enhance or reduce the biophysical and biochemical factors of induced resistance in crop plants against insect pests (Nazeem, 2011). Excessive use of inorganic fertilizers can cause nutrient imbalance and lower pest resistance in crops. Soils with high organic matter and active soil biology, generally, exhibit good soil fertility. Crops grown on such soils showed lower pest abundance, due to a low nitrogen content, in organically farmed crops (Altieri and Nicholls, 2003). Since the inorganic chemical fertilizers cause heavy incidence of pests and diseases, it is therefore, felt imperative to minimize the environmental risks by reducing the levels of inorganic fertilizers by adopting suitable practices of organic farming with FYM, composts, vermicompost, oilcakes, *etc*. These organically fertilized soils are most appropriate for crop production as it provides balanced feed to crop plants and maintain them healthy.

The efficacy of organic fertilizers like farmyard manure (FYM), vermicompost, poultry waste, dairy waste and others have been studied extensively. Varma (1994) reported minimum population of fruit borer, *H. armigera* in chilli plots, which received soil application of vermicompost than those applied with straight fertilizers. Similarly, the population build-up of pod borers in pigeon pea was minimum in FYM applied plot followed by FYM + straight fertilizers (Dayakar *et al*., 1995). The efficiency of vermicompost and FYM in managing fruit borers *H. armigera, Earias vittella* Fabricius and *E. insulana* of bhendi has been reported as significantly efficient in bringing down the fruit borer population, when applied at 7.5 and 30 tonnes per hectare, respectively, compared to NPK as inorganic fertilizers (Surekha and Arjuna, 2000).

The effects of organic (composted cow manure) and synthetic (NPK) fertilizers on pests *viz*., aphids and flea beetles associated with tomatoes were investigated, which resulted in lower populations of aphids on tomatoes grown with the organic fertilizer than on those grown with the synthetic fertilizers in the second year of the experiment, indicating that organic fertilizers may have the potential to reduce pest attacks in the long term (Yardum and Edwards, 2003). Organically manured groundnut with FYM @ 8 t/ha, neem cake @ 770 kg/ha and vermicompost @ 3.75 t/ha recorded lowest pest population of *S. litura* (1.03, 1.18 and 1.09 larvae/m row, respectively) compared to straight fertilized treatment of NPK (2.00 larvae/m row) (Rao, 2003). The overall influence of organics, integrated nutrient

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management and inorganic (RPP) treatments studied on the incidence of sucking pests and defoliators, vividly showed that the organically grown groundnut, which received FYM, vermicompost, green leaf manure and neem cake recorded significantly less incidence of aphids (8.55/ cm twig) and thrips (3.57/ leaflet). The same organic practices followed, recorded least incidence of sucking pests in soybean *viz.*, thrips (4.40/ leaflet), leafhoppers (2.90/ sweep) and defoliators like *S. litura* (3.12/m row), *Trichoplusia orichalceae* Fabricius (1.88/ m row) at Dharwad, Karnataka (Bharati, 2005). A positive and significant correlation between the insect-pest particularly cotton leaf hopper and nitrogen fertilizer was observed (Sagar *et al.*, 2014).

Organic amendments including vermicompost and vermiwash on translocation into the plant system may possibly alter the physiological processes, including enzyme activity thus leading to greater accumulation of plant metabolites leading to induced resistance v/s insect pests (Bhawalkar and Bhawalkar, 1992, and Bhinde, 1993). Farming practices using organic amendments causes nutrition imbalances that result in lower pest resistance (Magdoff *et al.*, 2000). Meyer (2000) proposed that soil nutrient availability not only affects the amount of damage that plants receive from herbivores but also the ability of plants to recover from herbivores.

Examples: The following recommendations are being made with respect to fertilizers to avoid increased population.

Paddy BPH- Apply recommended dose of NPK and avoid excess nitrogen application; Internode borer, *Chilo saccharifagus indicus* (Kapur)- Avoid excess application of N fertilizers

Sugarcane leafhopper (*Pyrilla perpusilla* Walker)- High humidity in May-June, heavy manuring and irrigation favours multiplication of the pest

Sugarcane whitefly, *Aleurolobus barbodensis* Mask- Avoid excess application of N fertilizers

Sugarcane white woolly aphid- Withhold application of nitrogenous fertilizers in case top dressing is due

Cotton leafhopper: *Amrasca biguttula biguttula* (Ishida)- Avoid excess application of N fertilizers

Coconut mite: *Aceria (Eriophyes) guerreronis* Keifer- Nutrient Management: a) Urea-1.3 kg, S/P- 2.0 kg, M/P- 3.5 kg, Gypsum-1 kg, Borax 50 g/plant c) Neem cake application @ 5 kg/plant/year. c) Root feeding with Azadirachtin (Nee azal) @ 7.5 ml or Econeem @ 10 ml + equal quantity of water

Hence, by ensuring the application of correct fertilizer materials with optimum dosages at the right time, crop resistance to pest and diseases can be improved.

(i) Soil and Irrigation Management

At the time of establishment of crop plants, land preparation has to be done effectively, so that different growth stages of insect pests and soil borne pathogens get exposed for the action of natural forces, which results in the reduction of pests, particularly those inhabiting the soil. Land preparation is also important in the control of weeds. Further, soil management practices should be adopted in such a way that soil erosion is minimised and the fertility of the soil is improved; the growth of crop plants on such soil becomes vigorous, leading to the greater resistance to pest and disease outbreaks.

Moisture is an important limiting factor that affects the survival of some the pests. Where sufficient water is available, flooding is sometimes used for insect and nematode control, *e.g.*, flooding of infested soils has been used to eliminate certain species of wireworms within three days. Certain other wireworm species are unable to withstand desiccation. Where these wireworms occur, drying out the soil could be an effective control measure (Stuart, 1989). Flooding of infested soils is also helpful in managing root grubs.

Improved irrigation and water standing in the field are conducive to the growth of the brown plant hopper *Nilaparvata lugens* (Stal) population, which could probably increase the crop damage. To prove the point, pest density at IRRI was monitored during the dry season in plots having varying degrees of standing water or soil moisture. When a plot was flooded continuously or periodically, two large population peaks developed. Only one moderate peak gets developed, when the soil was kept saturated but not flooded and few insects were found in unirrigated plots. Thus, it was concluded that flooding positively affects pest population increase. It is commonly stated in the literature that a humid environment is preferred by *N. lugens,* and is conducive to its development and population increase (Tirawat, 1975). A range of 70 to 85 per cent relative humidity is optimal for BPH development (Kulshreshtha *et al.*, 1974). Hence, frequent irrigations can lead to increased population density of BPH in rice.

The effect of drip irrigation on incidence of insect pests *C. infuscatellus*, *Melanaspis glomerata* (Green) and *Saccharicoccus sacchari* Cockerell in sugarcane was studied by Parsana *et al.* (1994). A maximum per cent dead hearts due to *C. infuscatellus* and the highest population of *M. glomerata* were recorded in the treatment of minimum level of irrigation (0.4 CPE). However, as the levels of irrigation increased with the drip system, damage due to *C. infuscatellus* and *S. sacchari* decreased. Highest population level of all

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pests was recorded in the traditional flood method of irrigation. Among the various levels of irrigation water with drip system, treatment of 0.8 CPE gave significantly higher yields than other treatments.

Examples

Paddy BPH- Alternate wetting and drying of paddy field to reduce relative humidity

Sugarcane leafhopper and Sugarcane white woolly aphid- Avoid water logging to reduce its population.

(j) Mixed cropping

In this approach, more than one crop is grown on the same piece of land. This reduces phytophagous insect pests by encouraging increases in natural enemies due to:

i) greater temporal and spatial distribution of nectar and pollen sources;

ii) increased ground cover, particularly important for diurnal enemies;

iii) increased prey, offering alternative food sources when the pest species are scarce or at an appropriate time in the predator's life cycle. It also affects the pest's ability to find host plants by conferring associational resistance, by the non-host plant masking the odours of the host plant. This system enables to get some yield from the crop that is not prone to severe infestation by insect pests, *e.g.* Cotton + chilli + onion

(k) Intercropping

In tropics, intercropping has been an important component of small farm agriculture (Lamb, 1978) and one of the reasons for the evolution of these cropping patterns may be the reduced incidence of insect pests (Altieri *et al.*, 1978). Intercropping, an important cultural practice in crop pest management, primarily involves increasing the plant diversity of a given agro-ecosystem to aid reducing insect pest populations and consequently, their attack (Singh *et al.*, 1986). The practice seeks to alter the environment to support favourable crop growth and yield, rather than encourage insect population build up (Songa *et al.*, 2007). Some plant combinations, for instance, with non-hosts lower the spread of pests within crops (Gautan and Kaushik, 1980). Non-host plants in such mixtures may emit chemicals or odours that adversely affect the pests, thereby, conferring some level of protection to the host plant (Reddy, 2012).

A testing of nine intercrops in soybean for their ability to reduce incidence of defoliators, namely *S. litura*, *Hedylepta indicate* Fab. and *Diachrysia orichalcea* Fab., revealed that maize and pigeon pea as most effective intercrops because of their phenology, repellent chemicals and physical barriers (Gandhi *et al.*, 2017). The same inter crops of maize and pigeon pea recorded reduced incidence of pink pod borer *C. ptychora* in soybean (Gandhi and Patil, 2015). Prasad and Gedia (2011) reported that groundnut intercropped with cluster bean and sunflower reduced the incidence of leafhopper, while castor and hybrid cotton reduced thrips in sole groundnut crop (Balakrishnan *et al.* 2010). Rao *et al.* (2012) reported that intercropping groundnut with blackgram or pearlmillet or soybean has reduced the larval population and damage due to leaf miner on groundnut. Similarly, intercropping of groundnut with sunflower or castor has reduced the population of *Spodoptera* on groundnut. Srinivas *et al.* (2007) documented that intercropping of red gram with sorghum, groundnut and blackgram reduced the pod damage by *H. armigera, M. vitrata* and *Melanagromyza obtusa* Malloch significantly.

Patel *et al.* (2012) found that intercropping of cotton with maize, cowpea, and sesamum reduced the population of sucking pests *viz.*, aphid (*Aphis gossypii* Glover), leafhopper (*A. bigutulla bigutulla*) and whitefly (*B. tabaci*). Intercropping onion with spider plant and carrot significantly reduced thrips population by up to 45.2 and 21.6 per cent, respectively, but French bean had no significant effect. The three vegetable intercrops significantly reduced thrips damage severity, with spider plant having the greatest reduction of up to 15.7 per cent (Gachu *et al.*, 2012). Spurthi *et al.* (2007) summarised that sorghum + cowpea recorded less number of eggs and per cent dead heart by shoot fly (*A. soccata*) than in sole sorghum.

Suresh and Dason (1996) recorded lowest population of leaf hopper and bollworms in cotton intercropped with black gram, cluster bean or green gram. Hegde and Lingappa (1996) from Dharwad reported that pigeon pea intercropping with cowpea followed by soybean followed by *Setaria* has reduced larval incidence of *H. armigera* compared to sole pigeon pea crop. Among different intercropping systems tested, chilli intercropping with coriander and onion performed well by recording lowest population of sucking pests, leaf curl index, larval population of *H. armigera* and fruit damage compared to sole chilli crop (Sujay and Giraddi, 2015). Manjunatha *et al.* (2001) reported that among different chilli intercropping systems, the lowest population of thrips and mites was recorded in chilli + tomato followed by garlic and coriander compared to sole chilli. Groundnut (Variety: VRI II) when intercropped with bajra (Variety: Co 7), maize (Variety; Co 6) and sorghum (Variety: Co 30) in 4:1 ratio, harboured significantly less population of sucking pests *viz.* leafhopper, *Empoasca kerri* Pruthi, Aphids, *Aphis craccivora* Koch and Thrips, *Scirtothrips dorsalis* Hood (Parthiban *et al.*, 2018).

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(l) Tillage Practices

This approach can help in the control of soil inhabiting forms of field crop pests by:

i) Bringing larvae and pupae onto the soil surface, thereby exposing them to desiccation and predation, freezing and thawing;

ii) Damaging the pest in its soil inhabiting phase, *e.g.*, wireworms;

iii) Destroying crop residues, which might harbour pests that could invade new crops;

iv) Burying residues so deep that emergence from eggs or pupae is made impossible.

Note: minimum tillage and direct drilling may, depending on habitat conditions, increase or decrease pest presence. Therefore, knowledge of the bioecology of the particular pests that are present in particular soil is essential.

Tillage practices changes the physical and chemical properties of soil and can also inhibit or enhance useful and harmful fauna (Singh *et al.*, 2013). The reports of Musick (1970), Edward (1975) and All and Gallaher (1976) are amongst the earliest records of the effects of tillage on arthropods. Later, Stinner and House (1990) and Kladivko (2001) extensively reviewed the subject. Pest incidence can be affected indirectly by tillage, which effects and residue management practices. Reduced and zero-tillage fallows, generally maintain higher populations of predators and pathogens of insect pests resulting in reduced pest attack on crops (Robertson, 2002). Population of predacious ground beetle are significantly higher in no-tillage fields than in conventionally tilled fields, which in turn reduces incidence of soft bodied insects (Kumar *et al.*, 2013).

Many insect pests spend their entire life or at least part of their lives as larvae or pupae in the soil. Hence, ploughing or digging when the soil is dry exposes the prevalent insect stage to sun rays leading to desiccation and on the other hand are picked off by birds or other predators. Ploughing can also push the pest deep down into the ground, where they would not be able to survive. Deep ploughing after harvest and before sowing reduces the potential carryover of the pests from one season to the other (Kishore and Sharma, 2007). Cultural practices like ploughing, hoeing and basin preparation influence directly, the survival of soil inhabiting pests by exposing them to harsh weather and to natural predators. Insects are most vulnerable, when in the pupal stage and most insect-pests pupate in the soil, which provides a protective habitat. Some insects *viz.*, grasshoppers, crickets and borers lay eggs in the upper layers of the soil, which are exposed during soil preparation and subsequently desiccate. Birds like king crow, myna, *etc.* pick up the exposed pupae following these cultural operations. (Parmar, 1998).

Tillage can reduce insect pest populations by crushing and destroying white grubs and cutworms, as well as overwintering of pupae of squash vine borers, tomato hornworms and tobacco hornworms. Unearthed white grubs, cutworms and wireworms become more available to birds and vulnerable to harsh weather (Robert, 2004). Summer ploughing is an effective practice to spoil the soil inhibiting stages of insect. Deep ploughing of the field after the harvest reduces the activity of fruit fly, red pumpkin beetle and cut worm, as these insects remain in the soil in earthen cocoon to complete the dormant stage of their life cycle. Similarly, summer ploughing is effective to reduce the soil borne pathogens population because of solarisation effect (Rai *et al.*, 2014). The tillage practices result in damaging the pest in its soil inhabiting phase, *e.g.*, wireworms, destroying crop residues, which might harbour pests that could invade new crops and also burying residues so deep that emergence from eggs or pupae is made impossible (Stuart, 1989).

Monitoring of abundance and damage of pests *viz.*, pink stem borer (PSB, *Sesamia inferens* Walker), termites (*Microtermes obesi* Holmgren and *Odontotermes obesus* Rambur) and root aphid (*Rhopalosiphum rufiabdominalis* Sasaki) in four altered tillage systems in rice-wheat cropping system under insecticide protected and unprotected conditions were evaluated. The investigations demonstrated that in conventional tillage, damage by PSB (0.6%) was minimum, whereas, termite damage (2.2%) was maximum as compared to all other tillage conditions. In zero tillage, PSB damage was maximum (1.4%) and root aphid incidence was minimum (3.1 aphids/tiller) in comparison to other tillage conditions (Singh *et al.*, 2003). In some instances, tillage systems can affect insect populations if they increase or decrease crop residue in the spring or early season weed growth as in case of black cutworms, which are influenced by the degree of crop residue, because the moths prefer to lay their eggs in fields with crop residue or existing vegetation in April. Similarly, some early season crop pests, such as seed corn maggots, are encouraged by newly tilled soil and the presence of decaying organic matter, which attracts the adult females to lay eggs. The use of cover crops and green manures should be carefully evaluated in light of the possibility of increasing damage from insect pests in some situations (Robert, 1995).

(m) Trap crops

Trap crops (often small plantings, usually planted

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earlier than the main crop) are used to divert insect attack away from the crop at risk by using more attractive food sources. A patch or few rows of preferred hosts can be grown in main fields to attract the pests. The trap crop must usually be destroyed before the insects reproduce.

This method involves the planting of a crop upon infested land so that the pest is stimulated to attack, but the crop is either removed before the pest can complete its life cycle or it will not provide all the requirements necessary for the completion of the pest's life cycle. Alternatively, the trap crop may be preferentially attacked in the presence of the crop one needs to protect (Stuart, 1989).

Trap crops have been defined as plant stands grown to attract insects or other organisms like nematodes to protect target crops from pest attack, preventing the pests from reaching the crop or concentrating them in a certain part of the field, where they can be economically destroyed (Hokkanen, 1991). Prior to the introduction of modern synthetic insecticides, trap cropping was a common method of pest control for several cropping systems (Talekar and Shelton, 1993).

Note: the pest must have a narrow host range and the trap crop species selected need not be different from the main crop.

Examples : Cotton + Okra (10:1 ratio) – for bollworms and shoot weevil

Chilli + Marigold (20:1) – for fruit borer

Soybean + Groundnut - for *S. litura* and leaf miner

Grow mustard as trap crop to attract diamond back moth, at 25:2 ratio (Cabbage: Mustard) (1st line-15 days before planting of cabbage and 2nd line in adjacent ridge 25 days after planting of cabbage).

Surrounding the borders of soybean field with maize or mung bean as plant traps offers a reliable protection against the infestation of *B. tabaci,* whereas, when surrounded by a mixture of maize, mung bean and sunflower plant traps, it escaped from aphid infestation (Abdallah, 2012). Similar findings were also reported by other workers. Ali *et al.* (1994) observed a positive relationship between *B. tabaci* nymph population and density of maize plants. The number of the whitefly considerably increased as the density of maize plants increased. Soybean plants alone harboured the highest population of *B. tabaci* and the lowest population was observed in soybean cropped with maize or sorghum (Rab, 1997).

The role of different trap crops in pest management in chilli was evaluated, which revealed lowest population of sucking pests and leaf curl index in tomato and brinjal trap cropping systems, respectively. However, with regard to fruit borer damage, significantly least larval population and damage was recorded in chilli trap cropped with marigold. This might be because of the preference of marigold as either a food source or oviposition site by the pest than the main crop (Sujay and Giraddi, 2016). Patel (1996) reported the efficacy of trap cropping in pest management of cotton crop. A lower leaf hopper population was observed on cotton when surrounded by marigold trap crop, whereas, lower white fly population was recorded from cotton surrounded by pigeon pea (Patel, 1996). Bhendi as a trap crop proved successful in reducing leaf hoper and aphid populations on cotton (Reddy, 1997). An IPM model comprising of marigold as trap crop resulted in reduction of *H. armigera* eggs and larvae on chilli thereby, increasing yield (Gundannavar and Giraddi, 2007). A similar effect on marigold as effective trap crop in chilli against *H. armigera* was reported by Mallikarjuna and Ahmed (1986), against aphids by Mallikarjuna *et al.* (1999) and against thrips and mites by Giraddi *et al.* (2003).

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Studies on the effect of organic and inorganic fertilizers on yield of coconut orchard in coastal ecosystem of Maharashtra State

V.V. Shinde, S.L. Ghavale, S.M. Wankhede, P.M. Haldankar and H.P. Maheswarappa

AICRP on Palms, Regional Coconut Research Station, Bhatye, Ratnagiri (M.S.), India
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-415 712
Email: agr_agronomist@yahoo.co.in

ABSTRACT

The field experiment on impact of integrated nutrient management and organics including biomass recycling in coconut based cropping system was initiated on a 30 years old healthy D x T coconut plantation at Regional Coconut Research Station, Bhatye, Ratnagiri (M.S.) during the years 2013-14 to 2017-18. The experiment consisted of four treatments viz. T_1: 75% of recommended NPK +25% of N through organic recycling with vermi-compost, T_2: 50% of RDF+ 50% of N through organic recycling with vermi-compost + vermiwash application +bio-fertilizer application +*in situ* green manuring, T_3: 100% of N through organic recycling with vermi-compost +vermiwash application +bio-fertilizer application +*in situ* green manuring and green leaf manuring (glyricidia leaves) +composted coir pith, husk incorporation and mulching with coconut leaves and T_4: control: mono-crop of coconut with recommended NPK and organic manure were imposed. The component crops were nutmeg, cinnamon, banana and pineapple. Annual leaf production did not significantly differ among the treatments, however, integrated treatments resulted in higher number of leaves (30.46 Nos.). Five years pooled data on nut yield indicated that application of organic manures in combination with inorganic fertilizer either in 50% of RDF+50% of N through organic recycling with vermi-compost +vermiwash application +bio-fertilizer application +*in situ* green manuring (141.28 nuts/palm/year) or 75% of recommended NPK +25% of N through organic recycling with vermi-compost (126.33 nuts/palm/year) resulted the higher nut yield. There was improvement in the nutrient status of coconut leaves with integrated nutrient management practices compared to inorganic or organic manure alone application. The highest benefit: cost ratio (3.03) was recorded in T_2 followed by T_1 (2.81) as compared to the other treatments.

Key words: *Coconut, INM, organic recycling, nutrient status, nut yield, microbial population*

INTRODUCTION

Coconut (*Cocus nucifera*) is widely grown in coastal sandy soils, which occur in Peninsular India. However, its productivity is very low in coastal sandy soils due to an array of factors like poor water holding capacity, excessive infiltration, rapid leaching loss of nutrients resulting in low nutrient retentive capacity and low availability of major and micro nutrients, small specific surface area on account of low clay and organic matter content, low CEC and low organic carbon content (Ollangnier and Ochs, 1978). Moreover, the sole crop of coconut planted at a wider spacing of 7.5 m x 7.5 m is not able to fully utilize the available basic resources of crop production, *viz*. soil, solar energy, water and nutrients. The soil resource base of the coastal sandy coconut zone is poor, which needs to be upgraded to ensure timely and adequate availability of nutrients especially when multi-storeyed cropping system is adopted for various reasons. There is a need to consider the system as a unit especially with respect to supply of inputs like organic manures, fertilizers, herbicides, water and plant protection chemicals (Nampoothiri, 2001). Generally, lesser quantities of inputs are sufficient in cropping systems compared to sole cropping. The fertilizer doze for coconut is 2.25:3.0:2.0 kg urea, single super phosphate and muriate of potash per palm per year and continuous application of large quantities of fertilizers over a considerable period of time will definitely affect the physico-chemical and biological properties of soils, turning the system unsustainable in all aspects. Sustainability can be built in the system by introducing compatible crops as component crops and promoting positive interferences by judicious application of inputs especially fertilizers. In this context, an investigation entitled "Studies on the effect of organic and inorganic fertilizers on yield of coconut orchard in coastal ecosystem of Maharashtra State" was carried out to develop appropriate cost effective practices for enhancing nutrient use efficiency, productivity and profitability of coconut based integrated nutrient management systems involving a combination of coconut, nutmeg, cinnamon, banana and pineapple in a typical coastal sandy zone.

MATERIALS AND METHOD

The field experiment in coconut based integrated nutrient management system was initiated at Regional Coconut Research Station, Bhatye, Ratnagiri, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (M.S) during the year 2013-14 to 2017-18. The soil of the experimental plot was sandy loam in texture, well drained with medium fertility status. The experiment was laid out in 30-year-old coconut (cv. D x T – COD x WCT) garden (0.40 ha area) which was planted at a distance of 7.5 m × 7.5 m in a square system. Each treatments consisted of 4 palms/plot (225 sq. meters), replicated 5 times in randomized block design. The treatments T_1: 75 % of recommended NPK +25 % of N through organic recycling with vermicompost, T_2: 50% of RDF+50% of N through organic recycling with vermicompost +vermiwash application +bio-fertilizer application +*in situ* green manuring, T_3: fully organic: 100% of N through organic recycling with vermicompost +vermiwash application +bio-fertilizer application +*in situ* green manuring and green leaf manuring (glyricidia leaves) +composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves and T_4: control: mono-crop of coconut with recommended NPK and organic manure were imposed on 70 coconut palms/acre along with component crops like nutmeg (Konkan Swad-54 plants/acre), cinnamon (Konkan Tej-246 plants/acre), banana (Konkan SafedVelchi-246 plants/acre) and pineapple (Kew-4320 plants/acre) as a farming model. The quantity of NPK and vermicompost applied under different treatments has been described by Maheswarappa *et al.* (2011). As per the treatments, vermicompost was applied during September–October and inorganic fertilizers in the form of urea, SSP and muriate of potash were applied in 2 equal splits during June-July and September–October. Vermicompost was obtained by decomposing coconut leaves as per the procedure explained by Prabhu *et al.* (1998). The biomass was recycled back into the system after making vermicompost and recommended dose of fertilizer was applied both for coconut and component crops as per treatment details and farm waste utilization was done effectively to meet nutrient requirement. Vermicompost was prepared and applied to meet the requirement of nutrients. Vermiwash collected was drenched in the basin of each crop by diluting it in the ratio of 1:10 with water and applied twice in the year for coconut @ 5 lits/basin, nutmeg @ 3 lits/tree, banana @ 2 lits/plant, pineapple 4 lits in a bed of 40 plants and cinnamon @ 2 lits/plant. In addition to this, glyricidia plants were grown as green manuring crop at border of the plot and green leaf manuring was done for coconut and intercrops in the month of June. Coconut palms were irrigated with drip system, while, the sprinkler irrigation was followed for irrigating different crops in the system. During December to January, 27 litres water and 32 litres water during February to May per palm/day was applied. Husk burial was followed before planting perennial crops and husk burial in the trenches was followed in each set of four coconut palms (once in 3 year). Dried coconut leaves were used for mulching in summer months (February-May) in order to reduce the evaporation of moisture from soil. Observations including annual leaf production, numbers of spadices, buttons, nuts yield, copra and oil yield were recorded. The growth and yield characters of component crops were also recorded and economics of coconut based INM system was worked out.

RESULTS AND DISCUSSION

Number of leaves on crown

The pooled data regarding to the number of functional leaves on crown shown (Table 1) that the highest number of functional leaves (30.46 Nos.) were in the treatment T_2, whereas, lowest (29.22 Nos.) in the treatment T_4. Nath *et al.* (2012) reported increase in number of leaves due to integrated nutrient management in coconut. The results are in tune with the observations of Maheswarappa *et al.* (2014) wherein, application of different sources of organics and inorganics did not reduce or increase the number of leaves on crown. The number of leaves present on the crown also did not differ among the treatments. Being a perennial crop, effect of different treatments might not have any influenced on the growth and development of the palms.

Rate of leaf production

Number of leaves produced per palm per year did not significantly differ among the treatments (Table 1). However, it was found from pooled data that the leaf production was higher (11.87 Nos.) in the integrated nutrient management treatments T_2 compared to other treatments. Nath *et al.* (2012) reported increase in leaf production owing to integrated nutrient management in coconut. Being a perennial crop, effect of different treatments might not have significantly influenced growth and development of the palms.

Number of spadices

Number of spadices produced per palm per year did not significantly differ among the treatments (Table 2). However, it was found from pooled data that the spadices production were higher (11.52 Nos.) in the integrated nutrient management treatments T_2 followed by treatment T_1 (11.38 Nos.) and T_3 (11.36 Nos.), whereas, lower mean of spadices production were in treatment T_4 (11.31 Nos.). Kalpana *et al.* (2008) reported increase in spadices production owing to integrated nutrient management in coconut and recorded maximum mean spadices per palm per year in the application

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Table 1: Effect of organic and inorganic fertilizers on growth characters of coconut

Treatment	Number of leaves on crown (Nos./palm)						Rate of leaf production (Nos./palm/year)					
	2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**Pooled**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**Pooled**
T_1	30.00	30.05	30.80	29.60	29.62	30.07	11.65	11.37	11.55	11.60	11.53	11.57
T_2	31.38	30.98	31.43	28.78	29.27	30.46	12.00	11.77	11.95	11.87	11.97	11.87
T_3	30.22	29.00	30.35	28.53	28.83	29.57	11.65	11.42	11.85	11.77	11.80	11.73
T_4	29.48	28.95	29.92	28.45	28.65	29.20	11.58	11.40	12.05	11.75	11.90	11.69
S.Em.±	**0.34**	**0.25**	**0.24**	**0.53**	**0.50**	**0.15**	**0.19**	**0.13**	**0.18**	**0.20**	**0.18**	**0.05**
C.D.@5%	**1.03**	**0.76**	**0.75**	**NS**	**NS**	**0.45**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.14**

Table 2: Effect of organic and inorganic fertilizers on yield and yield attributing characters of coconut

Treatment	Number of spadices (Nos./palm)						Number of buttons (Nos./palm)						Nut yield (Nos./palm)					
	2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**Pooled**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**Pooled**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**Pooled**
T_1	11.50	10.98	11.45	11.60	11.53	11.38	315.55	311.57	319.95	324.90	325.97	321.45	120.43	146.92	123.80	148.60	130.08	126.33
T_2	11.95	11.35	11.62	11.87	11.97	11.52	323.97	330.42	335.22	332.17	331.75	327.44	126.03	178.25	129.75	154.58	143.30	141.28
T_3	11.28	11.07	11.57	11.72	11.80	11.36	314.53	306.17	325.47	323.00	329.00	320.43	102.40	125.40	113.87	134.33	119.12	120.01
T_4	11.20	10.75	11.68	11.80	11.80	11.31	308.67	302.00	311.67	328.40	328.40	314.76	98.60	87.45	110.50	122.75	113.48	112.62
S.Em.±	**0.20**	**0.19**	**0.14**	**0.21**	**0.18**	**0.10**	**5.90**	**3.82**	**4.77**	**3.14**	**2.85**	**2.92**	**6.25**	**8.03**	**9.79**	**11.05**	**6.25**	**6.42**
C.D.@5%	**NS**	**NS**	**NS**	**NS**	**NS**	**0.29**	**NS**	**11.78**	**14.69**	**NS**	**NS**	**8.81**	**19.25**	**24.75**	**NS**	**NS**	**19.27**	**19.35**

of 100% CCP and 50% CCP + 50% RDF.

Number of buttons

Number of buttons produced per palm per year did significantly differ among the treatments (Table 2). However, it was found from pooled data that the buttons production was higher (327.44 Nos.) in the integrated nutrient management treatments T_2 followed by treatment T_1 and T_3, whereas, lowest mean of buttons production was in the treatment T_4. Kalpana *et al.* (2008) reported increase in buttons production due to integrated nutrient management in coconut and recorded maximum mean of female flowers per palm per year in the application of 100% CCP and 50% CCP + 50% RDF and Nath *et al.* (2012) reported increase in buttons production owing to integrated nutrient management in coconut.

Coconut nut yield

The coconut nut yield recorded among the treatments over the years and the pooled data are presented in Table 2. In general, there was an increase in the yield of coconut and the yield obtained in different treatments was higher over the years than the pre-treatment yields, which was mainly owing to the effect of treatments and irrigation provided to coconut palms. During 2014-2017, application of 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) recorded higher nut yield and was at par with 75% of recommended NPK + 25% of N through organic recycling with vermicompost (T_1) treatment, which significantly differed with the other treatments. The yield obtained under 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment was 141.28 nuts/palm/year, while that of the yield obtained under 75% of recommended NPK + 25% of N through organic recycling with vermicompost (T_1) treatment was recorded 126.33 nuts/palm/year. The pooled data on nut yield for 5 years (2013-14 to 2017-18) indicated significant differences among the treatments (Table 2). Application of 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment recorded higher nut yield and differed with the other treatments. Increase in yield under these treatments might be owing to better availability of required nutrients, which resulted in improvement in yield. Srinivasa Reddy and Upadhyay (2002), Talashilkar *et al.* (2008) and Nath *et al.* (2012) also reported increase in yield of coconut with the application of inorganic fertilizer (50%) and 50% through vermicompost and the positive effect of integration of organic and inorganic fertilizer combination on coconut yield in different soil types. Nut yield recorded under T_1, T_2 and T_3 treatments were at par with each other and ranged from 120.01 to 141.28 nuts/palm/year. An increase in annual productivity in coconut by following mix cropping has been reported by Nelliat *et al.*, 1974. Additional increased in yield of coconut with farming system component could be due to synergistic effect of crop combination and nutrient status maintained in the system. Application of vermicompost alone could not result in

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increase in yield of coconut, as it could not provide the required P and K and application of inorganic fertilizer alone could not provide the suitable soil environment for the growth and development of coconut.

Copra and oil yield

The coconut copra and oil yield recorded among the treatments over the years and the pooled data are presented in Table 3. In general, there was an increase in the copra and oil yield of coconut and the yield obtained in different treatments was higher over the years than the pre-treatment yields, which was mainly owing to the effect of treatments and irrigation provided to coconut palms. During 2014-2017, application of 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment recorded higher copra and oil yield and was at par with 75% of recommended NPK + 25% of N through organic recycling with vermicompost (T_1) treatment and was different compared to the other treatments. The pooled data on copra and oil yield obtained under 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment and 75% of recommended NPK + 25% of N through organic recycling with vermicompost (T_1) treatment and 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment was at par and ranged from 21.48 to 23.18 kg/palm/year and 14.60 to 15.75 kg/palm/year, respectively. The oil yield (tonnes/ha) obtained under 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) treatment and 75% of recommended NPK + 25% of N through organic recycling with vermicompost (T_1) treatment was at par and ranged from 2.79 to 2.80 tonnes/hectare. Increase in copra and oil yield under these treatments might be owing to better availability of required nutrients, which resulted in improvement in yield. Application of any single manure could not result in increase in copra and oil yield of coconut, as it could not provide the required P and K and application of inorganic fertilizer alone could not provide the suitable soil environment for the growth and development of coconut. Results analogous to these finding were also reported by Kalpana *et al.* (2008) in the coconut based INM system on nut yield and quality of coconut under coastal ecosystem.

Growth and yield of components crops

The growth of component crops as influenced by coconut based INM system in coconut is presented in Table 4. It was observed from pooled data that the height of nutmeg plants increased after the 4th year of treatment initiation and the maximum height of nutmeg plants was 157 cm in T_3, whereas, the minimum was in treatment T_2 (94 cm). The maximum number of nutmeg branches was in treatment T_3

Table 3: Effect of organic and inorganic fertilizers on copra and oil yield of coconut

Treatment	Copra yield kg/palm						Oil yield kg/palm						Oil yield tonnes/ha					
	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
T_1	20.47	24.98	21.05	25.26	22.11	21.48	13.92	16.98	14.31	17.17	15.03	14.60	2.44	2.97	2.50	3.00	2.63	2.79
T_2	21.43	30.30	22.06	26.28	20.25	23.18	14.57	20.61	14.99	17.86	13.77	15.75	2.55	3.61	2.62	3.12	2.40	2.80
T_3	17.41	21.32	19.36	25.28	19.29	20.60	11.84	14.50	13.16	15.53	13.12	13.73	2.07	2.54	2.30	2.71	2.29	2.40
T_4	16.76	14.87	18.79	20.87	24.36	19.99	11.40	10.11	12.77	14.19	16.56	13.59	1.99	1.77	2.23	2.48	2.89	2.38
S.Em.±	**1.06**	**1.37**	**1.66**	**2.27**	**1.06**	**1.27**	**0.72**	**0.93**	**1.13**	**1.28**	**0.72**	**0.85**	**0.13**	**0.16**	**0.20**	**0.22**	**0.13**	**0.20**
C.D.@5%	**3.27**	**4.21**	**NS**	**NS**	**3.28**	**3.84**	**2.22**	**2.86**	**NS**	**NS**	**2.23**	**2.58**	**0.39**	**0.50**	**NS**	**NS**	**0.39**	**0.61**

Table 4: Effect of organic and inorganic fertilizers on growth characters of component crops as an intercrops in coconut orchard

Treatment	Height of nutmeg plant (cm)						No. of branches in nutmeg (No.)						Height of cinnamon plant (cm)						No. of branches in cinnamon (No.)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
T_1	76.4	84.4	92.8	120	264	112.8	3.4	5.8	7.6	8.2	18.2	7.6	178.8	189.5	231.5	399.0	305.5	226.5	10.6	12.3	11.7	2.7	1.8	7.4
T_2	84.0	95.0	107.4	102	152	94.0	5.0	7.4	8.4	7.4	6.0	6.1	197.7	206.5	261.5	415.5	354.5	253.1	13.2	15.2	8.8	2.3	1.9	8.6
T_3	118.2	150.4	163.4	226	178	157.9	7.6	11.8	12.8	12.2	3.4	9.3	213.6	219.7	316.0	373.0	400.5	268.3	20.9	21.2	7.6	1.8	1.6	10.5
T_4 (Mono)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.Em.±	**22.31**	**24.67**	**25.88**	**38.64**	**36.05**	**9.94**	**1.81**	**2.19**	**2.57**	**1.53**	**2.90**	**0.75**	**9.88**	**10.72**	**18.92**	**33.34**	**28.73**	**6.94**	**1.16**	**0.75**	**0.79**	**0.21**	**0.12**	**1.24**
C.D.@5%	**NS**	**NS**	**NS**	**NS**	**NS**	**28.28**	**NS**	**NS**	**NS**	**NS**	**9.46**	**2.13**	**NS**	**NS**	**61.71**	**NS**	**NS**	**19.74**	**3.77**	**2.46**	**2.56**	**0.69**	**NS**	**NS**

Table 5: Effect of organic and inorganic fertilizers on yield of component crops nutmeg and cinnamon as an intercrops in coconut orchard

Treatment	Yield of component crops/block																	
	Number of nuts in nutmeg (No.)						Cinnamon bark (kg)						Cinnamon leaves (kg)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
T_1	2.0	2.0	3.8	8.0	8.0	4.2	8.0	8.0	8.0	17.5	17.5	10.7	40	40	40	45	50	44.2
T_2	2.2	2.6	3.6	9.4	12.0	5.1	8.4	17.0	18.0	15.4	15.4	13.0	42	60	65	67	57	55.2
T_3	6.6	7.0	6.0	7.0	7.0	5.9	9.0	8.4	9.0	20.0	20.0	11.7	43	42	45	48	62	45.0
T_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.Em.±	**1.90**	**1.87**	**1.49**	**1.58**	**0.48**	**0.58**	**0.37**	**0.62**	**0.58**	**0.81**	**0.81**	**1.34**	**1.26**	**1.85**	**2.56**	**1.68**	**1.28**	**3.25**
C.D.@5%	**NS**	**NS**	**NS**	**NS**	**1.58**	**NS**	**NS**	**2.03**	**1.88**	**2.65**	**2.65**	**NS**	**NS**	**6.03**	**8.35**	**5.49**	**4.17**	**10.23**

Table 6: Effect of organic and inorganic fertilizers on yield of component crops pineapple and banana as an intercrops in coconut orchard

Treatment	Yield of component crops/block											
	Pineapple (kg)						Banana (kg)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
T_1	45	50	60	30	20	36.0	400	360	370	430	420	362.3
T_2	50	60	70	35	13	39.5	450	420	450	490	450	406.6
T_3	40	70	75	40	13	40.9	350	480	500	580	380	401.7
T_4	-	-	-	-	-	-	-	-	-	-	-	-
S.Em.±	**2.74**	**1.83**	**5.40**	**1.94**	**0.86**	**2.40**	**12.97**	**9.57**	**12.38**	**12.71**	**12.65**	**21.69**
C.D.@5%	**NS**	**5.95**	**NS**	**6.32**	**2.79**	**NS**	**42.31**	**31.22**	**40.38**	**41.47**	**41.25**	**NS**

Table 7: Economics (per ha.) of coconut based integrated nutrient management system

Treatment	Cost of production (Rs/ha)						Gross return (Rs/ha)						Net return (Rs/ha)						B:C ratio					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	41739	33734	33733	30450	30486	34028	784120	967800	1236750	1546836	665168	1040135	629860	815880	1084590	148743	512739	638362	1.9	2.1	2.8	2.9	4.4	2.81
T_2	30852	30384	30432	33756	33754	31836	830650	1281300	1712550	2479897	686783	1398236	621954	1112629	1543885	2311117	518012	1221519	2.1	2.9	3.0	3.1	4.1	3.03
T_3	30458	30424	29749	29770	29734	30027	781650	900450	1388100	1495072	611146	1035284	504746	748328	1239357	1346222	462476	860226	1.6	1.9	2.1	2.4	4.1	2.42
T_4	11400	11400	11400	11400	11400	11400	214200	189000	258300	311682	392280	273092	157200	132000	201300	254682	335280	216092	1.6	1.7	1.9	2.1	3.9	2.25

(9.30 Nos.), whereas, minimum in treatment T_2 (6.10 Nos.). The maximum height of cinnamon plants was (268.3 cm) in T_3, whereas, the minimum was in treatment T_1 (226.5 cm). The maximum number of cinnamon branches was in treatment T_3 (10.50 Nos.), whereas, minimum in treatment T_1 (7.44 Nos.). The pooled yield of component crops as influenced by coconut based integrated nutrient management system in coconut is presented in Table 5 and 6. The highest yield of component crops namely pineapple and banana were in the treatment T_2 (40.92 kg/block and 401.67 kg/block, respectively), whereas, highest yield of component crops nutmeg nuts in T_3, cinnamon bark and cinnamon leaves in T_2 (5.87 nuts/block, 13.03 kg/block and 55.17 kg/block, respectively). Similar results were also reported by Bavappa and Jacob (1982) in coconut farming system.

Economics

The economics of coconut based integrated nutrient management system was worked out and presented in Table 7. The economics of the integrated nutrient management system revealed that the highest benefit: cost ratio (3.03) was recorded with the application of 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring (T_2) followed by the application of 75% of recommended NPK + 25% of N through organic recycling with vermicompost (2.81 B:C) as compared to the other two treatments. The economic analysis of mixed farming system maintained at CPCRI, Kasargod for the period 1989-90 to 1997-98 realized net returns between Rs. 49700 and 1,26900 (Maheswarappa *et al.* 2000).

CONCLUSION

It can be concluded that, application of organic manures in combination with inorganic fertilizer either in 50% of RDF+ 50% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring or 75% of recommended NPK + 25% of N through organic recycling with vermicompost was found to be beneficial in respect of

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maintaining nutritional status of coconut and improving the soil microbial population and coconut yield over a period of time.

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Response of agnihotra ash on the growth of pathogenic microorganisms

RA Ram[1], Neelima Garg[2] and Priti[3]

ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, P.O. Kakori, Lucknow-226 101
[1]*Principal Scientist (e-mail: raram_cish@yahoo.co.in), Division of Crop Production,* [2]*Principal Scientist and Head, Division of Post Harvest Management (e-mail: neelimagargg@rediffmail.com),* [3]*SRF, ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow-226 101, India*

ABSTRACT

Ash-1 collected after performing agnihotra with same materials without chanting mantras and timing Ash-2 collected after performing the agnihotra at sun rise and sun set with proper procedure. Different beneficial soil bacteria and yeast *viz., Bacillus sp., Klebsiella sp., Pseudomonas sp., Saccharomyces cerevisiae* (Baker's yeast), *Saccharomyces cerevisiae* (industrial yeast), *Saccharomyces cerevisiae* were inoculated in Nutrient Agar and Yeast extract Peptone Dextrose Agar medium containing Ash-1 and Ash-2. Growth of these microbes was recorded more in media containing Ash-2 and less in media having Ash-1. Growth of pathogens was restricted in Ash-2, while it was more in Ash-1.

Key words: Agnihotra ash, brown rice, cowdung patties, *Aspergillus fumigatus* and baker's yeast.

Environmental pollution has acquired global dimensions. Each component of the ecosystem of space and surrounding flora and fauna has been affected adversely in recent decades. Unthoughtful exploitation of natural resources, enormous increase in automobiles causing gaseous and noise pollution, rampant deforestation, killing animals, perforation in ozone layer allowing radiation, pollution in atmosphere are the chief sources of environmental degradation. Agnihotra, as a basic tool, has wide beneficial effect on soil, water resources and the atmosphere. In fact, Agnihotra is a gift to humanity from ancient most Vedic Sciences of bio-energy and climate engineering. It is the basic fire in *Homa*. Basically it is science of pyramidology, biorhythm of nature, burning of organic substances, sonic power of chanting special mantras and its electromagnetic effects, which is extended to a larger area by establishing resonance points. Agnihotra is also a process of fumigation which affects the intensity of pathogenic organisms in air, soil and water (Kartz, 2007). Agnihotra atmosphere results in better absorption of sun's rays by the water resources on Earth. Thus the energy cycle of planet is kept in rhythm (Berk and Jonson, 2009). No scientific study has been done to know the Agnihotra ash effect on beneficial and pathogenic microbes. Therefore, an experiment was planned to study the response of Agnihotra ash on the growth of some selected pathogen under laboratory conditions.

MATERIAL AND METHODS

Pyramid

Copper acts as a good energy conductor and it has anti-microbial properties (Abhang and Pathade, 2017). Copper pyramid of a specific size and shape is required for performing Agnihotra. The inverted pyramid shape of the *Agni kunda* allows controlled generation and multidimensional dissipation of energy (Joshi, 2009; Narang, 2009). This shape is said to generate and store special energy field, which possesses bacteriostatic properties and allows controlled generation and multi-dimensional dissipation of energy (Abhang and Pathade, 2017).

Cow ghee

Ghee (clarified butter) is potent source of energy. It contains glycerol, saturated and unsaturated fatty acids, acetone bodies, pyruvic aldehyde and glyoxol, methyl and ethyl alcohol, acetaldehyde, formic acid and acetic acid. Ghee contains medicinal substance and acts as carrier of subtle energies. Homemade ghee prepared from cow milk is well accepted for Agnihotra. Ghee is powerful vehicle for energies which sustains life. Energies generated from the Sun are captured through ghee which nourishes and strengthen every living being in the nearby area through its fragrance (Paranjape, 1989).

Dried cow dung patties

Cow dung is treated as medicine in all ancient cultures, whether they are Indians of North or South America, Scandinavians, East or West Europeans, Africans and Asians. It contains more than 60 species of bacteria and 100 species of protozoa encountered in rumen of cow and also contains plenty of menthol, ammonia, phenol and formalin. Especially, its bacteriophages are known to eradicate pathogens. Thin patties (strips) were prepared and dried in the Sun in such a way that patties should not contain any dust or grasses.

Brown rice

Polished rice looses nutritional value and gets brocken during processing and hence brown and unbroken grains were used for *Agnihotra*.

Agnihotra timings

Time component of *Agnihotra* is one of the most essential aspects. *Agnihotra* is performed exactly at sunrise and sunset of the place. Light radiated by Sun at sunrise and sunset is termed as diffused light, which has great ecological significance. Since Sun at the rise or set comes nearer to horizon in transverse/oblique position, solar rays have to cover a longer distance to reach to the Earth and in this course, solar rays (electromagnetic waves) of visible spectrum of lower wave lengths, *i.e.* violet, indigo, and blue and probably ultraviolet, X-rays and Y-rays are scattered and lost in the atmosphere. The other visible rays of higher wave lengths, *i.e.* yellow, orange, red and infra red of invisible spectrum reach to the earth and the sky looks yellowish red at the time of sunrise and sunset (Berk and Jonson, 2009). One can say that solar ray reaching to the Earth at both times contains greater proportion of infra red, which is lethal but more penetrating and greater energetic in nature.

Procedure for preparation of *Agnihotra* fire

Flat piece of dried cow dung was placed at the bottom of the copper pyramid. Pieces of dried cow dung were arranged, which were coated with ghee, in the pyramid in such a manner that it allowed air to pass. Little ghee on the small piece of cow dung was applied and ignited. Lighted piece of cow dung patty was inserted in center of the pyramid and all the dung in the pyramid caught fire.

Agnihotra process

Few grains of rice were taken on the left palm and few drops of ghee were applied. Exactly at sunrise mantra was uttered and after the word *SWAHA* a few grains of rice with right hand (as little as one can hold in the pinch of fingers will be sufficient) was added in the fire. Second *Mantra* was uttered and after the word *SWAHA* few grains of rice from the right hand was added in the fire. At sunset same mantra was uttered by using evening *Mantras*. In this study, fire was lighten in two pyramids. In one pyramid *Agnihotra* was performed at sunrise and sunset with mantras but in second pyramid *Agnihotra* was performed without chanting *Mantras* and following sunrise and sunset timings (Pathak, 2010).

Mantras

Vibrations exist everywhere. *Mantras* are only vibrations when these are uttered. Vibration consist sound and when sound uttered for *Mantras*, vibration creates certain energy releasing effects in the atmosphere and in turn the desired results are realized. These vibrations exist for everything, so anything can be activated, controlled or changed by Mantras.

Agnihotra Mantras

At sunrise

Soory'aya Sw'ah'a, Soory'aya Idam Na Mama

Praj'apataye Sw'ah'a, *Praj'apataye Idam Na Mama*

At Sunset

Agnaya Sw'ah'a, Agnaye Idam Na Mama

Praj'apataye Sw'ah'a, *Praj'apataye Idam Na Mama*

Collection of ash samples (Ash-1 and Ash -2)

Ash-1 - Ash collected after performing *Agnihotra* with same materials without chanting *Mantras* and timing

Ash-2 - Ash collected after performing the *Agnihotra* at sun rise and sun set following proper procedure

Preparation of Ash suspension (Ash-1 and Ash -2)

The experiment was conducted under aseptic conditions and one gram of both ash samples were transferred to nine ml sterile distilled water and diluted the sample up to 10^2 dilution by serial dilution methods and inoculated the sample on different media viz. Nutrient Agar (Himedia M561), Potato Dextrose Agar (Himedia M561), YPDA.

Micro flora of Ash samples

The pour plate method was used to study the microlfora of ash samples (Ash-1 and Ash -2) as per method of Garg *et al. (*2010). One ml of serially diluted (10^2) sample of ash was poured on different media plates (Nutrient Agar (Himedia M561) for bacteria, Potato Dextrose Agar (Himedia M561) for fungi and Yeast extract Peptone Dextrose Agar for yeast count. Thereafter, the microbial colonies was counted with the help of colony counter.

Application of ash on selected microbes

Antimicrobial activity of Ash sample (Ash-1 and Ash-2) was observed by plate assay method against fungus (*Colletotricum gloeosporioides, Aspergillus fumigatus* and *Fusarium solani),* yeast (S*accharomyces cerevisiae,* Baker's yeast and industrial yeast) and pathogenic bacteria (*Bacillus*

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pumillus, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*). The ash samples were pour plated individually on sterile petri dishes. Approximately, 5 mm agar plug of five days old cultures of fungal and bacterial pathogens and yeast was taken from the peripheral edge and each placed at the centre of the plates having ash samples with media and the culture plates were incubated at 30°C, along with a control plates of Ash-2 samples. After 3 days of growth the colony size was measured by Himedia colony size scale (Deka Boruah and Dileep Kumar, 2002).

RESULT AND DISCUSSION

Microbial load in Ash-1 and Ash-2 was observed and higher microbial population was counted in Ash-1 and it was recorded as $6x10^4$ CFU/g bacteria, $1x10^4$ CFU/g fungi and $1x10^3$ yeast, compared to $2x10^2$, nil and $2x10^2$, respectively in Ash-2 (Table 1). When different fungus pathogen, *i.e. Aspergillus fumigatus, Colletotrichum* and *Fusarium* were added in the Potato Dextrose Agar medium containing Ash-1 and Ash-2, no growth of these pathogen were recorded with media containing Ash-2, while colony size of 10 mm growth of *Aspergillus fumigatus*, 4 mm of *Colletotrichum* and 5 mm of *Fusarium* was recorded in media containing Ash-1 (Table 2). Nivedita, *et al.*, (2020) have observed that homa therapy effectively reduced the incidence of early blight disease of potato and tomato and bacterial blight disease of tomato in polyhouse. When different beneficial soil bacteria and yeast, *viz. Bacillus sp., Klebsiella sp., Pseudomonas sp., Saccharomyces cerevisiae* 1 (Baker's yeast), *Saccharomyces cerevisiae* 2 (industrial yeast), *Saccharomyces cerevisiae* 3 were inoculated in Nutrient Agar and Yeast extract Peptone Dextrose Agar medium containing Ash-1 and Ash-2. Growth of these microbes was recorded more in media containing Ash-2 and less in media containing Ash-1 (Table 3). Colony size of *Bacillus sp* recorded as 1 mm, *Pseudomonas sp* 2 mm, *Klebsiella sp* 2 mm, industrial yeast 10 mm and

Table 1: Microbial count of Ash-1 and Ash-2 in different media

Sample	N A	PDA	YPDA
Ash -2	2×10^2	-	2×10^2
Ash - 1	6×10^4	1×10^4	1×10^3

Table 2: Growth of different fungus pathogen in Ash-1 and Ash-2 containing media

Fungi	Control colony size (mm)	Ash -2 colony size (mm)	Ash -1 colony size (mm)
Aspergillus fumigatus	40	No growth	10
Colletotrichum	8	No growth	4
Fusarium	10	No growth	5

Table 3: Growth of different beneficial microbes in media containing Ash-1 and 2

Microorganisms	Colony size (mm)		
	Control	Ash -2	Ash -1
Bacillus pumillus	0.5	1	1
Pseudomonas aeruginosa	1	2	1
Klebsiella pneumoniae	0.5	2	1
Baker's yeast (*Saccharomyces cerevisiae* 1)	1	8	1
Industrial Yeast (*Saccharomyces cerevisiae* 2)	1	10	1
Saccharomyces cerevisiae 3	1	3	1

Saccharomyces cerevisiae 3 mm. While, colony growth of all microbes remained 1 mm in media containing Ash-1. Abhang, *et al.*, 2015 have also reported improved water quality and less pathogenic bacteria in *Agnihotra* atmosphere. This results match with principle of *Agnihotra* that population of beneficial flora and fauna improves in *Agnihotra* atmosphere and pathogen and harmful flora and fauna decreases (Pathak and Berk, 2014).

CONCLUSION

Agnihotra is an activity for reduction of pollution in the atmosphere through a specially prepared fire. This involves making fire with cow-dung cakes in a copper pyramid of fixed size and putting some grains of rice and ghee in the fire at sunrise and sunset with chanting of two simple mantras. It is said that ash received after proper *Agnihotra* is full of energy captured from healed atmosphere. It is used for seed storage, treatment of seed/plants, better establishment of the plant, encouraging plant vigour, management of pests and diseases. This experiment was conducted to see the effect of *Agnihotra* ash on the growth pattern of selected microorganisms. It was observed that *Agnihotra* ash possess anti-microbial activity against pathogen while bio-enhancing effect toward beneficial microorganisms.

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Decomposition analysis of cereals production in Nagpur division

S.B. Chavhan[1], *K.J. Patil[2] and B.N. Ganvir[3]

[1 and 3]*Department of Agricultural Economics and Statistics Section, College of Agriculture, Nagpur-440 001,*
[2]*Assistant professor, Department of Agril. Economics, Don Bosco College of Agriculture, Sulcorna, Quepem, Goa- 403 705*
**Correspondence email: kjpatil2525@gmail.com*

ABSTRACT

Agriculture is the most important sector of the Economy in India. Cereals, particularly, wheat and paddy are the mainstay for mitigating food grain requirement for the rising population. Consequently, efficient planning and development efforts are needed. The bottoms up approach *i.e.,* plan for the development of agriculture at desegregated level or at district and/or regional levels and thereafter, aggregate it at the macro or state/country level, has been found useful. Very few such studies have been undertaken at the district/regional levels. The information, particularly, for different districts of Nagpur division and the division as a whole was not available. Consequntly, the present study attempts to undertake a decomposition analysis of cereal production in different districts of Nagpur Division along with the entire division for two periods, *viz.,* Period-I: 1995-96 to 2004-2005; Period-II: 2005-06 to 2014-15; and Overall (Pooled) Period: 1995-96 to 2014-15. Compound growth rates (CGR) were worked out for area, production and yield for five districts, *viz.,* Wardha, Nagpur, Bhandara, Chanderpur and Gadchiroli and the overall Nagpur division. The highest significant CGR in yield of wheat was 4.17 per cent in Gadhchiroli district, while for the production, the CGR for wheat was 4.19 per cent for the Nagpur division as a whole during overall period. The docomposition analysis indicated area effect for increasing production of wheat was maximum, i.e. 596.45 in Gadchiroli district followed by 421.13 in Bhandara district. In all the districts, the decomposition analysis indicated that cubic models provided best fit for area, production and productivity of wheat and rice.

Key words: Decomposition analysis, Compound Growth Rate (CGR), Wheat, Rice

Agriculture is the most important sector in Indian economy. India is the world's second largest producer of rice, wheat and other cereals. Cereals are the basic ingredient and important source of calories in the diets of a vast majority of the Indian population. They provide perfect mix of vegetarian protein component of high biological value, when supplemented with pulses. Cereals are important alternative to vegetable for supplementing the diet of most food of the country. The huge demand for cereals in the global market is creating an excellent environment for the export of Indian cereal products.

The important cereals are wheat, paddy, sorghum, millet (Bajra), barley, maize, etc. According to the final estimate for the year 2011-12 by Ministry of Agriculture of India, the production of major cereals like rice, maize and bajra stood at 105, 21.76 and 10.28 million tones, respectively. India is the largest producer of cereal, as well as largest exporter of cereal products in the world. India's export of cereals stood at Rs. 58279.80 crore during the year 2014-15.

Nagpur division of Maharashtra is primarily an agrarian region. There is a need to formulate viable plans for agricultural development in the region. However, in Maharashtra, particularly the Nagpur division no such studies have been attempted so far. Keeping in view these aspects, the present study was based on decomposition analysis of cereals production in Nagpur division.

Methodology

The methodology may be divided under the following sub-heads.

1. Selection of area

The study was confined to five district of Nagpur division of Maharashtra state namely Nagpur, Bhandara, Gadchiroli, Chandrapur and Wardha district for the analytical purpose.

2. Selection of period

The data were collected for area, production and productivity of cereals grown in respective regions during the period from 1995-96 to 2014-15 (20 years). The entire study period was split into two sub-period and overall as follows.

Period I: 1995-96 to 2004-05

Period II: 2005-06 to 2014-15

Overall: 1995-96 to 2014-15

3. Source of data

The district-wise time series data on area, production and productivity was collected from Government publication *viz.* Agricultural Statistical Information, Maharashtra

4. Analytical tools

Growth rate analysis

The district-wise compound growth rates of area, production and productivity were estimated by using following exponential model.

$Y= ab^t$

$\text{Log } Y = \log a + t \log b$

$\text{CGR} = \{\text{Antilog} (\log b\text{-}1)\} \times 100$

Where,

CGR = Compound growth rate

t = time period in year

Y = Area/production/productivity

a & b = Regression parameters.

't' test was applied to test of significance of 'b'

Instability Analysis

To measure the instability in area, production and productivity, an index of instability was used as a measure of variability.

The coefficient of variation (CV) was calculated by using the formula.

$$\text{C.V. } (\%) = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

Decomposition Analysis

To measure the relative contribution of area, yield to the total output change for the major crops, Minhas (1964) decomposition analysis model as given below was used. Sharma (1977), redeveloped the model and several research workers used this model and studied growth performance of crop in the state. A_o, P_o and Y_o are area, production and productivity in base year and A_n, P_n and Y_n are values of the respective variable in n[th] year, respectively.

$P_o = A_o \times Y_o$ and

$P_n = A_n \times Y_n$ ---------------------- (1)

Where,

A_o and A_n represent the area and Y_o and Y_n represents the yield in the base year and n[th] year, respectively.

$P_n - P_o = \Delta P$

$A_n - A_o = \Delta A$

$Y_n - Y_o = \Delta Y$ ———————————— (2)

From equation (1) and (2) we can write

$P_o + \Delta P = (A_o + \Delta A)\ (Y_o + \Delta Y)$

Hence,

$$P = \frac{A_o \Delta Y}{\Delta P} \times 100 + \frac{Y_o \Delta A}{\Delta P} \times 100 + \frac{\Delta Y\, \Delta A}{\Delta P} \times 100$$

Production = Yield effect + area effect + interaction effect

Thus, the total change in production can be decomposed into area effect and the interaction effect due to change in yield and area.

RESULTS AND DISCUSSION

Growth Rate

In this study, the growth in area, production and productivity of cereals were estimated using compound growth rates as indicated in the methodology. The general growth performances of the crop in Nagpur division were examined by fitting exponential growth function with time normalization on area, production and productivity.

The Table 1, revealed that during period I, the compound growth rates of area were negative for all district and Nagpur division as whole except Wardha district. In period-II, the compound growth rate were positive for all district and Nagpur division as whole except Wardha district for productivity of wheat. The highest compound growth rate in productivity was estimated in Gadchiroli (4.17) followed by Chandrapur (3.31), Bhandara (3.26) and Nagpur (0.63) district, respectively.

The compound growth rate for production in Nagpur division as whole was estimated 4.19 per cent per annum in last 20 years. At the overall period, the compound growth rate were negative but non-significant in Wardha district in productivity of wheat crop. The compound growth rate in Nagpur division as whole for area, production and productivity were positive except area in period I, which was negative.

The growth performance of rice pertaining to two period and overall has been presented in the Table 2. It revealed that during period-I, the compound growth rate of productivity was negative in all district and Nagpur as whole except Wardha district. The compound growth rate

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Table 1: District wise compound growth rate for wheat

Particular		Wardha	Nagpur	Bhandara	Chandrapur	Gadchiroli	Nagpur division
Period I	Area	0.18	-7.26	-13.47	-2.51	-8.34	-5.60
	Production	3.63**	-4.73	-11.11	-3.07	-9.24	4.18**
	Yield	-5.89	2.73*	2.77*	-0.54	-0.98	1.51
Period II	Area	-1.70	6.47**	0.71	-4.03	-6.10	2.27*
	Production	-1.47	7.79**	4.01**	-0.81	-2.09	4.18**
	Yield	-1.36	0.63	3.26**	3.31**	4.17**	2.14
Overall Period	Area	1.26	3.33**	-3.53	-0.23	-3.10	1.35
	Production	4.09**	5.62**	-0.01	2.65	0.05	4.19**
	Yield	-0.26	2.30*	3.52**	2.91*	3.11*	0.12

Note: * *Significant at 1% level * Significant at 5% level

Table 2: District wise compound growth rate for Rice

Particular		Wardha	Nagpur	Bhandara	Chandrapur	Gadchiroli	Nagpur division
Period I	Area	23.16**	3.69**	-9.23	0.59	-0.16	-3.59
	Production	-19.01	2.47*	-12.09	-2.83	-7.80	-7.72
	Yield	1.69	-1.17	-3.15	-3.32	-7.67	-3.88
Period II	Area	-	6.79**	1.16	1.14	-0.16	1.66
	Production	-	8.58**	3.81**	-1.62	1.02	2.18
	Yield	-	-0.44	2.62*	-2.73	0.37	0.15
Overall Period	Area	-	5.25**	-2.56	0.29	0.32	-0.50
	Production	-	5.92**	-1.33	0.02	0.49	0.02
	Yield	-	0.67	1.26	-0.28	-0.01	-1.18

Note: ** Significant at 1% level, * Significant at 5% level

for area in period-II was found positive and significant in Nagpur district. The highest compound growth rate for area in period-I was registered in Wardha district, i.e. 23.16 per cent per annum followed by Nagpur (3.69) district, respectively. The highest compound growth rate for area in period II was registered in Nagpur district (6.79 per cent).

The compound growth rate for production in period-I were negative but non-significant in all district and Nagpur division as whole except Nagpur district. The compound growth rates of production in overall period were positive in Nagpur district. The highest (5.92) compound growth rate for production was found in Nagpur district in period-II.

Instability of crop

One should not judge the instability by observing the growth rates only. Because the growth rates will explain only the rate of growth over the period, whereas, instability judges, whether the growth performance is stable or unstable for the period for the pertinent variable. To facilitate better understanding of the magnitude and pattern of changes in the level of production, cropped area and productivity of crop in the different cereals growing region, instability of production, area and productivity of cereals crop have been worked out for the periods mentioned in methodology. In order to know the instability in area, production and yield of crop, the fluctuation was measured with the help of coefficient of variation. The results are presented in Table 3 and discussed as under for the period with ten years breakage and overall also. Fluctuation in area production and productivity due to the uncontrollable factors like climatic conditions can cause upward swings in coefficient of variation.

1. Wheat

As seen from Table 3, that coefficient of instability for area under wheat in Wardha district was found to be lowest, i.e., 10.17 per cent followed by Chandrapur (16.03), whereas, c.v. was high in, Bhandara (42.39) district followed by Nagpur (30.14) and Gadchiroli (29.10). The coefficient of instability for production of wheat was less in period-II as compare to period-I in all the districts. However, in overall period, the coefficient of instability for production under wheat was in between 28.94 to 37.16, except Nagpur (46.63) district.

Further instability in productivity in relation instability in area was contributed marginality toward production fluctuation. This instability of wheat in the zone was the effect of the instability experienced by wheat growers, probably due to the introduction of improved wheat technology in the farming system, where the local varieties were also under production.

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Table 3. District wise instability indices in Wheat

Particular		Wardha			Nagpur			Bhandara		
	Area	S.D.	Mean	C.V.	S.D.	Mean	C.V.	S.D.	Mean	C.V.
Period I	Production	19.3	187.2	10.17	133.24	442	30.14	65.92	155.5	42.39
	Yield	60.20	213.2	28.24	177.29	457.1	38.79	56.97	117.2	48.62
	Area	306.37	1120.7	21.34	249.6	1047.3	23.83	192.19	765.6	25.10
Period II	Production	46.49	230.4	20.18	158.71	688.1	23.07	20.16	112	18.01
	Yield	94.63	239.4	27.88	271.76	883.1	30.78	494.6	120.8	24.46
	Area	150.55	1457.1	10.33	204.94	1298.8	15.78	132.2	1067.8	12.38
Overall Period	Production	41.07	208.8	19.67	190.97	565.05	33.71	52.4	133.75	39.20
	Yield	100.74	276.3	36.46	312.46	670.1	46.63	44.21	119	37.16
		291.5	1288.9	22.62	257.01	1173.01	21.91	233.18	916.7	24.35

Particular		Chandrapur			Gadchiroli			Nagpur division		
	Area	S.D.	Mean	C.V.	S.D.	Mean	C.V.	S.D.	Mean	C.V.
Period I	Production	41.95	261.5	16.03	3.25	11.2	29.10	224.91	1057.4	21.27
	Yield	47.45	174.5	27.20	2.61	7.8	33.54	308.04	969.8	31.76
	Area	166.0	670	24.78	130.68	690.9	18.92	168.14	858.9	19.58
Period II	Production	51.34	283.9	18.09	3.06	9.6	31.90	181.2	1324	13.69
	Yield	64.19	261.1	24.59	2.20	9.2	23.92	370.4	1613.6	22.96
	Area	213.4	933.6	22.87	170.74	983.5	17.36	126.39	1148.16	11.01
Overall Period	Production	47.04	271.7	17.25	3.18	10.4	30.63	241.28	1190.7	20.26
	Yield	70.65	217.8	32.44	2.46	8.5	28.94	467.99	1291.7	36.23
		230.05	801.8	28.69	210.78	837.2	25.18	207.315	1003.53	20.66

CV = Coefficient of variation SD = Standard Deviation

Table 4. District wise instability indices in Rice

Particular		Wardha			Nagpur			Bhandara		
	Area	S.D.	Mean	C.V.	S.D.	Mean	C.V.	S.D.	Mean	C.V.
Period I	Production	3.977	6.6	60.27	56.96	381.5	14.93	855.01	2394.4	35.71
	Yield	4.92	5.4	91.22	110.83	446.4	24.83	1348.06	3074.7	43.84
	Area	1667.1	1303.7	127.88	222.73	1167.4	19.68	239.97	1256.4	19.10
Period II	Production	-	-	-	132.34	643.3	20.57	73.37	1838	3.99
	Yield	-	-	-	233.45	813.4	28.70	745.4	2815	26.48
	Area	-	-	-	220.99	1305.5	16.93	386.8	1526.4	25.35
Overall Period	Production	-	-	-	166.94	512.4	32.58	655.97	2116.2	31.00
	Yield	-	-	-	258.99	629.9	41.12	1068.5	2944.85	36.29
		-	-	-	227.27	1236.45	18.38	342.5	1331.4	24.62

Particular		Chandrapur			Gadchiroli			Nagpur division		
Period I	Area	S.D.	Mean	C.V.	S.D.	Mean	C.V.	S.D.	Mean	C.V.
	Production	46.50	1430.2	3.25	55.63	1443	3.86	789.70	5655.7	13.96
	Yield	417.23	1637.7	25.48	567.37	1724.4	32.90	2142.6	6888.6	31.10
Period II	Area	278.66	1145.9	24.32	369.7	1189.9	31.07	429.25	1212.66	35.40
	Production	189.92	1456.1	13.04	128.4	1494.5	8.60	368.78	5431.9	6.79
	Yield	605.60	1824.8	33.19	448.98	2010.6	22.32	1742.0	7463.8	23.34
Overall Period	Area	255.06	1241.1	24.32	288.20	1313	21.95	224.23	1077.2	20.82
	Production	135.23	1443.15	9.37	99.91	1468.75	6.80	610.74	5543.8	11.02
	Yield	515.17	1731.25	29.76	519.0	1867.5	27.80	1923.3	7176.2	26.80
		314.46	1993.5	26.34	328.78	1251.45	26.27	340.4	1144.93	29.74

CV = Coefficient of variation SD = Standard Deviation

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Table 5. Per cent contribution of area, yield and their interaction for increasing production of wheat

Particular		Wardha	Nagpur	Bhandara	Chandrapur	Gadchiroli	Nagpur division
Period I	Area effect	22.86	157.27	113.53	82.11	96.72	142.32
	Yield effect	72.60	-91.88	-33.10	20.53	5.77	-59.96
	Interaction effect	4.54	36.61	19.57	-2.64	-2.49	17.64
Period II	Area effect	78.13	96.16	-47.47	299.97	226.10	38.40
	Yield effect	24.95	2.73	157.55	-275.86	-206.35	56.77
	Interaction effect	-3.08	1.11	-10.08	75.89	80.25	4.83
Overall Period	Area effect	30.73	46.61	421.13	-21.57	596.45	19.65
	Yield effect	55.62	36.70	-593.43	133.20	-831.55	70.65
	Interaction effect	13.65	16.69	272.15	-11.63	335.10	9.70

Table 6. Per cent contribution of area, yield and their interaction for increasing production of Rice

Particular		Wardha	Nagpur	Bhandara	Chandrapur	Gadchiroli	Nagpur division
Period I	Area effect	95.74	119.50	84.76	-22.57	3.10	56.10
	Yield effect	14.92	-15.18	27.82	118.28	98.24	55.14
	Interaction effect	-10.65	-4.32	-12.58	4.29	-1.33	-11.23
Period II	Area effect	-	127.24	45.11	-63.58	979.29	201.58
	Yield effect	-	-17.33	51.11	151.92	-842.12	-91.38
	Interaction effect	-	-9.91	3.78	11.66	-37.17	-10.20
Overall Period	Area effect	-	85.70	169.78	66.88	223.28	37.15
	Yield effect	-	6.50	-117.51	31.12	-113.89	70.46
	Interaction effect	-	7.80	47.73	2.00	-9.38	-7.61

2. Rice

The Table 4 indicated that coefficient of instability for area under rice in Chandrapur district was the lowest (3.25) followed by Gadchiroli (3.86), Nagpur (14.93), Bhandara (35.71) districts, respectively. The coefficient of instability for productivity of rice in Wardha district was found highest, i.e., 127.8 per cent followed by Gadchiroli (31.07%), Chandrapur (24.32%), Nagpur (19.68%) and Bhandara district (19.10%), respectively. The coefficient of instability of Nagpur division as whole, in period-I was the highest as compare to the period-II and overall period for variable area, production and productivity. The coefficient of instability for production under rice in period-I was between 24.83 to 43.84 per cent except Wardha (91.22%) district.

The Nagpur division had shown the highest yield instability than area instability and likewise they contribute toward production fluctuation.

Decomposition analysis

A quantitative assessment of contribution of the various factors to production in the districts of Nagpur division is helpful in reorienting the programmes and setting priorities of agricultural development so as to achieve higher growth rates of agricultural production. There are many factors which affect the growth of crop output. These factors are believed to affect the production of crop *viz.*, area, yield and their interaction have been considered in the present study. The result of decomposition scheme was worked for two equally divided sub period and overall period as pooled 20 years data. The Table 5 demonstrates the contribution of area, yield and their interaction for increasing/decreasing of production in Nagpur division over period of time.

The above data showed that during period-I, in Wardha district yield effect was 72.60 per cent per annum and interaction effect 4.54 per cent per annum. Chandrapur and Gadchiroli district, the yield effect was -275.86 and -206.35 per cent per annum, respectively. In overall period Gadchiroli showed the highest area effect 596.45 as compare to period-I. The Bhandara district showed the highest yield effect of 157.55.

Table 6 showed that in period-I, the Gadchiroli district had the highest area effect i.e. 979.29. Chandrapur district show the highest yield effect, i.e., 151.92 in period-II where, as; Nagpur division as whole the period-I showed the highest area effect i.e. 201.58.

CONCLUSIONS

Compound growth rates of production of wheat was 4.18 per cent in Nagpur division. The area, production and productivity instability in cereals was observed in almost all districts in the Nagpur division. It may be because the crop largely depends on vagaries of nature, which cause heavy losses. Percent contribution of yield effect was more responsible for production of the selected cereals. Maximum instability was found in the overall period for selected cereals crops. The compound growth rate of wheat production in period-I and period-II was same in Nagpur division as whole. The highest coefficient of variance for area and production was found in Bhandara district, i.e., 42.39 per cent per annum and 48.62 per cent per annum, respectively during period-I. The Chandrapur district recorded the lowest instability (3.25 per cent) for area under rice in period-I. During period-I the highest (36.61) interaction effect was found in Nagpur district, followed by Bhandara (19.57). In overall period, the area effect was positive in all district except Bhandara district and Nagpur division as whole. In all districts the area, production and productivity for wheat and rice, the cubic models were the best fit.

IMPLICATIONS

Provision of subsides, various facilities to the farmer on crops like wheat and rice is necessary along with Social awareness programmes by extension expert to meet the demand of cereals. Also allow the mill and other industrial corporate in input growing area to avoid loss of products. In addition, the technology so far generated by the State Government Institution and other agencies be transferred to the farmer by state extension agencies.

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Use of agricultural information by fertilizer and pesticide dealers in relation to their socio-economic parameters: a study in Coochbehar District

Ganesh Das, Suraj Sarkar, Sujan Biswas, Dipak Kumar Sinha and Sankar Saha

Coochbehar Krishi Vigyan Kendra, Uttar Benga Krishi Viswavidyalaya, Pundibari, Coochbehar, (W.B.), India
Email: ganesh.ext@gmail.com

ABSTRACT

The source of agriculture information is a crucial point for farmers. They are getting agriculture information from variety of sources. Among these sources fertilizer and pesticide dealers play an important role in dissemination of information about agriculture practices to the farmers. They are in close contact with farmers. Dealers also diagnose the plants, pests and diseases and suggest some pesticide. But the questions arise as from which sources they gather these informations and disseminate it to the farmers. On the basis of above statement Coochbehar Krishi Vigyan Kendra organized an awareness programme of fertilizer and pesticide dealers of Coochbehar district in eastern zone of India to know the uses of information about agricultural practices with respect to their socio-economic variables. The study was conducted during February, 2016. Survey method was used to get responses of participants. Trainees available at the time of awareness programme were considered as respondents. Semi-structure interview schedule was used for collection of data. The sample size for the study was 50. The dependent variable of this study was source of information and independent variables were age, occupation, education, land holding, religion, family members and number of years associated with their occupation. The descriptive statistics like frequency, percentage and other statistical tools were used for the analysis of data.

Key words : *Agricultural information, communication, awareness, socio-economic parameters*

Agriculture is one of the most prominent sectors in Indian economy. The rapid progress in modern information and communication technology is seen as one of the potential tools in furthering development communication strategies. The creation and passing of information between farmers and extension agents, farmers and researchers, and researchers and extension agencies, among others, is critical to innovation and increased productivity through adoption of better farming practices and technologies.

Today computer, internet and mobile are turning out to be extremely important. Information and communication technologies (ICTs) are facilitating fast sharing of information and innovations and acting as a key agent for changing agrarian situation and farmers' lives by improving access to agricultural information (Parganiha *et al.,* 2012). Plsek (2003) reported that perceived complexity can be reduced by practical experience and demonstration. Adler *et al.* (2003) concluded that if the knowledge required for the innovation's use can be codified and transferred from one context to another, it will be adopted more easily. Mittal *et al.*, (2010) found from their study that producers serving local markets are reliant on information delivered informally through local networks of communicaiton, where trust and risk reduction are major factors that govern their dependence on those networks.

Glover (2007) studied farmers' participation in agriculture extension services and reviewed the Training and Visit (T&V) approach and compared the participation and accountability of farmers between public and private sectors. The private sector was more effective in benefitting farmers as compared to public sector.

The effect of family size and composition on agricultural technology adoption is not clear in adoption literature as both positive and negative relationships have been reported (Oluoch-Kosura *et al.*, 2001).

Fertilizer and pesticide dealers play an important role in information dissemination about agriculture practices to the farmers. They remain in close contact with farmers. Farmers get many advices from fertilizer and pesticide dealers. They act as key extension person in a village for suggesting plant protection, fertilizer dose and other practices in agriculture. But the problem is that whether they give right information or not? If they give right information to farmers, then from which sources they got information and disseminate them to farmers? A one day awareness programme on fertilizer and pesticide dealers of Coochbeahr district in estern zone of India was organized to know the sources of information about agriculture practices in relation to their socio-economic variables. The purpose of this study was to identify the sources of agricultural information utilized by fertilizer and pesticide dealers and its distribution among different independent variable selected for the study.

MATERIALS AND METHODS

The study was conducted on the respondent of Coochbehar district, West Bengal, who participated in awareness programme on use of agriculture information of input dealer by Coochbehar Krishi Vigyan Kendra during February, 2016. A pre-tested semi-structure interview schedule was used for collection of data. Survey method was used at the time of investigation. All the trainees available at the time of awareness programme were considered as respondents. The sample size was 50. The variables were selected based on recommendations of the scientists of Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal. The dependent variable of this study was use of information and independent variables were age, occupation, education, land holding, religion, family members and number of years associated with their occupation. The descriptive statistics like frequency, percentage, range and other statistical tools were used for the data analysis.

RESULT AND DISCUSSION

It was observed from the study that the major percentage of the respondent's educational level at the time of survey was high school pass (60%) followed by graduate and above (40%). The study revealed that educated respondents were doing fertilizer and pesticide business. It was noted from the study that majority of respondent's occupation was business (74%) followed by business and farming both (26%). The data collected during the investigation showed that majority of the respondent's (40%) land holding size as more than 10 acre followed by 5 to 10 acre (32%) holding. It indicated that most of the respondent's land holding size was large. The survey showed that majority of respondent's (56%) were in age group of 30 to 50 years. The majority of respondent's religion was Hindu (68%) followed by Muslim (32%). It was revealed from the study that fertilizer and pesticide business in the District was owned by Hindus. Large proportion of the respondent family size was less than 5 (76%). The majority of respondents (40%) were associated with their major occupation for 6 to 10 years followed by more than 20 years (28%). It showed that majority of respondents had good experience in their occupation. The survey also showed that majority of respondents used ADA office (90%) as source of agriculture information, followed by private fertilizer and pespticide company's representatives (80%). The findings are in confirmation with the results reported by (DAC 2014 and Glover, 2007). The study revealed that ADA and private fertilizer and pesiticide company representative were playing major role in agriculture information dissemination to fertilizer and pesticide dealers. It was also interesting to note

Table 1: Variables and their measurement

Variable	Measurement
Dependent variable	
Information	Schedule developed for the study
Independent variable	
Age	Chronological age of the respondents in completed years
Occupation	Schedule developed for the study
Family member	Schedule developed for the study
Education level	Procedure used by Sivamurthy (1994)
Land holding	Schedule developed for the study
Religion	Schedule developed for the study
Numbers of year associated with their occupation	Schedule developed for the study

Table 2: Classification of the respondents with different independent variable

Category	Frequency	Percentage
Educational level		
Illiterate	-	-
Can read only	-	-
Can read and write only	-	-
Primary school	-	-
Middle school	-	-
High school	30	60
Pre-university	-	-
Graduate and above	20	40
Occupation		
Business	37	74
Business and Farming	13	26
Land holding (acre)		
Less than 2	4	8
2-5	10	20
5-10	16	32
More 10	20	40
Age		
Less than 30 years	12	24
30 to 50 years	28	56
More than 50 years	10	20
Religion		
Hindu	34	68
Muslim	16	32
Others	-	-
Family member		
Less than 5	38	76
More than 5	12	24
Number of year's respondent associated with the occupation		
Less than 1	2	4
1-5	4	8
6-10	20	40
11-20	10	20
More than 20	14	28

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Table 3: Sources of information utilized for agricultural information dissemination

Sources of Information	Frequency	Percentage	Rank
Own knowledge	35	70	III
ADA (Assistant Director of Agriculture) office	45	90	I
Krishi Vigyan Kendra	20	40	IV
Kisan Call Centre	10	20	VI
T.V. (Television)	12	24	V
Newspaper	8	16	VII
Private fertilizer and pesticide company representative	40	80	II

that the accessibility of agriculture information of fertilizer and pesticide dealers on newspaper, Kisan Call Centre and TV contributed 60 per cent of the information, which supported the results found by Parganiha *et al.* (2012).

CONCLUSION

It could be concluded from the investigation that majority of the respondents were above high school pass. They were theoretically more knowledgeable and can codify a technology in one or the other context. They can take more advantage from the modern information communication technology in agriculture and disseminate to the farmers. The majority of the respondents land holding size was large. This category of respondents may motivate the farmers on agricultural practices by demonstrating the technology in their own fields. The age group category of 30-50 years was more involved professionally in fertilizer and pesticide business. Small family respondents get more time to participate in different agricultural programms and make aware the farmers on scientific agricultural practices. The majority of the respondents were experienced fertilizer and pesticide dealers. They can easily motivate the farmers to adopt latest technologies. Due to high source of agricultural technology, ADA office can take more initiative in providing agriculture information to the farmers through fertilizer and pesticide dealers.

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Demonstration of three Seeding Methods and Two Varieties of Sorghum (*Sorghum Bicolor*) with Farmers' Participatory approach in Hamelmalo Area, Eritrea

Woldeamlak Araia, Syed Danish Yaseen Naqvi* and Abdulrezak Ahmedin

Department of Agronomy, Hamelmalo Agricultural College, Eritrea
Department of Plant Protection, Hamelmalo Agricultural College, Eritrea and
Department of Agronomy, Hamelmalo Agricultural College, Eritrea
**Email: syeddanishnaqvi84@gmail.com*

ABSTRACT

A demonstration was carried out on the seeding methods and varieties of Sorghum on farmers' fields in two locations in Basheri and Genfolom (Hamelmalo area), ZobaAnseba, Eritrea during 2015/16 cropping season. Three methods of sowing (Direct, transplanting and hydro seed priming) and two varieties (*Hamelmalo* and *Hariray*) were demonstrated with a total of 6 treatments. A total of 20 farmers in each of the two locations participated in the evaluation of the sowing method at maturity using a scoring scale of 1 to 10. There was no significant difference among the varieties, method of sowing and the interaction in biomass. Hydro seed priming was better in biomass with 4650 kg/ha compared to transplanting (3023 kg/ha) with a difference of 1605 kg/ha or 53.1% increase, when averaged over the locations even though, it was non-significant. In grain yield, there was significant difference among the seeding methods with Hydro seed priming giving higher yield (962 kg/ha), which is an increase of 283 kg/ha or 41.7% compared to transplanting (679 kg/ha), when averaged over the locations. The evaluation by farmers was the highest for Hydro seed priming with a score of 8.13 compared to direct seeding, when averaged over the locations. The methods of planting were demonstrated to farmers by organizing field days in the two locations.

Key words: Demonstration, Hydro seed priming, Sorghum, Productivity, Semi-arid areas

Crop establishment is often poor in the semi-arid tropics including Eritrea which has erratic rainfall situation and distribution. Adequate crop stand and establishment is essential for the efficient use of water and light, which is a pre-requisite for the success of crop production. Poor seedling establishment and poor crop stand results in lower yield. There are several reasons for poor crop establishment for sorghum in semi-arid areas such as inadequate seed bed preparation (Joshi, 1987), low seed quality and untimely sowing (Oosterom *et al,* 1996), poor sowing techniques (Radford, 1983), inadequate soil moisture or drought, which delays the onset of the rainfall and reduce the rate of germination events, leading to reduction in plant growth and final crop yield (Gurmu and Taylor, 1991; Harris, 1996) (Figure 1) and adverse soil properties leading to formation of surface crusts. The formation of surface crust and hard layers in the soil surface forms impermeable barriers to shoot emergence and root penetration. In addition, the plant eventually emerges often slowly and it becomes highly susceptible to abiotic stresses (drought) and biotic stress (insects and diseases) (Soman, *et al.*, 1992; Towned, et al., 1996). The resource poor farmers in marginal areas, with poor rainfall distribution, suffer more in most cases from the poor yield of crops.

One of the crop management technique that is utilized for better crop establishment, higher yield and resistance to biotic (diseases and insects) and abiotic stress (drought) in sorghum is seed priming (Harris, 1996; Chivasa *et al.*, 2000). The conditions after sowing had a large influence on emergence and seedling vigour in sorghum and speed in germination and emergence is an important determinant in successful crop establishment. Rapidly germinating seeds could emerge and produce deep root system before the soil

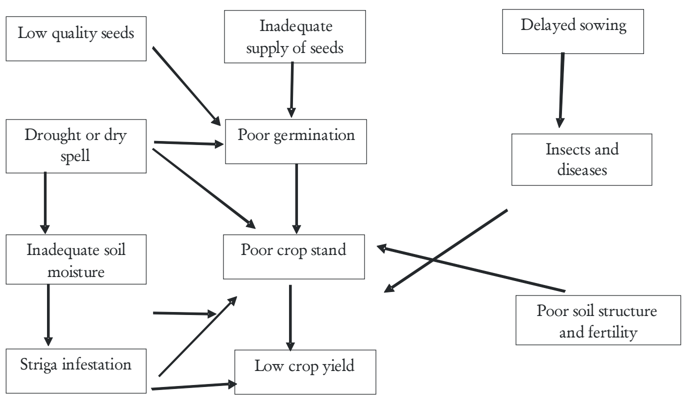

Fig. 1. Schematic presentation of constraints affecting yield under semi-arid conditions

layer dries out (Harris, 1996).

Even though sorghum and pearl millet are drought tolerant crops under semi-arid conditions, the production is, most of the time, challenged by erratic rain-fall pattern often characterized by total failure of already short rainy season of April or delay in the on-set and/or early cessation of the rain fall during the main rainy season (June-September). It is critical to provide farmers with various techniques to enable them to minimize the risk of losing their harvests so that food security can be achieved using Hydro seed priming, which is proposed to be a low cost, low intervention agronomic practice that is appropriate to all farmers irrespective of their socio economic status (Harris, 1996; Haris *et al.*, 1999).

Purpose of the research

Seed priming is soaking seeds in water before sowing, which gives the germinating seed a head start and speeds up seed establishment with a corresponding increase in survival rates and yields of crops under semi-arid regions (Rogers, 2002). It is practiced to enhance germination process, germination rate, germination uniformity and germination percentage compared to direct seeding. In seed priming, seeds are soaked with water and drying it before planting, which is a useful practice under dry land farming for several crops such as sorghum, maize, chickpea, wheat, etc. compared to direct seeding (Rathore, 2005).

Seeds spend large proportion of the time for water imbibition very slowly. In the mean time the soil may be drying, hardening and crusting. Seed germination and seedling emergence can be significantly speeded up by soaking seeds in water before sowing (Harris, 2006). Primed crops could emerge earlier and produce flowers earlier. Farmers indicated better drought tolerance and higher yields in seed priming practice, with an increase ranging from 10-30 per cent (Harris, 1992).

The research on the effect of seed priming was carried out for 3 years from 2012-2014 in the research site of Hamelmalo Agricultural College, Eritrea. The results have indicated that the variety 'Heilo' with seed priming gave the highest grain yield (4389 kg/ha) compared to direct sowing (2778 kg/ha) (Woldeamlak, et al., 2016). The disease infestation could also reduce to a greater degree in seed priming compared to direct seeding, especially smut infestation which is problematic in sorghum, resulting in a better yield compared to other methods of planting such as direct seeding (Mc Donald, 2000).

Transplanting is another seeding methods which is practiced in arid regions for better growth and survival of seedlings resulting in better yield. Seeds are planted in a nursery during on-set of the main rainy season and farmers are able to minimize risk of water stress by maximizing water use efficiency and improving yields under marginal conditions. A total of 80 participating farmers in Zimbabwe have used transplanting and obtained higher yield in transplanting sorghum, with a yield range between 3.5 to 4.6 ton/ha. The yield for direct sown fields were 1.8 to 2.8 ton/ha for sorghum and 0.9 to 1.6 ton/ha for millet (Roger, 2002). Some of the main agronomic benefits of transplanting are earlier harvests (by 2-3 weeks) and the possibility of avoiding thermal drought, often substantially increased grain yields (increased 0.1-1.5 ton/ha), particularly, in striga infested fields, together with improved grain size and quality. Transplanting is useful when there is shortage of seeds and to provide insurance for optimum plant density. Transplanting is a feasible technique as an option to reduce risk associated with the direct sowing of sorghum and improve food security status of the farming community (Chivasa, *et al.*, 2000; Joshi and Witcombe, 1996).

Farmers in limited area of Gash Barka (Forto and Haycota) have tested transplanting of sorghum in a field in an area of 300 m^2. They planted the seedlings 20 days before the start of the rain. The crop also matured 15 days earlier than the fields that were planted with dry seeds. The farmers were able to get 833 kg/ha (0.0830 kg/m^2) while direct seeding gave an yield of 567 kg/ha (0.067kg/m^2), depicting an yield increase of 47 per cent. Farmers have also indicated that the panicles were bigger and the number of seeds per panicle was higher compared to the direct seeding (MOA, 2008). In general, technologies should be popularized or verified in farmers' fields with the participation of farmers. Farmers normally adopt technologies when they see it working under their own situation. The linkage between research and extension is weak in most of the cases, where each one of them stands aloof and tries to solve the problem independently. There should be a feedback between researchers, extension and farmers after the technique is tested and popularized. A technology generated will be useless, if it is not tested or verified in the actual farmers' fields and prove that it is adaptable under that situation.

Farmers in sub Zoba Hamelmalo and in other parts of Eritrea have not applied the techniques of Hydro seed priming under optimal sowing conditions. There is a lack of exposure and uptake of Hydro seed priming in various crops, which is not a surprise. Adoption studies on seed priming have never been carried out and the there is inadequate information from farmers on benefits or relative merits of using primed versus non-primed seeds of sorghum.

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Objectives

- To test, verify, demonstrate and popularize the effect of seed priming and transplanting with the participation of farmers;
- to create awareness and provide training to farmers on the techniques of seed priming and transplanting in sorghum compared to direct seeding in their own field; and
- to assess the adoption rate of the technique in the case of Hydro seed priming.

MATERIALS AND METHODS

Demonstration site

The demonstration was carried out in farmers' field in Basheri and Genfelom, Sub Zoba Hamelmalo. The site was selected in these two areas because the farmers were willing to carry out the demonstration on seed priming during the summer of 2015/16. Both sites had an altitude within the range of 1280 m above sea level. The rainfall situation and distribution was erratic with the major rainfall being in July and August. The average rainfall ranged from 350 to 450 per year with an average temperature of 31°C.

Treatments

Three seeding methods were tested, which included direct seeding (unprimed seed), Hydro seed priming and Transplanting (seedlings of sorghum) on two varieties-Hamelmalo (improved variety) and Hariray (local landrace) with 3 methods of sowing. The variety 'Hamelmalo' was obtained from the college, which was multiplied during the previous season, while 'Hariray' was obtained from the farmers directly.

There were a total of 6 treatment combinations with 3 seeding methods and two varieties. In Hydro seed priming, the seed of sorghum was soaked in water for 12 hours over night and dried under shade to be sown immediately in the field. In transplanting, the seeds were sown in a nursery bed two weeks earlier and later transferred to the experimental field. In Direct sowing method, the seed was sown directly, without soaking it in water, to the main field as commonly practiced by farmers.

Design and analysis

Each treatment was planted in a gross plot size of 10 m x 10 m (100 m^2). The demonstration was laid out in a Randomized Complete Block Design with factorial experimentation having 2 factors (3 methods of sowing and 2 varieties) replicated 2 times. The data was analyzed using GENSTAT software for the Analysis of Variance, mean comparison using LSD at 5 per cent, CV value was estimated.

Crop husbandry

A total of 100 kg/ha DAP (Di ammonium phosphate) was applied at the time of planting for the trial and 50 kg/ha applied in split with 1/3 at sowing and 2/3 at knee height stage. The trial was planted at 75 cm spacing between rows of and 15 cm spacing between plants at a seeding rate of 10 kg/ha and a depth of planting of approximately 3-5 cm. Two hand weedings were carried out to remove all the weeds at 30 days and 60 days after sowing.The trial was planted during the first week of July, even though, after transplanting there was a shortage of rainfall in both locations.

Inter-culture operation was carried out in the demonstration plot using oxen plough when the crop reached 40 cm in height. The inter row cultivation helped the crop to get proper aeration, infiltration rate of water was better, moisture conservation enhanced, weeds were removed and organic matter decomposition enhanced.

Data collection

The data collected included stand count (number/m^2), number of days taken to flowering, number of days taken to maturity, plant height (cm/plant at maturity), panicle size, smut affected panicle count, biomass yield (kg/ha) and grain yield (kg/ha).

Stand count is the total number of plants measured using a quadrant (1 m x 1m) at crop establishment stage. Plant height (cm) was measured from 5 plants using a ruler from the base to the tip of the panicle at maturity and averaged on per plant basis. The number of days to flowering was recorded when 50% of the plants reached that stage and number of days counted from planting up to flowering. The number of days to maturity was recorded when 90% of the plants reached maturity and number of days counted from planting up to maturity. Panicle size was measured by the length from the base to the tip of the panicle during maturity stage. The plants that were attacked by smut were counted and recorded per plot. Biomass yield is the above ground parts from each plot harvested and weighed per plot and then converted on hectare basis. Grain yield (kg/ha) was taken after the panicle of each plot was threshed, the seed weighed and converted on hectare basis.

A field day was organized separately in the two villages and farmers were shown the performance of each treatment. After looking at each treatment, they were requested to evaluate the crops using a scale of 1 to 10 where 1= very poor and 10= excellent. The performance was evaluated by farmers taking into account criteria such as plant height, crop stand, earliness, spike size and biomass

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at maturity. During the evaluation both male headed and female headed households participated. The farmers were guided by the researchers concerned during the evaluation and in filling evaluation sheet using a score from 1 to 10. The extension agents also assisted farmers in filling the evaluation sheet especially for those who are not able to read and write.

During the field day farmers, who were interested to test Hydro seed priming in sorghum or pearl millet in their own field, were registered from the two villages (Basheri and Genfelom) and the list of names were given to the Sub Zoba Administration for a follow up and for planting their crops using Hydro seed priming.

There was a plan to find out the acceptance of Hydro seed priming by farmers after they test it in their fields. According to Harris, *et al.* (1999) farmers (Indian villages) who tested seed priming have utilized Hydroseed priming in crop production with satisfactory level of uptake and the technique was prevalent among farmers even in the absence of an extension staff.

In adaption studies, the farmers' perception on seed priming and the benefits of seed priming has to be ranked and looked into using pairwise ranking matrix. Eight criteria namely ease of sowing, early germination, plant stand, resistance for dry spell, early flowering, early maturity, pests' escape and estimated biomass and grain yield need to be assessed in farmers' fields in order to find out the relative merits of using primed or dry seeds in crops.

Fig. 2a: The trial at maturity

Fig. 2b: Field day in Basheri

RESULTS AND DISCUSSION

The results on crop phenology and crop stand averaged over the two villages have been presented in Table 1.

Crop phenology and crop stand

There was no significant difference in stand count/m^2 among the varieties and the interaction but it was significant among the seeding methods. There was no variation in crop stand among the two varieties-Hamelmalo and Hariray. In seeding methods, Hydro seed priming was the highest in seed count compared to the other methods with a difference of 8 plants/m^2 compared to transplanting when averaged over the varieties. Transplanting showed the lowest stand count because after transplanting there was a delay of rainfall that contributed to low survival rate of seedlings. In the interaction, Hydro seed priming x Hamelmalo and Hydro seed priming x Hariray showed higher crop stand compared to the other interactions (Table 1).

Hydro seed priming normally led to faster emergence by 2-3 days compared to direct seeding. Faster emergence leads to better and more uniform crop establishment. The improvement in germination is because the seeds imbibe the water content, which reaches a plateau and changes little until the radicle emergence. Hydro seed priming up to this point can have a positive effect, while extended priming duration could negatively affect germination. Primed seeds can rapidly imbibe and revive seed metabolism resulting in higher germination rate. The positive effect on stand establishment was enough in itself to justify the use of seed priming. Primed crops grew more vigorously and tolerated dry spells better as compared to direct seeding or transplanting. The beneficial effect of priming on crop establishment is consistent with reports of farmers' perception of the effect of priming on various crops. According to Harris (1996) and Harris (2006), seed priming in maize led to better crop establishment, growth and greater yields. In chickpea, the varieties matured earlier, increased crop stand and the grain yield was better in primed seeds. In Zimbabwe, Harris, *et al.* (1999) showed that priming increased maize yields from 0.73 to 0.84 t/ha with an increase of 14 per cent.

Days to flowering

There was no significant difference in the number of days to flowering among the varieties, seeding methods and the interaction. The variety, Hamelmalo produced flowers earlier compared to Hariray with a difference of few days. In Hydro seed priming, there was only a difference of 2 days compared to the other methods which is very narrow.

Days to maturity

There was no significant difference in number of days to maturity among the varieties, seeding methods and the interaction. There was no difference in maturity among the two varieties. Hamelmalo is early maturing type compared to Hariray but there was no difference in number of days to maturity due the rainfall situation in the area with uneven distribution. Joshi and Witcombe (1996) mentioned that seed priming resulted in earliness in order to avoid drought. In chickpea, the same results were obtained where primed seeds

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Table 1. Crop phenology and stand count (number/m²) on the demonstration of Hydro seed priming and two varieties of sorghum averaged over two locations (Basheri and Genfolom)

Seeding methods	Stand count/m²			Days to flowering			Days to maturity		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Hydro seed priming	17.8	15.5	16.63	85.5	76.5	81	101.5	98	100
Transplanting	8	8.5	8.28	83	83	83	97	101	99.9
Direct seeding	9.75	15	12.4	85	81.5	83.3	103.5	102.5	102.5
Mean	**11.65**	**13**	**12.4**	**84.5**	**80.33**	**82.42**	**100.5**	**100.5**	**100.5**
LSD 5%									
Varieties		**NS**			**NS**			**NS**	
Seeding methods		**3**			**NS**			**NS**	
Seeding methods x varieties		**NS**			**NS**			**NS**	
CV%		**20.8**			**3.9**			**30**	

Note: V1= Hamelmalo, V2= Hariray

matured earlier compared to non-primed ones. However, in the current work, there was no difference in number of days taken to maturity among varieties and seeding methods.

Plant height, panicle length and smut counts

The results on plant height (cm), panicle length and number of smut is shown in Table 2.

Plant height (cm)

There was significant difference in plant height among the varieties and the interaction but it was not significant among the seeding methods. There was a difference of about 7 cm between Hydro seed priming and transplanting. In general, numerically Hydro seed priming contributed to the increase in plant height compared to the other seeding methods but it was not significant. There was a varietal difference in plant height with Hariray being taller than Hamelmalo. In interaction, Hydro seed priming x Hariray showed the tallest height (172.5 cm) compared to that of Hydro seed priming x Hamelmalo.

Panicle length (cm)

There was significant difference in panicle length between the varieties and seeding methods but not among the methods of planting. In varieties, Hamelmalo showed higher panicle length compared to Hariray. In seeding methods, the panicle length was better numerically in transplanting compared to Hydro seed priming. In the interaction, Transplanting x Hamelmlo (22.5 cm) followed by Hydro seed priming x Hamelmalo (21.1 cm) showed the highest panicle length compared to the other interactions.

Number of plants with smut

There was significant difference in number of smutted plants among the seeding methods but not among the varieties and the interaction. Comparing the two varieties, the number of plants with smut was higher in Hamelmalo compared to Hariray when averaged over the methods of planting. In Hydro seed priming the number of smutted plants were the lowest while in Direct seeding the number of smutted plants were as high as 59, when averaged over the varieties. The number of smuts were higher in Direct seeding x Hamelmalo compared to Direct seeding x Hariray. Smut is a seed born disease which can be controlled or minimized by seed treatment with chemicals and using clean seed from previous harvest. In Hydro seed priming, the seeds are washed, which helps to remove the conidia from the seed reducing the infestation as compared to direct seeding. Previous studies have shown that disease incidence especially of smut are reduced using Hydro seed priming. This is in agreement with Mc Donald (2000), who reported that the disease infestation especially smut is greatly reduced in Hydro seed priming, which has an influence on yield of sorghum compared to direct seeding. Harris (1996) and Chivas, *et al.* (2000) also reported that Hydro seed priming is a crop management technique, which can be utilized for resistance to biotic (diseases and insects) in sorghum.

Primed crops suffer less damage from some pests and diseases than crops grown from non-primed seeds. However, it is difficult to conclude that the yield increase in a wide range of crops from primed seeds are solely the result of increased disease resistance but the increase in resistance may contribute in many situations where diseases is present

Table 2. Plant height, panicle length and smut count (per plot) on the demonstration of Hydro seed priming and two varieties of sorghum averaged over two locations (Basheri and Genfelom)

Seeding methods	Plant height (cm)			Panicle length (cm)			Number of smut/plot		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Hydro seed priming	121.7	172.5	147.1	21.1	11.8	16.5	10.5	4	7.3
Transplanting	118.2	161.2	139.7	22.55	13.25	17.8	23.5	7	15.3
Direct seeding	121	165.7	143.3	20	13.95	17	95	22.5	58.8
Mean	**120.3**	**166.4**	**143.4**	**21.3**	**12.95**	**17.1**	**43**	**11.2**	**27.1**
LSD 5%									
Varieties		**11.5**			**1.0**			**NS**	
Seeding methods		**NS**			**NS**			**41**	
Seeding methods x varieties		**10**			**1.65**			**NS**	
CV%		**9.3**			**6.5**			**15.6**	

Note: V1= Hamelmalo, V2= Hariray

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at low level. However, a well-designed and exhaustive study on the disease resistance in Hydro seed priming in different crops is required.

Biomass, grain yield and farmers evaluation

The results of biomass, grain yield and farmers' evaluation is shown in Table 3.

Biomass yield

There was non-significant difference in biomass among the varieties, seeding methods and the interaction. Comparing the two varieties, Hamelmalo numerically gave higher biomass of 4656 kg/ha compared to Hariray (3619 kg/ha), which is an increase of 1037 kg/ha or 28.7 per cent. Comparing the methods of planting, Hydro seed priming gave higher biomass with 4628 kg/ha compared to transplanting with a difference of 1605 kg/ha which is an increase of 53.1 per cent. The interaction showed that Hydro seed priming x Hamelmalo (5236 kg/ha) gave higher biomass followed by Direct seeding x Hamelmalo (5071 kg/ha). The lowest biomass was obtained by Transplanting x Hamelmalo (2961 kg/ha). The improved biomass as a result of Hydro seed priming might be due to earlier and uniform emergence, which ended up in increased biomass yield.

Grain yield

There was non-significant difference in grain yield among the varieties but it was significant among the methods of planting but not among the interaction. Comparing the varieties, Hamelmalo gave the highest grain yield with 917 kg/ha, which is a difference of only 148 kg/ha. In seeding methods, Hydro seed priming gave higher grain yield (962 kg/ha) with a difference of 283 kg/ha, which is an increase of 41.7 per cent compared to transplanting. The interaction showed that Hydro seed priming x Hamelmalo (1046 kg/ha) followed by Direct seeding x Hamelmalo (1016 kg/ha) compared better with the other interactions.

The increases in grain yield may indirectly reflect to the increase in crop stand from primed seed, which requires less gap filling, reducing the cost of establishment. Hydro seed priming would be expected to increase yield indirectly through the effect of crop stand because higher crop stands give higher yield compared to seeding methods with lower crop stand.

Farmers' evaluation

There was no significant difference among the varieties and the interaction in farmers' evaluation but there was a difference among the seeding methods. Comparing the varieties, the evaluation showed that the evaluation is almost the same. In methods of planting, Hydro seed priming had the highest evaluation (8.13) followed by Direct seeding (7.0), while, transplanting showed a very poor performance (5.35). In the interaction, Hydro seed priming x Hamelmalo and Hydro seed priming x Hariray showed a better performance compared to the other interaction. Harris, *et al.* (1999) mentioned that seed priming is a good example of key technique which is simple, low cost intervention, the impact of which is large enough to induce farmers use the agronomic practice.

Table 3. Biomass (kg/ha), Grain yield (kg/ha) and farmers evaluation on the demonstration of Hydro seed priming and two varieties of sorghum averaged over two locations (Basheri and Genfelom)

Seeding methods	Biomass (kg/ha)			Grain yield (kg/ha)			Farmers Evaluation (0-10)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Hydro seed priming	5236	4020	4628	1046	878	962	8.25	8.0	8.13
Transplanting	2961	3086	3023	690	669	679	5.7	5.0	5.35
Direct seeding	5071	3753	4412	1016	761	888	7.0	7.0	7.0
Mean	**4656**	**3619**	**4021**	**917**	**769**	**843**	**6.97**	**6.84**	**6.91**
LSD 5%									
Varieties	**NS**			**NS**			**NS**		
Seeding methods	**NS**			**50**			**0.85**		
Seeding methods x varieties	**NS**			**NS**			**NS**		
CV%	**21.1**			**20.6**			**15.5**		

Note: V1= Hamelmalo, V2= Hariray

Conclusion and Recommendations

Conclusion

(i) Hydro seed priming was demonstrated to farmers in the two villages by organizing field days. A total of 40 farmers visited the demonstration work and evaluated the performance of seeding methods using a scale 1-10.

(ii) Hydro seed priming showed higher yield compared to other methods of planting, which matches with the evaluation given by farmers.

(iii) The disease incidence, particularly, smut incidence, was also very low in Hydro seed priming compared to direct seeding.

(iv) Hydro seed priming is more pronounced in areas and years, where, there is erratic rainfall distribution for facilitating early germination and good crop establishment.

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(v) Transplanting could be an alternative technique to reduce the risk associated with moisture stress and improve food security; however, the performance of transplanting was not as expected due to absence of rainfall after transplanting. Another problem with transplanting is that it is difficult to apply in large area of land because of high demand for labor, hence, it could be only feasible at small farm holdings.

Recommendation

There were 25 farmers who agreed to use Hydro seed priming in their farm by dividing their land into two so that ½ of the land is planted with dry seeding and ½ of it with Hydro seed priming.

(i) Adoption studies need to be conducted taking eight characteristics into account and make evaluations using pair wise ranking matrix and collect information on the relative benefits, merits and problems associated with Hydro seed priming and dry seeding in farmer's fields.

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Growth, Development and reproduction of fruit fly, *Bactrocera dorsalis* Hendel (Diptera : Tephritidae) on different Mango cultivars, viz. Dashehari, Langra, Chausa and Amrapali

Rajesh Kumar

Assistant Development Officer – Cooperative, Vikas Bhawan Lucknow and Former Research Associate, Department of Crop Protection, CISH, Lucknow.
E-mail: drrksingh034@gmail.com

ABSTRACT

India is the largest producer and exporter of mangoes. It produces choicest cultivars in different region of the countries. However, its export is hampered by susceptibility to fruit fly *Bactrocera dorsalis* Hendel, as the importing counties are wary of introduction of Indian strain of *B. dorsalis* into their counties. Consequently, they have imposed many pre export requirements viz., hot water treatment, vapour heat treatment, irradiation, etc.

The present study attempts to study growth, development and reproductive cycle of fruit fly, *Bactrocera dorsalis*, Hendel on four mango cultivars, viz. Chausa, Langra, Dashehari and Amrapali. The development of the immature stages of *B. dorsalis* was found to differ, when they were reared on four mango cultivars. The incubation period of eggs of *B. dorsalis* was minimum (1.75 ± 0.11 days) on Chausa cultivar and maximum (3.30 ± 0.13 days) on Amrapali cultivar. Duration of first larval instars was fastest (1.85 ± 0.13 days) on Chausa and slowest (3.55 ± 0.16 days) on Amrapali. The developmental of second larval instars of *B. dorsalis* varied from 2.25 ± 0.11 to 4.00 ± 0.15 days with the minimum period on Chausa and maximum on Amrapali (F= 35.12; P<0.001). The third larval instar developed fastest (4.45 ± 0.69 days) on Chausa and slowest (7.60 ± 0.22 days) on Amrapali (F=17.53; P< 0.001). The total developmental period of immature stages of *B. dorsalis* was shortest (19.45 ± 0.68 days) when fed on Chausa and longest (30.65 ± 0.33 days) when fed on Amrapali (F=93.57; P<0.001). The fastest development took place on Chausa cultivar and slowest on Amrapali.

The different reproductive parameters of *B. dorsalis* varied significantly when fed on four different mango cultivars. Fecundity of *B. dorsalis* on mango cultivar varied from 189.80 ± 1.44 to 561.20 ± 3.21 eggs with the least on Amrapali and highest on Chausa (F= 7288.07; P<0.001). The percent egg viability was least (73.22 ± 1.02 %) when adults were reared on Amrapali cultivar and highest (82.50 ± 0.39%) on Chausa cultivar (F=20.00; P <0.001).

Key words: Fruit fly, *Bactrocera dorsalis* Hendel, Mango Cultivars, Chausa, Langra, Dashehari and Amrapali.

INTRODUCTION

Mango is the choicest fruit of the country and abroad and because of its popularity, nutritive value and taste. It has a high potential and bright future both for the fresh consumption as well as processed products.

Insect infestation on mango is common in India, which is largely responsible for its low demand in the national and international markets. Export of fresh mangoes and grafted plants is being hampered due to pests like fruit flies and stone weevil. The Japan and USA, which are the promising buyers, have put embargo on the export of fresh fruits due to fear of introduction of the above insects in their countries. The acceptable quarantine requirement of these countries is to treat the fruit fly *Bactrocera dorsalis* by vopour heat treatment for exports to Japan and by irradiation for the export to USA. Whereas, in other countries hot water treatment is acceptable. Besides many methods, control of fruit flies involving pheromones are being developed. Methyl eugenol formulation like 3-4 dimethyl- hexopropyl- benzene, 3,4 – dimethoxy- ethoxy- benzene and 3-4 dimethoxy-methoxy methyl- benzene are being used against fruit flies. However, O-methyleugenol is still widely used. This is one of the very powerful male lure and is quite long lasting against fruit fly.

The present study on the growth development and reproduction of fruit fly *Bactrocera dorsalis* Hendel (Diptera : Tephritidae) was conducted on different mango cultivars. *viz,* Dashehari, Langra, Chausa and Amrapali.

MATERIAL AND METHODS

Growth development and reproduction of *B. dorsalis* on diffent mango cultivars

Site description

The experiment was carried out at the laboratory of Department of Crop Protection, Telibagh, Raibareli Road, CISH Rehmankhera, Lucknow between January 2004 to December 2008.

(i) Stock Culture

An initial culture of fruit flies was raised from field collected infested material in rearing cages (45 cm^3) covered with black cloth. The cages were one fourth filled with sieved and sterilized sand at temperature 25 ± 2ºC and 65 ± 5 per cent RH for the purpose of pupation. Whole fruits were kept inside the cages for allowing oviposition by the females and these were changed daily so as to prevent fungal contamination. Water was kept in cavity block with a cotton wicks at the top. Eggs laid in the fruit were collected by sectioning the fruit and lifting the eggs with the help of soft camel hair brush. The eggs were removed and shifted to a new fruit for further development till adult emergence. The adults and instars were used in experiments as required.

(ii) Growth and Development of Immature Stages

The effect of four different mango cultivars, viz. Dashehari, Langra, Chausa and Amrapali on pre-imaginal development of fruit fly, *B. dorsalis* was studied.

A subculture was prepared in which the adults were placed in 1/4 super script sand filled black cloth covered glass jars (14.0 x 25 cm) provided with either one of the four different mango cultivars and allowed to oviposit. The mouths of the jars were closed with help of muslin cloth held by rubber bands. Fresh fruits were provided daily till the requisite number of eggs were obtained.

A total of hundred eggs were collected from each fruit and kept in Petri dishes (16.0 x 2.6 cm) at room temperature (10 eggs per replicate). In addition, water was kept in cavity block with a cotton wicks at the top. After hatching, the first instars were transferred to respective fresh fruits placed in 1/4 super script sand filled black cloth covered glass jars (14 x 25 cm) with the help of soft camel hair brush (No. Zero). The development of eggs was followed up to adult emergence via three larval instars and prepupal and pupal stages (Fig. 1).

Incubation period, duration of the three larval instars, and the duration or prepupal and pupal stages were recorded. Survival of each immature stage was also recorded. Percent (%) larval survival and adult emergence was worked out using following formula:

$$\text{Larval survival (\%)} = \frac{\text{Number of pupae formed}}{\text{Number of first instar hatched}} \times 100$$

$$\text{Adult emergence (\%)} = \frac{\text{Number of adult fruit flies emerged}}{\text{Number of pupae}} \times 100$$

(iii) Reproduction

Adults emerging from the above setups were paired in 1/4 super script sand filled black cloth covered glass jars (14 x 25 cm) and provided with any one of the four mango cultivars. The fruits were replaced daily and the reproductive traits, viz. pre-oviposition period (the period from the time of emergence to the time of first oviposition), oviposition period (day from first to last day of oviposition) and post-oviposition period (day of last oviposition till death of female), fecundity (total oviposition), egg viability (total no. of eggs hatched) of *B. dorsalis* were recorded and have been presented in Table 2. The egg viability was worked out with the help of following formula (Table 3).

$$\text{Egg Viability (\%)} = \frac{\text{No. of larvae hatched}}{\text{No of eggs laid by female}} \times 100$$

The longevity of both adult males and females was also recorded.

(iv) Statistical Analysis

The observations on incubation period, durations of first, second and third instars, prepupal and pupal durations, total larval, pupal and developmental periods on different mango cultivars were subjected to one-way ANOVA followed by Tukey's post hoc test for comparison of means. Similar analysis was also done for pre-oviposition, oviposition and post-oviposition periods, fecundity, percent egg viability and adult longevity.

RESULT AND DISCUSSION

Growth development and reproduction of *B. dorsalis* in relation to diffent mango cultivars

(i) Growth and development

The results on growth and development of *B. dorsalis* on four different mango cultivars, *viz.* Chausa, Langra, Dashehari and Amrapali, revealed that the fastest development of the immature stages of this fruit fly species was on Chausa, followed by Langra, Dashehari and Amrapali (Table 1). The egg incubation period was lowest when the adult fruit flies were reared on Chausa than on other mango cultivars. The short incubation period of eggs on the mango cultivar Chausa may possibly be due to its better nutritional contents in relation to the other three mango cultivars. Similar effect of nutritional content provided to the immature stages of fruit fly on their development has been observed by Narayanan and Batra, 1960; Mehta and Verma, 1968; Pruthi, 1969; Butani, 1975; Ibraham and Gudom, 1978; Gomes, 2001. The above authors have also mentioned egg incubation period in the range of 2 to 3 days. The durations of different larval instars and thus the total

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larval period were also shortest on Chausa and longest on Amrapali. This is also probably owing to the varying nutritional content amongst four mango cultivars. Another factor that may play a role in the variation in larval development is the differential palatability of the four cultivars. It is likely that the differential consumption acceptiblity may have also affected the growth and development of the larval stages. The effect of quality and quantity of different food provided has been observed by numerous workers in a number of insects. Omkar and Srivastava, 2003a; Omkar and Bind, 2004; Omkar and James, 2004a; Omkar and Pervez, 2004a; Pervez and Omkar, 2004a; Omkar and Mishra, 2005). Iwaizumi *et al*. (1994) has previously noticed differential larval development of *Bactrocera spp*. after feeding on different hosts. Iwaizumi *et al*. (1994) reported that the growth rate of larvae of *Bactrocera spp*. was found proportionate to the amount of food eaten. Similar inference has also been drawn by other workers (Dohrey, 1983; Iwaizumi *et al*., 1994; El Aw *et al*., 2003). The increased consumption of Chausa and short larval period after feeding on this cultivar indicates the probable good nutritive value for the fruit. The better food value of mango fruit for fruit fly development in comparison to other fruits has also been observed by Doherey, 1983. The pupal duration of *B. dorsalis* was shortest when the larvae were fed on Chausa than on the other three mango cultivars, *viz*. Langra, Dashehari and Amrapali. This was, as discussed above, probably owing to the better nutritional content of Chausa cultivar. The shorter pupal duration on Chausa is probably because of larger quantity and better quality of nutrients in the cultivar, which were consumed by the larval instars. Similar effect of food on pupal duration has been recorded (Dohrey, 1983; Gupta *et al*., 1993; Bhagat and Kaul, 1999; El Aw *et al*., 2003). The overall order of development of *B. dorsalis* was on Chausa followed by Langra, Dashhari and Amrapali (Table 1 and 2).

(ii) Reproduction

The life time fecundity of the fruit fly *B. dorsalis* varied when fed on different mango cultivars and the maximum fecundity of fruit fly was recorded on Chausa. This is probably because of the difference in nutritional contents amongst four cultivars. The palatability of the food provided could also have an effect on the reproductive parameters of the fruit fly, since palatability effects the amount of food consumed. Thus, the probable higher fecundity on

Table 1: Growth and development of *B. dorsalis* on different mango cultivars

Cultivars	IP	Maggot Period (days)			Total Larval Period	Prepupa	Pupa	Total Pupal Period	Total Development Period
		First Instar	Second Instar	Third Instar					
Chausa	1.75 ± 0.11a	1.85 ± 0.13a	2.25 ± 0.11a	4.45 ± 0.69a	8.55 ± 0.69a	1.30 ± 0.13a	7.90 ± 0.23a	9.20 ± 0.21a	19.45 ± 0.68a
Langra	2.10 ± 0.15b	2.20 ± 0.20b	3.00 ± 0.23b	5.05 ± 0.35b	10.25 ± 0.38b	1.55 ± 0.16b	8.60 ± 0.34b	10.15 ± 0.37b	22.50 ± 0.50b
Dashehari	2.90 ± 0.12b	2.70 ± 0.11b	3.40 ± 0.15c	6.20 ± 0.25c	12.30 ± 0.27c	1.80 ± 0.08c	9.60 ± 0.22c	11.20 ± 0.20c	26.40 ± 0.43c
Amrapali	3.30 ± 0.13c	3.55 ± 0.16c	4.00 ± 0.15d	7.60 ± 0.22d	15.15 ± 0.31d	2.05 ± 0.12d	10.25 ± 0.17d	12.10 ± 0.16d	30.65 ± 0.33d
F value	**30.31**	**29.10**	**35.12**	**10.85**	**40.94**	**6.65**	**17.53**	**24.60**	**93.57**

Values are Mean ± S.E.

Means in the same row followed by different letters are significantly different at P<0.001.

Table 2: Reproductive attributes of *B. dorsalis* in different mango cultivars

Cultivars	Fecundity	Egg Viability (%)	Pre-oviposition Period	Oviposition Period	Post-oviposition Period	Male Longevity	Female Longevity
Chausa	561.20 ± 3.21d	82.50 ± 0.39c	8.70 ± 0.26a	38.50 ± 0.76d	5.70 ± 0.30a	35.50 ± 0.65c	52.90 ± 0.85d
Langra	351.30 ± 0.75c	78.51 ± 0.49b	9.10 ± 0.28b	31.50 ± 0.85c	6.90 ± 0.43b	32.70 ± 0.52b	47.50 ± 0.91c
Dashehari	249.80 ± 1.29b	75.76 ± 0.89ab	9.80 ± 0.33b	26.00 ± 0.49b	7.10 ± 0.50b	32.10 ± 0.50b	42.90 ± 0.64b
Amrapali	189.80 ± 1.44a	73.22 ± 1.02a	11.10 ± 0.31c	19.20 ± 0.39a	8.20 ± 0.29c	27.20 ± 0.47a	38.50 ± 0.58a
F-value	**7288.07**	**20.00**	**12.68**	**158.36**	**6.81**	**40.79**	**66.45**

Values are Mean ± S.E.

Means in the same row followed by different letters are significantly different at P<0.001.

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consumption of Chausa cultivar could be both because of nutritional content as well as the quantity consumed. The findings on the effect of food on the fecundity of *B. dorsalis* have also been confirmed in a number of studies (Rana and Prakash 1993; Gupta and Verma, 1993; Kaul and Bhagat, 1994; Jakhar and Pareek, 2003; Yee, 2003). The egg viability was also found to be influenced by the food consumed by the parent adults and was highest when fed on Chausa cultivar. The effect of food on egg viability observed in the present study is also in conformity with the findings of Lakra *et al.*, 1989. The effect of food on the egg viability could be owing to the subsequent quality and quantity of the yolk present in the eggs. The pre-oviposition period of *B. dorsalis* was shortest when they were fed on cultivar Chausa and highest on Amrapali. This can be attributed to the early maturity of the ovarioles owing to the probable better nutritional quality of the cultivar on which the adults have fed. Such effect of different food is in conformity with the findings of many earlier studies (Bala, 1987; Borah and Dutta, 1997; Clare, 1997; Bhagat and Kaul, 1999; Channa, 2000; Gomes, 2000). The oviposition period of *B. dorsalis* was longest when the adult flies were reared on Chausa. The significant differences in the oviposition period of female fruit fly on different mango cultivars may be due to the difference in their nutritive quality as well as quantity discussed above. The better quality of food probably helps sustain ovariole development for longer duration thus affecting the oviposition period. Similar findings have also been recorded for *Bactrocera spp*. on different foods (Borah and Dutta, 1997; Bhagat and Kaul, 1999; Channa, 2000). The post-oviposition period of *B. dorsalis* differed greatly when the fruit flies were fed on different mango cultivars. The shortest post- oviposition period was recorded on Chausa, which can be attributed to the food quality and quantity as discussed above. Thus, when the fruit flies were fed on preferred Chausa cultivar of mango, the reproductive periods got enhanced, while the consumption of non preferred food increased the non- reproductive phase (Lakra *et al.*, 1989), (Channa, 2000). Similar effect has been seen in a number of insects (Omkar and Srivastava, 2003a; Omkar and Bind, 2004; Omkar and James, 2004a; Omkar and Pervez, 2004a; Pervez and Omkar, 2004a; Omkar and Mishra, 2005). The longevity of male and female adults of *B. dorsalis* was also found affected by their consumption of different mango cultivars during the course of their development. The longest lifespan of both adults was on the Chausa cultivar and the lowest on Amrapali. The above discussed points about nutritional quality and quantity are also applicable in this case in relation to varying adult longevity in relation to varying cultivars. The better quality and increased quantity of food consumption is likely to provide better nutrition and

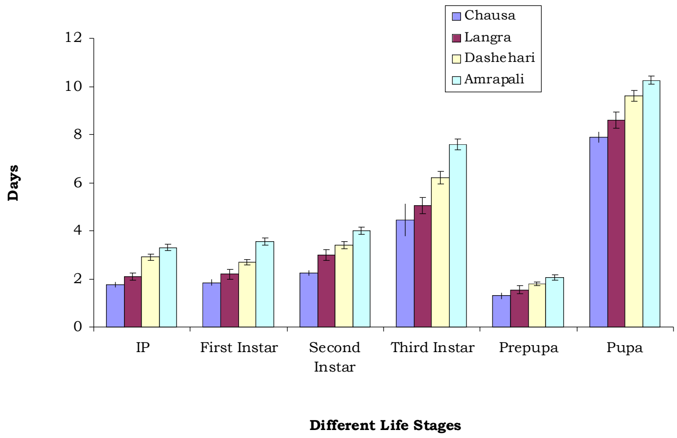

Fig. 1: Duration of different life stages of *B. dorsalis* in relation to four mango cultivars.

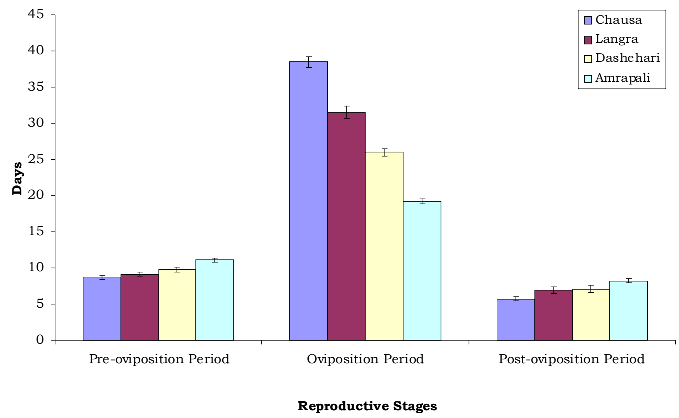

Fig. 2: Reproductive stages of *B. dorsalis* in relation to four mango cultivars.

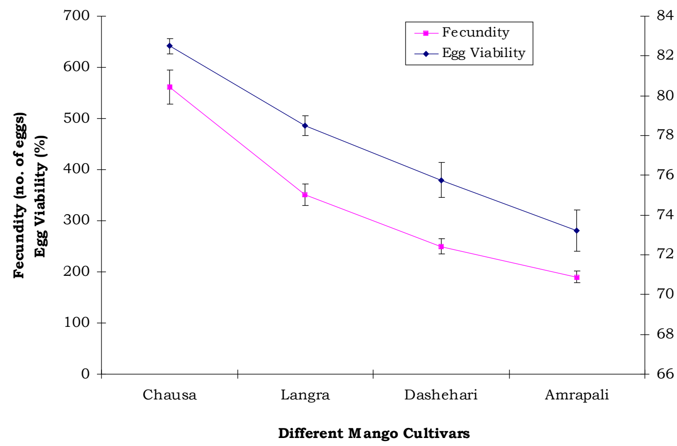

Fig. 3: Fecundity and egg viability of *B. dorsalis* in relation to four mango cultivars.

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nutrient reserves. This inference is in conformity with the findings of Batra and Renjhan (1952), Dohrey (1983), Patel and Patel (1998), Baboo (2002) and Rajesh and Shukla (2020).

CONCLUSION

Studies were under taken to study the growth, development and reproduction potential of fruit fly on mango in four cultivars viz, Chausa, Langra, Dashehari and Amrapali. The incubation period on chausa cultivar was minimum (1.75 ± 0.11 days) and maximum 3-30 ± 0.13 days on Amrapali. The total development period of immature stages of *B. dorsalis* was shortest (19.45± 0.68 days) when fed on chausa and longest (30.65±) when fed on Amrapali. The fecundity of *B. dorsalis* was least on Amrapali and highest on Chausa ($F = 7288.07$; $P<0.001$). The egg viability was least (73.22 ± 1.02) in Amrapali and highest (82.50 ±0.39%) in Chausa.

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Removal of seed leaves in tomato during transplantation to restrict the infestation of serpentine leaf miner, *Liriomyza trifolii Burgess*

Ravi Kumara R and P.D. Kamala Jayanthi

Division of Entomology and Nematology, ICAR-Indian Institute of Horticultural Research, Hesseraghatta Lake, PO 560089, India
E-mail:

ABSTRACT

The present study explores the potential of removal of seed leaves (cotyledons) during transplantation in tomato on the incidence of serpentine leaf miner, *Liriomyza trifolii* Burgess. The plants, where the seed leaves were removed consistently, recorded lower infestation of *L. trifolii* over a period of three weeks (0+0.00, 9.70+2.00, 24.10+2.86 mines per plant, respectively) compared to the plants transplanted along with the seed leaves (4.30+0.83,20.10+2.32, 38.90+5.93 mines/plant, respectively). This study establishes the bencficial role of removal of seed leaves in the management of *L. trifolii* in tomato.

Key words: Tomato, *Solanum lycopersicum*, Insect pest management, Cotyledons, Serpentine leaf miner

INTRODUCTION

Serpentine leaf miner (*Liriomyza trifolii* Burgess) (Diptera: Agromyzidae), also known as American serpentine leaf miner or celery leaf miner, is a species of leaf miner fly in the family Agromyzidae. This occurs mostly in tropical and subtropical regions and has resistance for changing environmental conditions (Mason *et al*., 1998). It completes its life cycle within 21 to 28 days after the female lays eggs on lower surface of leaves, preferably on vegetable crops. Eggs are oval in shape, small in size and creamy white in colour. Larva is a minute apodous maggot, orange yellow in colour and undergoes four instars in its larval stage. The pale-yellow larvae pupate within mined leaves. Adults are small with yellowish head and red eyes. The thorax and abdomen are mostly grey and black, although the ventral surface and legs are yellow. The wings are transparent and the adult flies live for about 13 to 18 days (Michael and Clifford, 1984). The Leaf minor is a polyphagous and serious pest of many vegetable and ornamental crops and also has 55 alternative host plants (Stegmaier, 1966; Schuster *et al*., 1991). It causes severe damage to plant growth and development, through larval leaf mining that decreases leaf photosynthetic area. The infestation is found both in open field and green houses. The damage is maximum under high temperatures (up to 30ºC) (Minkenberg, 1988).

Many alternative control measures, involving parasitoid wasps (Minkenberg and van Lenteren 1986), insect growth regulators (Michael *et al*.,1982), yellow sticky traps (Gencsoylu, 2006), cultural methods like adjusting the planting season, deep ploughing, timely intercultural operations (Price and Poe, 1976) are being employed to manage leaf miner infestation, as it exhibits resistance to several insecticides (Scott, 2004). In case of Tomato (*Solanum lycopersicum* L.) seedling transplantation is a common practice. Usually, 20-25 days old seedlings with 3-5 leaves along with seed leaves (cotyledon leaves) are used for transplanting. Usually, *L. trifolii* attacks the tomato plants from early seedling stage itself. Therefore, in all probability the seed leaves may serve as source of infestation for leaf miner. Considering that the prevention is best method rather than curative, we hypothesized that the removal of seed leaves during transplantation may influence the incidence of leaf miner in tomato. In this direction, the present study was carried out to understand the influence of seed leaves removal in tomato plants during transplantation.

MATERIALS AND METHODS

The present study was carried out during November, 2019 to January, 2020 at an experimental field of ICAR-Indian Institute of Horticultural Research, Bengaluru, India. Tomato seedlings (20 days old) (Cv Namadhari 501 F_1 hybrid) were procured from the commercial nursery (Shri Durgamba Sasya Nursery, Hessaraghatta, Bangalore) and transplanted in pots (12x12") as per standard procedures and followed by regular agronomic practices. During transplantation two treatments, namely T_1 (wherein the seed leaves were removed while planting) and T_2 (the seed leaves were left intact) were imposed. Each treatment had 10 replications. The pots containing the plants belonging to both T_1 and T_2 were placed under open field conditions and maintained as per recommended agronomic practices. Insecticidal applications were completely avoided. Observations were recorded on weekly basis continuously for three weeks on number of leaves infested/plant by leaf miner through visual observations based on the presence of the serpentine mining symptoms. Data was analysed with the help of paired *t*-test.

RESULTS AND DISCUSSION

Serpentine leaf minor is a serious foliage pest of tomato and destroys 50 per cent of plant biomass (Dan, 1966). The intensive larval feeding on host plant leaves not only reduced the normal growth and development of plant but also reduced the plant yield (Spencer, 1973). The present study was carried out to study the effect of removal of seed leaves during transplanting on leaf miner incidence in respective plants.

The data on the serpentine leaf miner infestation in both the treatments for three weeks period revealed that there is significant difference in the mean number of mines per plant between the treatments during the observation period. In the first week, T_1 was significantly (P = 0004) superior to T_2 having zero infestation, while 4.30+0.83 mines/plant were notice in the later. During the second week, also T_1 recorded significantly lower leaf miner infestation (P= 0.01) with 9.70+2.00 mines per plant over T_2 (20.10+2.32). The treatment T_1 recorded significantly (P = 0.01) lower leaf miner infestation (24.10+2.86) in the third week over T_2 which recorded 38.90+5.93 mines/plant (Fig. 1). The leaf miner incidence also progressed quite rapidly in T_2 compared to the T_1 where the seed leaves were removed.

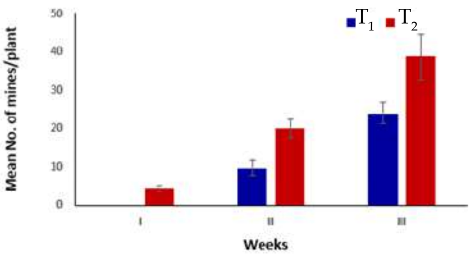

Fig. 1. Weekly incidence of leaf miner, *Liriomyza trifolii* on plants without (T_1) and with seed leaves (T_2)

Fig. 2. Comparative performance of treatments without (T_1) and with seed leaves (T_2)

In the present study, we observed that the infestation of serpentine leaf miner *L. trifolii* started early in plants having seed leaves (T_2) compared to the plants without seed leaves (T_1). During the first week after transplantation no infestation was observed in the T_1 as against T_2 that recorded 4.30 + 0.83 mines per leaf. The present study clearly indicates that simple practice of removal of seed leaves not only delays the serpentine leaf miner infestation, but also brings down the same. The seed leaves or cotyledons are embryonic first leaves of tomato seedlings, two in numbers representing the cotyledons, which play an important role in seed germination and serves pre-photosynthetic leaf function until true leaves appear (Warren and Richard,1976). During transplantation, as tomato seedling would have developed 3-5 true leaves (Jankauskiene et al., 2013), removal of seed leaves might not influence plant growth, however, it brings down the leaf miner infestation drastically (Fig. 2). Earlier studies also reported that the early blight disease and flea beetle incidence first appears in tomato cotyledons and spread later to growing plant parts. It has been advised that incidence could be avoided by removing the cotyledons, while planting (*https://homeguides.sfgate.com/cutting-off-tomato-cotyledons-75847.html*).

CONCLUSIONS

The present study clearly indicated that removal of seed leaves during transplanting in tomato can bring down the serpentine leaf miner infestation and can be part of IPM module against this dreaded pest. Similar studies might be envisaged to explore the role of removal of seed leaves during planting time in other crops, where serpentine leaf miner is a major problem.

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Status and abundance of Maize stem borer (*Chilo partellus*) in Maize under temperate conditions

S.A. Hakeem, Z.A. Dar, M.A. Sofi, R.A. Wani, S. Bashir, S. Nissa, S. Naseer and F. Rasool

Dryland Agriculture Research Station, Srinagar, SKUAST, Kashmir-190 025
E-mail: muneerento@yahoo.co.in

ABSTRACT

Maize stem borer *(Chilo partellus)* is a serious threat to cultivation of kharif maize in India. Losses due the pest varied from 24-83 per cent in different agro-climatic zones of the country. Study was undertaken to find out incidence of the pest in relation to date of sowing and stage of crop growth during sowing season of the crop at Dryland Agriculture Research Station, SKUAST, Kashmir. An experiment was laid in randomized Block Design, in which sowing was done at 15 days interval starting from March 1 during 2016 and 2017. The observations on Maize Stem Borer infestation and Dead Hearts were recorded. The study revealed that the borer infestation was considerably high during April 1 and April 16 sown crop. Consequently, the control measures need to be initiated during the period for effective maize stem borer management strategy.

Key words: Maize, Maize stem borer, *Chilo partellus*, Pest infestation, Dead heart of maize.

INTRODUCTION

The Maize stem borer (*Chilo partellus*) is a key pest of maize during kharif and pose a serious threat to Maize cultivation in India. The losses due to *Chilo partellus* varied from 24 to 83 per cent in the different agro-climatic regions of the country (Chatterji *et al.*, 1969 and Sarup, 1979). *Chilo partellus* damages young plants causing dead heart, while in later stage it bores into the internode, resulting in tunneling which reduces the plant vigour and strength of stem. Peduncle damage at critical stage adversely affects the grain yield (ICRISAT, 1986).

Maize stem borer (*Chilo partellus*) is very serious pest of maize, which is vary widely distributed along the various ecological zones of India. Panwar and Sarup (1979) reported that its infestation progressively increased with the maize sowing from April. It not only damages the maize crop grown in kharif season but also serves as a source of infestation in the main growing season. Hence an attempt was made to find out the incidence of this pest in relation to date of sowing and stage of crop growth during the spring season in a temperate zone.

MATERIALS AND METHODS

Maize evaluation trial was conducted at Dryland Agriculture Research Station, SKUAST, Kashmir during the *kharif* season of 2016 and 2017. Composite-6 Maize Variety was sown in 8 rows with spacings of 40 cm, 70 cm and 50 cm in a Randomised Block Design. In order to study the effect of stages of crop growth on the incidence of Borer, sowing was done on five dates at an interval of 15 days starting from March. All standard of Agronomic procedures were followed. Observations were recorded from two central rows on the following aspects:

1. **Maize stem borer infestation**: Newly hatched larvae cause pin hole injury, which was recorded at weekly interval from 15 days after germination to tasseling stage. Plants were numbered serially in each row and every time fresh infestation was recorded by observing pin hole injury in the plant whorl.
2. **Dead hearts:** The boring larvae caused Dead hearts which were recorded at the time of observation on borer infestation. The percentage borer infestation and dead hearts were transformed into angular form and subjected to analysis of variance.

RESULTS AND DISCUSSION

Incidence of Maize stem borer in relation to date of sowing.

In *Kharif* 2016, maximum borer incidence of 70.0 per cent was recorded in the crop sown on April 15, followed by 60 per cent on April 1. These infestations did not differ significantly among themselves but were significantly higher than the borer infestation of 35.12 per cent recorded in the crop sown on March 1. Similarly, in *kharif* 2017, maximum borer incidence (68.12%) was recorded in the crop sown on April 15 followed by 67.22 per cent on May 1. These infestations were significantly higher than those recorded in the crop sown on March 1 and 15 and April 1 (Table 1).

But the infestation increased with delay in the sowing dates. However, in the present investigation 35.12 and 23.63

Table 1. Incidence of Maize stem borer during Spring sown Maize under temperate conditions

Date of sowing	Percent Borer infestation		Dead heart	
	2016	2017	2016	2017
March 1	35.12	23.63	3.25	0.0
March 16	53.78	24.17	3.60	0.00
April 1	60.0	22.95	2.93	1.00
April 16	70.0	68.12	7.17	1.72
May 1	51.24	67.22	4.25	5.20
CD at 5 %	**13.90**	**13.37**		

per cent borer infestation was recorded in the crop sown on Ist March 2016 and 2017 respectively. Trend of borer infestation was found in increasing order in the crop sown up to April 16, 2016 while in 2017, it was more or less similar in the crop sown up to April 1 (Table 2). The highest borer infestation, however, occurred in the crop sown on April 17 during both the years. As per data of Table 2 borer infestation was highest in 29 days crop of spring 2016, whereas, it was maximum in 22 days crop followed by 29 days crop in spring 2017. Borer infestation was invariably low in 15 and 43 days old crop during both the years. It is clear from the observations that the borer infestations was considerably higher in crop of 3 to 4 weeks. Therefore, control measures should be initiated at this stage of crop growth.

Table 2. Incidence of Maize borer incidence to stages of crop growth during spring sown Maize

Stage of crop growth days after germination	Mean borer %	
	2016	2017
15	4.00	3.70
22	13.10	11.89
29	16.20	12.62
36	13.68	8.60
43	5.50	4.20
CD at 5 %	**3.97**	**3.92**

The magnitude of borer infestation in the crop sown before April 17 in 2016 was comparatively higher than the crop sown on similar dates in 2017. The reason may be due to favorable conditions, which prevailed in 2016. It has been reported that there is borer free Maize crop, if sowing is done up to March 1 (Panwar and Sarup 1979). It is, therefore, concluded that sowing of Maize be done before April to avoid the pest attack and breeding ground for this pest.

CONCLUSION

An attempt was made to study the incidence of Borer infestation and stage of crop growth during spring season of 2016 and 2017. The maximum borer infestation was recorded in the crop sown on April 16 during both the years. This was followed by that sown on 1st April in 2016 and May (2016, 2017). However, borer infestation was comparatively less in the crop sown on March 1 and March 15 and April 1. It was clear from the observations that the borer infestation was considerably higher in crop of 29 days and control measures should be initiated at this stage of crop growth.

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Management Modules for *Spodoptera litura* and *Myzus nicotianae* in FCV Tobacco

K China Chenchaiah

Principal Scientist, ICAR-CTRI Research Station, Kandukur-523 105. A.P.
E-mail: kcchenchaiah@gmail.com

ABSTRACT

Four Management modules for the control of *Spodoptera litura* and *Myzus nicotiana* in FCV tobacco under Southern Light Soil condition were evaluated during 2015-16 and 2016-17 crop season. Results obtained during two years were pooled and subjected to RBD analysis. The mean infestations reached its peak during 55 to 65 DAP of the crop in both the seasons. The infestation of caterpillar and aphid was low to medium in both the years. The mean proportion of plants damaged (4.25 to 11.15%) and damage score (2.1 to 2.45) recorded due to caterpillar in IPM module was less when compared to that of control plots (4.75 to 12.45% plants damaged and 2.25 to 2.85 damage score). Similar observation was recorded in case of aphid with the mean proportion of plants damaged (6.20 to 11.25%) and damage score (0.76 to 1.61) in IPM module, while control plots had 5.95 to 13.70% plants damaged and 1.40 to 2.41 damage score. Significant differences in yield parameters were observed among seasons and as well as in treatments. The seasonal variation in yield is due to changing weather conditions in successive years. The IPM module consisting of Jowar as barrier crop, NSKS @ 0.5% spray, *Spodeptera* NPV 250LE spray, Proclaim @ 5g/10 L water spray, Confidor @ 3ml/ 10 L water spray based on ETL gave highest mean yield of green leaf (11,577.5 kg/ ha), cured leaf (1,807.1 kg/ ha), bright leaf (1,091.2 kg/ ha) and grade index (1,206.2). The cured leaf yield recorded 25.63 per cent increase over the control. The mean total income from this module was Rs. 2,10,527/- per ha and the Cost: Benefit ratio was 1: 6.58. It also gave 25.63 per cent higher returns over the control module. This IPM module was demonstrated in 1.0 acre area of a nearby farmers' field during 2017-18 cropping season and the farmer got convinced with the technology with a production of 8.0 Q/acre cured leaf.

Key words: Pest Management modules, *Spodoptera litura, Myzus nicotianae,* FCV Tobacco, Southern Light Soil condition.

Flue Cured Virginia (FCV) Tobacco is one of the commercial crops of the farmers of Southern Light Soil (SLS) area of Prakasham and Nellore Districts of Andhra Pradesh. It is grown mainly on low to medium fertile, light red sandy loams, which receive a meager rainfall of 850-900 mm annually (Gopalachary, N.C. 1984), out of which 550 mm is received during NE monsoon period, mostly in the form of cyclonic rains. During 2017-18, it was grown in about 47,475.45 ha, with a production of 77.40 million kg of cured leaf (Anonymous, 2018a). The tax revenue generated in India during 2016-17 by Tobacco and tobacco products is to the tune of Rs. 34,000 Crores and the tobacco industry provided a livelihood to 45.7 million farmers and farm labourers (Anonymous, 2018b). According to one study, about 19.35 per cent cured leaf is lost by insects of both sucking and caterpillar pests (Anonymous, 2004). Insect pests *Spodera litura,* and *Myzus nicotianae* are major limiting factors in the production of FCV Tobacco. According to Sitaramaiah, *et al.*, 2001, *S. litura* alone can cause 10-20 per cent damage to the field crop of FCV tobacco. Similarly, 8-10 per cent infestation by aphid can cause a monetary loss of Rs. 2,000 to 2,600/ hectare (Anonymous, 1991). Farmers believe that application of pesticides is essential to curtail the yield loss by insects. Heavy dependence on chemical pesticides, however, brings various undesirable effects on agro climate and environment, besides leaving higher residues in the leaf. The residues in the cured leaf, that is not complying with the recommendation of Guided Residue Levels (GRL), affects the exports from the country and thereby, directly affecting the economy of the farmers as well as the Nation. Several pest control methods are followed by the farmers to combat the individual pest. However, location specific management module consisting of cultural, biological and need based pesticide use is required to be developed to overcome the above problems. Chenchaiah, K.C., 2008 reported a suitable IPM module consisting of need based Bio and Chemical control module for FCV tobacco in SLS region. The chemicals used in the above study require revision as the current GRL levels of those chemicals were changed. Hence, in the current study, three management modules along with control were evaluated. The modules have chemicals of low GRL levels for the management of *Spodoptera litura* and *Myzus nicotianae,* the important pests of FCV tobacco. The economics for each module was also calculated and compared.

MATERIALS AND METHODS

One thousand seedlings each of FCV Tobacco cv. Siri were planted at 65 x 65 cm spacing in the main field under three Management Modules and one control plot. The treatments were imposed on each of the plot. In each module 20 x 5 plants were tagged as five replications to record insect incidence and intensity at regular intervals. Five blocks of 36 plants each were marked in each module and used as five replications for the purpose of recording yield parameters. Recommended dose of fertilizers (60-60-80 kg/ha NPK) and standard agronomical practices were followed to raise the crop (Anonymous, 2007). One life saving irrigation was given to the crop from the harvested and stored rain water at 40 days after planting (DAP). The experiment was conducted for two seasons, during 2015-16 and 2016-17 year. The best module thus arrived was demonstrated in one farmer's field during 2017-18 cropping season. The three management modules used in this experiment were 1) Chemical control module: Proclaim @ 5g/ 10 L water spray at 35-40 DAP, Novoluron @ 10 ml/ 10 L water spray at 50-55 DAP, Confidor @ 3ml/10 L water spray at 40-45 DAP and Thiomethoxam @ 3g/ 10 L water spray at 60-65 DAP; 2) Bio control module: Jowar as barrier crop, NSKS @0.5% spray at 20-25 DAP, *Spodoptera* NPV-250 LE spray at 35-40 DAP, *Verticellium lacani* spray @ 50g/ 10 L water at 45-50 and 55-60 DAP; 3) IPM module: Jowar as barrier crop, NSKS 0.5% spray, *Spodeptera* NPV 250LE spray , Proclaim @ 5g/ 10 L water spray, Confidor at 3ml/ 10 L water spray based on ETL and 4) control module (no spray). All the component sprays in Chemical control and Bio-control modules were applied in the field as per the schedule and in IPM module the sprays were applied on the basis of pest intensity and the decision was taken only after considering the economic threshold level (ETL) of the pest (*i.e.*, 10% plants damaged or 10 moths/ week in the pheromone trap for *S. litura* and 10% top leaf infested plants for *M. nicotianae*).

Observations on the incidence/ intensity of the tobacco cater pillar was recorded by per cent plants damaged and plant damage score by *S. litura*; per cent plants damaged by aphid and aphid count score on plants by *M. nicotiana* and yield parameters like weight of total harvested green, cured, bright, medium, low grade leaf and from harvested yield, the grade index was calculated for each module. The results obtained from 4 treatments and 5 replications were subjected to statistical analysis under Randomized Block Design (season wise and pooled analysis) as suggested by Gomez, A.K and Gomez, A.A (1984). Economics of each of the treatment was also calculated. Income was calculated based on the mean cured leaf price of @ Rs.116.50/- per kg (as obtained for the produce of our Research Station in the Tobacco Board auctions during the two cropping seasons). Similarly, benefit over control, cost of control involved, Cost: Benefit Ratio and proportionate returns increase over control was also calculated.

RESULTS AND DISCUSSION

The incidence and intensity of *Spodoptera litura, and Myzus nicotianae* were recorded along with the activity of different parasites. The infestation of *S. litura* was recorded from 25[th] DAP and the per cent plants damage ranged between 3.80 to 11.8 in the first year and 3.9 to 13.20 during the second year. The mean infestations reached its peak during 55 to 65 DAP of the crop in both the seasons and it ranged between 4.0 to 12.45 per cent plant damaged by caterpillar (Fig. 2) and a damage rating of 2.10 to 2.85 (Fig. 1).

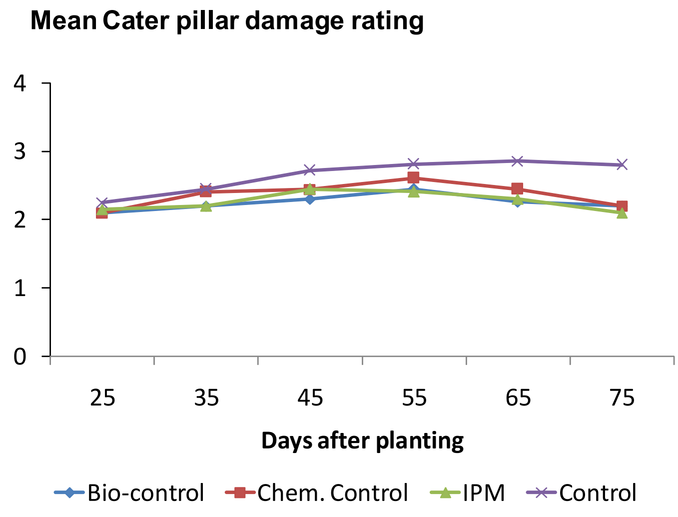

Fig. 1. Mean Cater pillar damage rating.

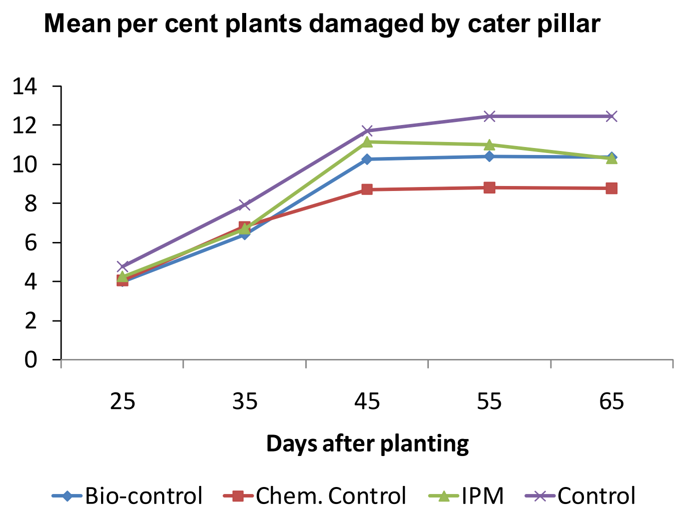

Fig. 2. Mean per cent plants damaged by cater pillar.

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The mean per cent plants damaged (4.25 to 11.15) and damage score (2.1 to 2.45) recorded due to caterpillar in IPM module was less when compared to that of control plots (4.75 to 12.45% and 2.25 to 2.85 damage score), which is due to the presence of more number of predators on the barrier crop as well as on tobacco. Sreedhar *et al.*, (2004) also recorded similar type of lower damage score and per cent plants damaged by caterpillar in IPM plots of FCV tobacco.

The incidence of *M. nicotianae* is observed in the 45th DAP and the highest peak of 16.6 per cent plants damage on 65 DAP and it varied from 6.2 to 16.6 per cent in the first year and 4.2 to 12.1 per cent in the second year with a mean of 4.8 to 13.7 per cent in different modules (Fig. 4), while the mean damage score of aphid ranged between 0.76 to 1.77 (Fig. 3). The mean plants damaged (6.20 to 11.25%) and damage score (0.76 to 1.61) was recorded due to aphid in IPM module. It was less when compared to that of control plots (5.95 to 13.70 % and 1.40 to 2.41 damage score) which is due to the presence of more number of predators on the barrier crop as well as on tobacco and timely control of pest intensity by IPM methods. Sreedhar *et al.* (2004) also recorded similar type lower damage score and plants damaged by aphid in IPM plots of FCV tobacco. This shows that the infestation of caterpillar and aphid was low to medium in both the years. The predators recorded during this study in abundance were grub (5 no) and adults (3 no.) of Coccinellid beetles, maggots of syrphid flies (6 no), *Verticellium sp* on aphid (6 no. infected aphids) and different stages of Mirid bugs (6 no.) per affected tobacco leaf.

The different yield parameters (green leaf, cured leaf, bright leaf yields and grade index) recorded in this experiment over the two years on hectare basis has been presented in Table-1. All the yield parameters differed significantly among the treatments. The green leaf yield of tobacco ranged between 8,139.4 to 10,994.1 kg/ ha during the first year (1) and 10,655.7 to 12,160.9 kg/ ha during the second year (2), being the highest yield recorded from IPM module (10,994 and 12,160.9 kg/ ha) in both the years. Similar trend was observed in case of cured leaf and bright leaf yields. The highest cured leaf yield, 1,810.7 kg/ ha (1) and 1,803.5 kg/ ha (2) with a mean of 1,807.1 kg/ ha (Table-2) was obtained from IPM module. The variation of the leaf yields obtained over the two seasons is due to the rainfall received and climatic conditions prevailing during the

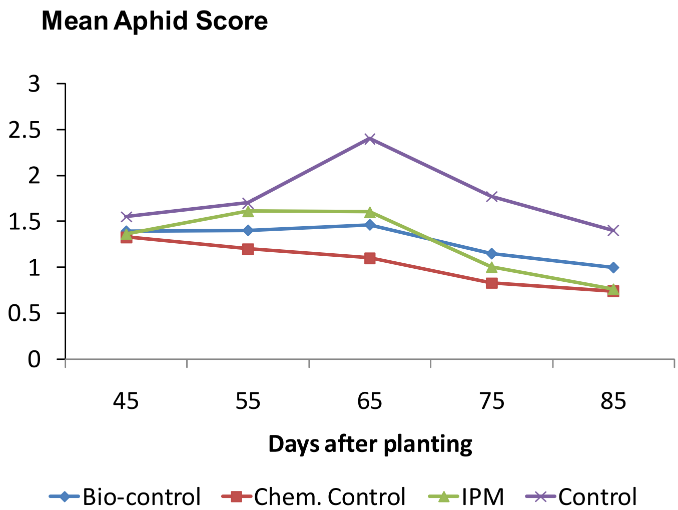

Fig. 3. Mean Aphid score.

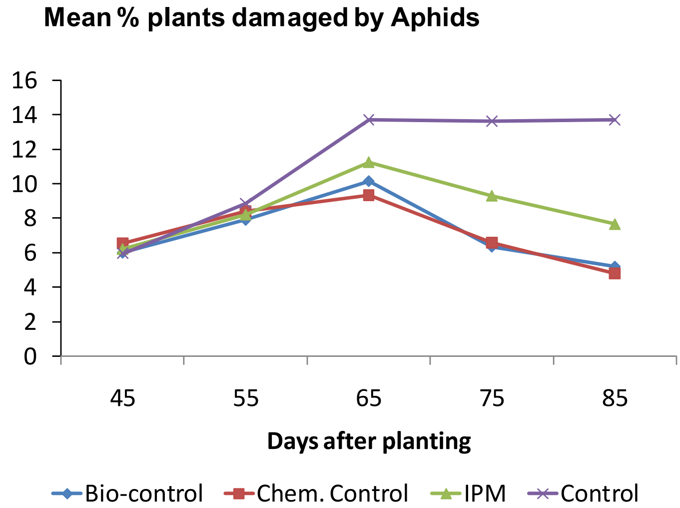

Fig. 4. Mean per cent plants damaged by Aphid.

Table 1: Performance of Management Modules of *S. litura* and *M. nicotiana* in FCV Tobacco under SLS Condition during 2015-16 and 2016-17 (Yield kg / ha).

Management Modules	Year	Green leaf	Cured leaf	Bright grade	Grade index
1. Bio control Module	1	9254.1	1556.9	852.1	912.6
	2	10892.3	1672.6	917.2	1160.3
2. Chemical control Module	1	10026.31	1642.3	938.9	961.2
	2	1697.1	1789.3	952.2	1198.6
3. IPM Module	1	10994.1	1810.7	1059.8	1108.5
	2	12160.9	1803.5	1122.6	1303.9
4. Control.	1	8139.4	1359.6	804.7	813.9
	2	10655.7	1517.2	896.1	1075.9
F Test		Sig.	Sig.	Sig.	Sig.
Sem. ±	1	277.4	43.6	33.9	35.3
	2	311.9	68.2	39.3	48.1
CD 5%	1	851.4	133.7	104.1	108.4
	2	957.5	209.4	120.6	147.6
CV%	1	6.46	6.12	8.30	8.33
	2	6.15	9.00	9.04	9.08

cropping season. This type of variation is observed generally in the low fertile, low rain fall and uncertain rain receiving areas of SLS region. In one study, Chenchaiah, (2008) reported highest cured leaf yield of FCV tobacco 712 to 1,541 kg/ ha from IPM plots in SLS region of Andhra Pradesh, while Sreedhar, *et al.* (2005) recorded 2,050 to 2,250 cured leaf yield of FCV tobacco from IPM plots in NLS region of Andhra Pradesh. This variation occured due to the crop condition during growth period, moisture availability and fertility status of the native soils.

The bright grade leaf yields also differed significantly in both the years. The highest yields, 1,059.8 kg/ ha in the first year and 1,122.6 kg/ ha in the second year with a mean of 1,091.2 kg/ ha (Table-2) was obtained in the present study from IPM module, which might be due to the timly control of insects like cater pillar and aphid. Sooty mold, which grows on the aphid infected plants, causes loss of yield and in addition makes the affected leaf unfit for curing. So, the aphid infected molded leaf leads to low grade produce. In another study, Shenoi *et al.* (2005) reported that bio intensive integrated module for the management of tobacco aphid gave a bright grade yield of 1,176-1,231 kg/ ha cured leaf with more than 95 per cent control of the insect in Karnataka light soil region. Chenchaiah, (2008) reported similar highest green leaf (6,952 kg/ ha), cured leaf yields (1,126 kg/ha) and bright grade leaf (796 kg/ ha) from need based Bio & Chemical control modules of FCV tobacco in SLS region. The grade index in the current study, recorded highest in IPM module in both the years as 1,108.5 and 1,303.9 with a mean of 1,206.2 also indicates the superiority of IPM module in controlling the insects effectively and in giving higher yields.

The results obtained during the two years were subjected to pooled analysis and it was presented in Table-2. The green leaf, cured leaf, bright leaf yields and grade index obtained in various treatments differed significantly. The mean green leaf and cured leaf yield varied between 9,397.6 to 11,577.5 and 1,438.4 to 1,807.1 kg/ha, respectively and the highest cured leaf yield (1,807.1 kg/ ha) was recorded from IPM module. In one study, Raghupathi and Jaya Krishna, (2005) reported a relatively high green leaf and cured leaf yields in the IPM module plots receiving biointensive + chemical involving ecofriendly and need based application of Endosulfan, Chlorpyriphos and Acephate. The increase in the cured leaf yield was 17 per cent over control. Similarly, Chenchaiah, (2008) reported 22.13 per cent increase in cured leaf yield from need based Bio and Chemical module-5 in SLS region, which was as high as 1,126 kg/ ha cured leaf. In the current study, the bright grade leaf (1,091.2 kg/ ha) and grade index (1,206.2) is also highest with 25.63 per cent cured leaf increase over control was obtained from IPM module due to timely control of pest and presence of higher bio control agents on barrier crop and as well as on tobacco plants of IPM module plots. Mean income from one hectare cropped area ranged between Rs. 1,67,574/- in control to Rs. 2,10,527/- in IPM Module. The benefit over the control in different treatments ranged between Rs. 20,550/- from Bio- control module to Rs. 42,953/- from IPM module. The mean cost of control was also calculated based on cost the treatment(s) used in the field which ranged between Rs. 6,525/- to Rs. 11,260/-. The Cost and Benefit ration was highest, 1: 6.58 in IPM module followed by chemical control module. The returns increase over the control was also highest, 25.63 per cent in IPM module. All the above parameters indicate the superiority of IPM module involving the application of cultural, bio and

Table 2: Performance of Management Modules of *S. litura* and *M. nicotiana* in FCV Tobacco: Mean Yields and Economics per hectare during 2015-16 & 2016-17. (Pooled analysis)$^{\$}$.

IPM Module	Green leaf (kg)	Cured @ leaf (kg)	Bright grade (kg)	Grade Index (kg)	Income $ from Cured leaf Rs./ha	Benefit over control (Rs.)	Cost of Pest control (Rs.)	Cost : Benefit ratio	% returns, increase over control
1. Bio control Module	10073.2	1614.8 (12.26)	884.7	1036.5	1,88,124	+20,550	8350	1: 2.46	12.26
2. Chemical control Module	10861.7	1715.8 (19.29)	945.6	1079.9	1,99,891	+32,317	11260	1: 2.87	19.29
3. IPM Module	11577.5*	1807.1* (25.63)	1091.2*	1206.2*	2,10,527	+42,953	6525	1: 6.58	25.63
4. Control.	9397.6	1438.4	850.4	944.9	1,67,574	---	---	---	---
S.E.m. ±	229.7	44.6	24.1	32.3					
CD at 5 %	670.3	130.1	70.3	94.2					
CV %	7.6	9.5	8.1	9.7					

$Calculated @ Rs. 116.5 each kg of cured leaf (mean of two years).
@Figures in parenthesis indicate the values of cured leaf % increase over control.
*Significant at 5% level of probability.

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chemical control methods based on ETL. This saves avoidable wastages of inputs on control of the pest and reduces the pollution of the environment and residues in the cured leaf of tobacco in addition to higher returns.

The IPM module which proved superior in this study was demonstrated as FLD in 1.0 acre plot of a nearby farmer (Sri. D. Bramhaiah, Oguru village, Kandukur Mandal of Prakasham District) during 2017-18 cropping season. He harvested an average of 8.00 Q/ acre cured leaf and was convinced with the technology. The technology resulted in increased yield and was also appreciated by the local farmers.

CONCLUSION

The IPM module consisting of Jowar barrier crop, NSKS @0.5% spray, *Spodeptera* NPV 250LE spray, Proclaim @ 5g/ 10 L water spray, Confidor @ 3ml/ 10 L water spray based on ETL was found to be effective and recommended for pest control in FCV tobacco grown areas under SLS domain of Andhra Pradesh.

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Screening the rust resistant genotypes against root rot complex of soybean under glasshouse

Preeti Teli, Shamarao Jahagirdar and Basavaraja G.T.

Department of Plant Pathology, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: shamaraoj@gmail.com

ABSTRACT

Soybean is an important oil seed and pulse crop. Among various disease root rot disease is complex in nature, which causes predominant yield loss. Since disease is soil borne in nature, chemical method of management is expensive, hence, utilization of resistant cultivars in farming is simple, effective and economical in the management of diseases. In present investigation, ten advanced lines, which are resistant to rust disease were screened against root rot complex of soybean in sick soil in pots under glasshouse. The result revealed that, two genotypes *viz*., DSb 28-3 and DSb 30-2, were showing moderately susceptible reaction. Five of the genotypes depicted susceptible reaction *viz*., DSb 24, DSb 25, DSb 33, DSb 34 and DSb 21. Three of the genotypes were highly susceptible *viz*., DSb 23-2, DSb 27 and JS 335 under glasshouse condition.

Key words: Glass house, Soybean, Rust, Resistant genotypes, Root rot complex

Soybean [*Glycine max* (L.) Merril] which has been referred as 'gold from the soil' evolved from *Glycine ussuriensis*, a wild legume native to China, which has been used in China since eleventh century BC. It is considered as a golden bean, miracle bean and wonder crop of the 20th century because of its characters and usage. Soybean is a legume crop, but it is widely used as oilseed due to its poor cooking ability on account of inherent presence of trypsin inhibitor that limits its usage as pulse crop. Soybean has a good nutritive value and very rich protein food, because it contains more than forty per cent protein and all the essential amino acids particularly glycine, tryptophan and lysine, etc. Soybean also contains about twenty per cent oil with an important fatty acid, lecithin and Vitamin A and D. The four per cent mineral salts of soybean are fairly rich in phosphorous and calcium.

Soybean is grown throughout the world including USA, Brazil, Argentina, China and India. It is grown throughout the tropical, subtropical and temperate regions of the world. The crop is grown over an area of 11.07 m ha with a production of 8.64 mt having a productivity of 781 kg/ha (Anon., 2015). Madhya Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, Karnataka and Telangana are the important soybean growing states in India. In Karnataka, soybean is grown over an area of 2.90 lakh ha with a production of 1.81 lakh tonnes and productivity of about 615 kg/ha (Anon., 2015). Soybean crop can be affected by more than 100 pathogens {Sinclair and Shurtleff (1975)}. The major economically important diseases are rust, wilts, leaf spots, rots, powdery mildew, bacterial and viral diseases. Among the soil borne diseases of soybean, root rot complex caused by *Sclerotium rolfsii* Sacc., *Rhizoctonia bataticola* (Taub.), Butler (*Sclerotium bataticola* Taub.) (Pycnidial stage: *Macrophomina phaseolina*) and *Fusarium oxysporum* [(Schlet) Emed. Snyd and Hans] are gaining more importance. This disease is distributed throughout the world and is prevalent in areas that experience warm climate and causes significant yield losses seen in monoculture or short rotation of soybean {Aken and Dashiell (1991)}. All the three pathogens are soil inhabitants and polyphagous facultative parasites.

Plant pathogens exhibit variations in their morphological, biological and pathogenic characters. Hence, understanding the structural and molecular variation may be useful in devising novel management strategies. Information in this aspect is very much limited and soybean, being an important pulse crop, is receiving wider attention in India as well as in Karnataka. Root rot complex has become an important production constraint in northern Karnataka for last few years. Sangeetha and Shamarao Jahagirdar (2013) reported the association of *Sclerotium rolfsii, Rhizoctonia bataticola and Fusarium* sp. in causing root rot complex of soybean in northern Karnataka. Among them *Rhizoctonia bataticola* was predominately associated and the degree of pathogenic variability of these pathogens varied from one region to other. Since root rot complex pathogens are soil borne, use of resistant variety is very feasible approach to combat the diseases. In the present investigation, ten genotypes were screened against the root rot complex of soybean in glasshouse, where none of the genotypes were immune, resistant and moderately resistant.

MATERIALS AND METHODS

Ten advanced lines, which are resistant to rust disease, were obtained from the All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. These were screened against root rot complex of soybean in sick soil in pots under glasshouse (Fig. 1). The pathogens *R. bataticola*, *Fusarium* sp. and *S. rolfsii* were mass multiplied by standard techniques (Fig. 2) and applied at 10 g per 100 g of soil to the 15 days old soybean seedlings at the root zone. Observation was recorded on per cent disease incidence, days taken for first appearance of root rot complex symptoms and days taken for complete death and also individual plants were split open and recorded the root rot length rotted after 60 days of sowing.

List of genotypes used for screening at glass house at AICRPS Dharwad

SL. No.	Genotypes
1	DSb 21
2	DSb 23-2
3	DSb 24
4	DSb 25
5	DSb 27
6	DSb 28-3
7	DSb 30-2
8	DSb 33
9	DSb 34
10	JS 335

The above mentioned 10 soybean genotypes were screened in glass house of AICRPS, Dharwad. The sowing was done on 2nd February and observations were recorded as 30 and 60 days after sowing, the observations were recorded as per cent disease incidence by using following formula

$$\text{Per cent disease incidence} = \frac{\text{Number of plants affected}}{\text{Total number of plants observed}} \times 100$$

The per cent disease was recorded and grouped by using following grade system applied for chickpea crop (Riyaz *et al.*, 2013). The grade 0-5 scale was used with the following descriptions.

Grade	Per cent incidence (%)	Description
0	0	Immune
1	1-10	Resistant
2	10.1-20	Moderately Resistant
3	20.1-30	Moderately Susceptible
4	30.1-50	Susceptible
5	>50	Highly susceptible

Based on their disease reaction, genotypes were categorized into immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible genotypes.

RESULTS AND DISCUSSION

The management of the disease through host plant resistance is important component in all the crop improvement programmes. Utilization of resistant cultivars in farming is the most simple, effective and economical method in the management of diseases. Besides these, the resistant cultivars conserve natural resources and reduce the cost, time and energy, when compared to other methods of disease management.

In present investigation, ten rust resistant lines were screened against root rot complex diseases. The results of screening of rust resistant material against root rot are presented in Table 1 and Fig. 3. The observations taken for symptom expression such as yellowing ranged from 23 to 45 days. The genotype DSb 23-2 and JS 335 took 25 days for yellowing while, DSb 24 and DSb 25 took 35 to 40 days for drying. Eleven genotypes were screened against the root rot complex of soybean in glasshouse, where none of the genotypes were absolute resistant, resistant and moderately resistant. Two genotypes showed moderately susceptible reaction *viz.*, DSb 28-3 and DSb 30-2. Five of the genotypes showed susceptible reaction *viz.*, DSb 24, DSb 25, DSb 33, DSb 34 and DSb 21. Three genotypes were highly susceptible *viz.*, DSb 23-2, DSb 27 and JS 335. In the present investigation, eleven genotypes were screened against the root rot complex of soybean in glasshouse where none of the genotypes were immune, resistant and moderately resistant. Two genotypes

Table 1: Screening of soybean genotypes in glasshouse against root rot complex of soybean caused by *Sclerotium rolfsii*, *Rhizoctonia bataticola* and *Fusarium* sp.

Genotypes	Root rot incidence (%)	Reaction
DSb 21	41.67	S
DSb 23-2	66.67	HS
DSb 24	45.56	S
DSb 25	38.89	S
DSb 27	58.33	HS
DSb 28-3	27.78	MS
DSb 30-2	23.33	MS
DSb 33	31.67	S
DSb 34	33.33	S
JS 335	72.22	HS

Note : HS- Highly susceptible (>50 %)
MS- Moderately susceptible (20.1-30%)
S- Susceptible (30.1-50%)

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Fig. 1: General view of screening experiment under glasshouse

Fig. 2: Mass multiplications of root rot complex pathogens

were showing moderate susceptibility reaction *viz.*, DSb 28-3 and DSb 30-2. Five of the genotypes showed susceptible reaction *viz.*, DSb 24, DSb 25, DSb 33, DSb 34 and DSb 21. Three genotypes were highly susceptible *viz.*, DSb 23-2, DSb 27 and JS 335 to the root rot complex disease. These genotypic reactions are previously reported by Prabhu (2004) that among the 64 varieties no variety was resistance. Uma and Thapliyal (1991) reported that among the five varieties screened (Bragg, PK 262, PK 308, PK 327 and PK 416), Bragg was highly susceptible with pre emergence rot of 83.3 per cent. This necessitates the screening of more and more diverse germplasms against wilt Sangeetha (2011).

When the genotypes screened against *Fusarium* sp., *Rhizoctonia bataticola* and *Sclerotium rolfsii*, all the genotypes were highly susceptible as breeding for resistance for a single soil borne pathogen is challenging work and breeding for resistance to all the soil borne pathogens is highly difficult.

Fig. 3: Screening of soybean genotypes in glasshouse against root rot complex of soybean

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Management of sigatoka leaf spot disease of banana with fungicides and petroleum based mineral oil formulations

B.K. Pradhan*[1], G. Biswal[2] and S. Swain[3]

[1]*Junior Plant Pathologist. AICRP on Fruits,* [2]*Professor, Dept. of Plant Pathology,* [3]*Scientist in Charge, AICRP on Fruits*
Orissa University of Agriculture & Technology, Bhubaneswar – 751 003, Orissa
**Corresponding Auther: B.K. Pradhan, Email: bipinpradhan99@gmail.com*

ABSTRACT

The experiment was carried out at Horticultural Research Station, O.U.A.T, Bhubaneswar during 2013-14 and 2014-15 with the objectives of finding out the best treatment for management of sigatoka leaf spot disease (*Mycosphaerella musicola*) of banana. The investigation revealed that among eight treatments tested, T6 (application of 0.05 per cent propiconazole + 1 per cent mineral oil) recorded its superiority in respect of disease control, yield and quality of fruit than rest of the treatments. This treatment also resulted in least disease severity and more disease free leaves (YLS) (1.29 & 7.7 respectively) along with the highest bunch yield (21.00 kg plant^{-1}) and B:C ratio of 2.60. Difenconazole 1 ml l^{-1} (0.1%)+ petroleum based mineral oil (1%) with the disease severity of 1.89 in 0-6 scale was found to be the second best treatment. Maximum disease severity and lowest bunch weight was observed in control. Hence, the spraying(s) of 0.05 per cent propiconazole + 1 per cent mineral oil is recommended for effective control of sigatoka leaf spot disease of banana.

Key words: Sigatoka leaf spot, Propiconazole, Petrolium based mineral oil, Disease severity, Youngest leaf spot disease, Yield

Banana (*Musa* spp.), commercially grown in many tropical and subtropical countries for its utilization as dessert and staple food is the fourth most important fruit crop of India. The crop, having wide distribution in the country, accounts for 27.01 million tonnes from an area of 0.765 million ha contributing nearly 22.15 per cent of the global production (FAO, 2012). Despite the fact that crop is grown in diverse agro climatic conditions of the country, its production is continuously hampered by a number of diseases causing losses both in quantity as well as quality. Of the many diseases occurring on banana, sigatoka leaf spot disease caused by *Mycosphaerella musicola* Leach, is considered as serious threat to world banana production (Leach (1946), Maurichon *et al.* (1997). In the recent past, cultivation of banana in the parts of Odisha is gaining momentum with increased irrigation sources. This situation has virtually led to the congenial microclimate for perpetuation and spread of the pathogen (Elangovan *et al.*, 1990). Further, vast area under banana in Orissa is occupied with cv. Champa (AAB), Patkapura (AAB) and Grand Naine (AAA), which are highly susceptible to sigatoka disease (Romero and Sutton, 1997).

The sigatoka leaf spot disease not only affects the banana leaves but also results in pre-mature fruit ripening and bunches, rendering these unmarketable. The crop loss due to leaf spot disease ranged from 15 to 45 per cent. The chemical control of disease being practiced in the county involves excessive use of chemical fungicides which pose serious danger to the environment and also compell the pathogen to develop strains resistant to fungicides. Therefore, petroleum based mineral oil (Banole), which is biodegradable in nature, in combination with half of the recommended dose of different fungicides *viz.*, propiconazole, carbendenzim, tridemorph, against their sole applications, were evaluated.

MATERIALS AND METHODS

The field trials were laid out with banana cv. Graind Naine during 2013-14 and 2014-15 in experimental plots of All India Co-ordinated Research Project on Fruits of O.U.A.T, Bhubaneswar. The experiment was conducted with eight treatments in Randomized Block Design in three replications. The plant to plant and row to row spacing was 1.5×1.5m. All the recommended agronomic practices for raising crop were followed. The treatments were T1= untreated check, T2= petroleum based mineral oil, T3= propiconazole (0.1%), T4= difenconazole (0.1%), T5= mancozeb (0.25%) + carbendazim (0.1%), T6= propiconazole (0.05%) + petroleum based mineral oil (1%), T7= carbendazim (0.05%) + petroleum based mineral oil (1%), and T8= difenconazole (0.1%) + petroleum based mineral oil (1%).

The fungicides were sprayed thrice at 25 days interval after five month of planting. Their effectiveness was recorded on the basis of severity of sigatoka leaf spot disease. A (0-6)

Table 1. Mean of different treatments on growth and yield parameters in the year 2013-14 and 2014-15

Treatments	Growth parameters				Yield parameters			B:C Ratio
	Plant height (cm)	Plant girth (cm)	No of leaves	Leaf area (sq. cm)	No of hands	No of finger	Yield bunch^{-1} (kg)	
T1	164.5	52.2	6.6	7923.8	7.1	102.3	12.5	1:1.7
T 2	178.6	56.1	6.8	8011.2	7.8	109.4	14.0	1:1.82
T 3	179.2	57.3	6.9	8264.8	8.0	117.8	15.4	1:1.97
T 4	182.9	58.1	7.3	8339.5	8.3	124.7	17.2	1: 2.08
T 5	189.2	58.9	7.2	8420.3	8.4	126.3	17.5	1:2.11
T 6	198.3	66.1	7.9	8772.6	9	155.7	21.00	1:2.60
T 7	189.4	60.5	7.3	8578.4	8.7	136.2	18.5	1:2.27
T 8	194.8	61.9	7.7	8676.8	8.8	142.7	19.1	1:2.38
S.Em(±)	2.18	1.78	0.39	67.55	0.25	1.59	0.27	-
CD at 5%	6.57	5.36	1.19	203.59	0.74	4.78	0.82	-

scale was followed for scoring the disease index (Huffaker and Gutierrez (1991), Jeger *et al.* (1995).

where, 0 = No symptoms,

1 = Less than 1% of lamina with

symptoms (only streaks and / or Up to 10 spots),

2 = 1 to 5% per cent of lamina with symptoms,

3 = 6 to 15% per cent of lamina with symptoms,

4 = 16 to 33% per cent of lamina with symptoms,

5 = 34 to 50% per cent of lamina with symptoms

6 = 51 to 100% per cent of lamina with symptoms.

Observations were recorded with respect to growth parameter (plant height, plant girth, no of leaves at the time of harvesting and leaf area). PDI, youngest leaf spotted (YLS) and yield parameters (no of hands, no of finger, bunch weight and economics).

RESULTS AND DISCUSSION

The pooled data of two years presented in the Table 1, revealed least disease severity of 1.29 in plots applied with propiconazole 0.5 ml l^{-1} (0.05%) + petroleum based 1 per cent mineral oil (T-6). Difenconazole 1 ml l^{-1} (0.1%) + petroleum based mineral oil (1%) (T-8), recording 1.89 disease severity, was found the second best treatment (Table 2). The per cent disease severity (0-6 scale) in rest of the treatments ranged between 2.31 to 3.42 against the highest (4.21) in untreated control. The treatment with 0.05 per cent propiconazole + 1 per cent mineral oil recorded highest number of disease free leaves (7.7), while, difenconazole 1 ml l^{-1} (0.1%) + petroleum based mineral oil (1%) recorded second highest number of disease free leaves (7.0) and was statistically at par resulting in higher yield bunch^{-1} (21.00 kg and 20.10 kg, respectively). The rest of the treatments recorded disease free leaves (YLS) in the range of 5.5 to 6.5 and the yield per bunch in the range of 13.9 kg to 18.5 kg against the least (12.5 kg) in control. The treatments with 0.05 per cent propiconazole + 1 per cent mineral oil recorded higher B:C ratio (2.60) followed by difenconazole 1 ml l^{-1} (0.1%) + petroleum based mineral oil (1%) with second highest (2.38) and the lowest in untreated control (1.7). Mineral oil used alone did not perform good compared to other fungicides tested.

Table 2. Per cent disease intensity and numbers of youngest leaf spotted (YLS) in different treatments

Treatments	PDI (0-6 scale)	Number of YLS
T1	4.21	4.7
T 2	3.31	5.5
T 3	3.42	5.8
T 4	2.59	5.8
T 5	3.11	6.3
T 6	1.29	7.7
T 7	2.31	6.5
T 8	1.89	7.0
S.Em(±)	0.12	0.34
CD	0.35	1.03

CONCLUSION

Sigatoka leave spot disease of banana causes yield and quality loss significantly, if not managed efficiently. Attempts were made to control the disease using fungicides and mineral oils. The study indicated that application of 0.05 per cent propiconazole + 1.00 per cent mineral oil provided the best control, yield and quality of fruits. Mineral oil alone did not give effective control.

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Integrated management of Asian soybean rust caused by *Phakopsora pachyrhizi* Syd. & Syd. through fungicide and nutrients in India

H. Sharadha, Shamarao Jahagirdar and Basavaraja G.T.

Department of Plant Pathology, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: shamaraoj@gmail.com

ABSTRACT

Soybean rust caused by *Phakopsora pachyrhizi* Syd. and Syd. is the potential disease, causing severe losses in yield and also quality of oil in soybean. The continuous use of chemical fungicides in the management of disease leads to the development of resistance in the pathogen and also causes deleterious effect on existing ecosystem. However, the influence of plant nutrition status on susceptibility and tolerance of crops to diseases is an important aspect to be considered. A field experiments was laid out in split plot design with two main treatments and six sub treatments at the AICRP on Soybean, Main Agricultural Research Station, University of Agricultural Science, Dharwad, Karnataka and Research and Development Unit, Ugar Sugar Works Ltd., Ugarkhurd, (Belagavi district) during *kharif* season. Results of the integrated disease management with fungicide and nutrients in both the location revealed that two sprays of hexaconazole 0.1% + KNO_3 2% recorded minimum disease severity followed by hexaconazole 0.1% + neem oil 1%. Further two sprays of these treatments recorded maximum seed yield, number of pods and 100 seed weight over unsprayed control.

Key words: Hexaconazole, KNO_3, Neem oil, *Phakopsora pachyrhizi*, Soybean rust, Integrated management

Among the oilseed crops, soybean cultivation is wide spread in the world and ranks first among the oilseeds. The full potential of the soybean crop is far from being exploited due to several abiotic and biotic stresses. The crop suffers from many fungal diseases, in which foliar diseases take a heavy toll by reducing the yield. Among the foliar diseases, soybean rust caused by *P. pachyrhizi* is the potential disease causing severe losses in yield and also quality of oil in soybean. The continuous use of chemical fungicides in the management of disease leads to the development of resistance in the pathogen and also causes deleterious effect on existing ecosystem. However, the influence of plant nutrition status on susceptibility and tolerance of crops to diseases is an important aspect to consider. Nutrients are important for growth and development of plants and also microorganisms and they are important factors in disease management. Hence, an attempt was made on integrated management of soybean rust through fungicide and nutrients.

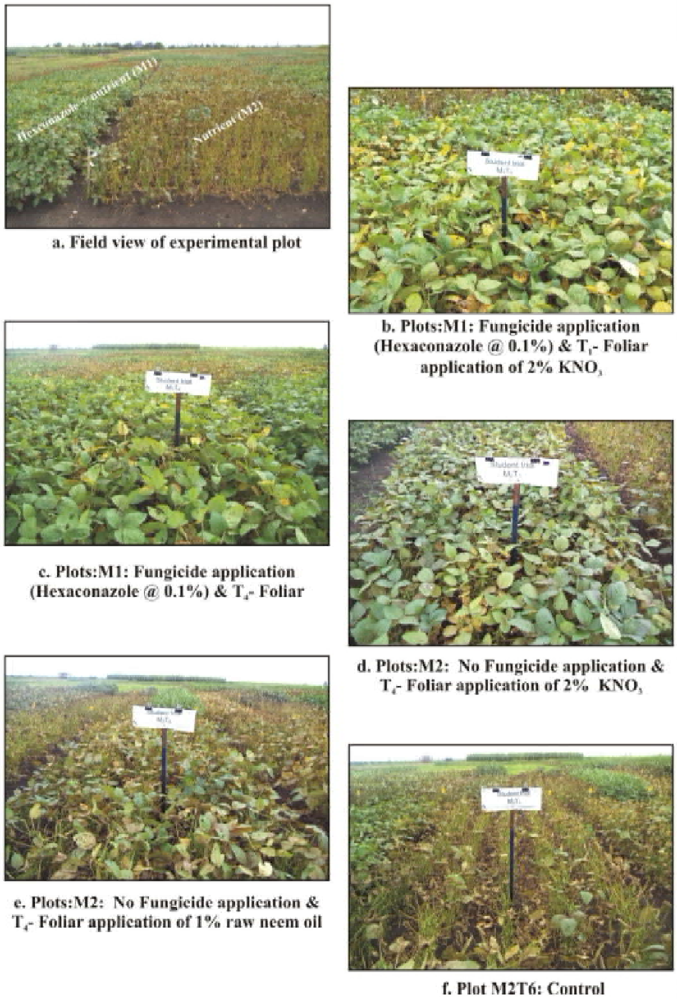
MATERIALS AND METHODS

A field experiment was laid in split plot design with two main treatments (M1: Fungicide application (Hexaconozole 0.1%) and M2: No fungicide Spray), six sub treatments, i.e. S1: Foliar application of 2% KNO_3, S2: Foliar application of 1% $MgSO_4$, S3: Foliar application of 1% multinutrients (Mn, Zn, Cu, B, *etc*.), S4: Foliar application of 1% raw neem oil, S5: Foliar application of 2% urea and S6: Check (No spray) with three replications at the All India Co-ordinated Research Project on Soybean (AICRPS), Main Agricultural Research Station, University of Agricultural Science, Dharwad, Karnataka and Research and Development unit, Ugar Sugar Works Ltd., Ugarkhurd, (Belagavi district) during *kharif* season. The recommended susceptible soybean genotype JS 335 was used. Different treatments comprising of fungicide and nutrients were screened by providing two sprays at 45 and 55 DAS (First application at the disease appearance followed 15 days after first application). Observations were recorded using 0-9 scale (Mayee and Datar, 1986) and per cent disease index was estimated (Wheeler, 1969). The data on number of pods per plant, 100 seed weight (g), seed yield and benefit cost ratio was also recorded.

RESULTS AND DISCUSSION

The results on integrated disease management of soybean rust through fungicide and nutrients are presented in Table 1, Plate 1 and 2.

At Dharwad, after two spray, significantly lower mean disease severity (20.05 PDI) was recorded in main plot sprayed with 0.1% hexaconazole (M1) as compared to no fungicide (M2) sprayed plot (43.85 PDI). Similarly, lowest



a. Field view of experimental plot

b. Plots:M1: Fungicide application (Hexaconazole @ 0.1%) & T_1- Foliar application of 2% KNO_3

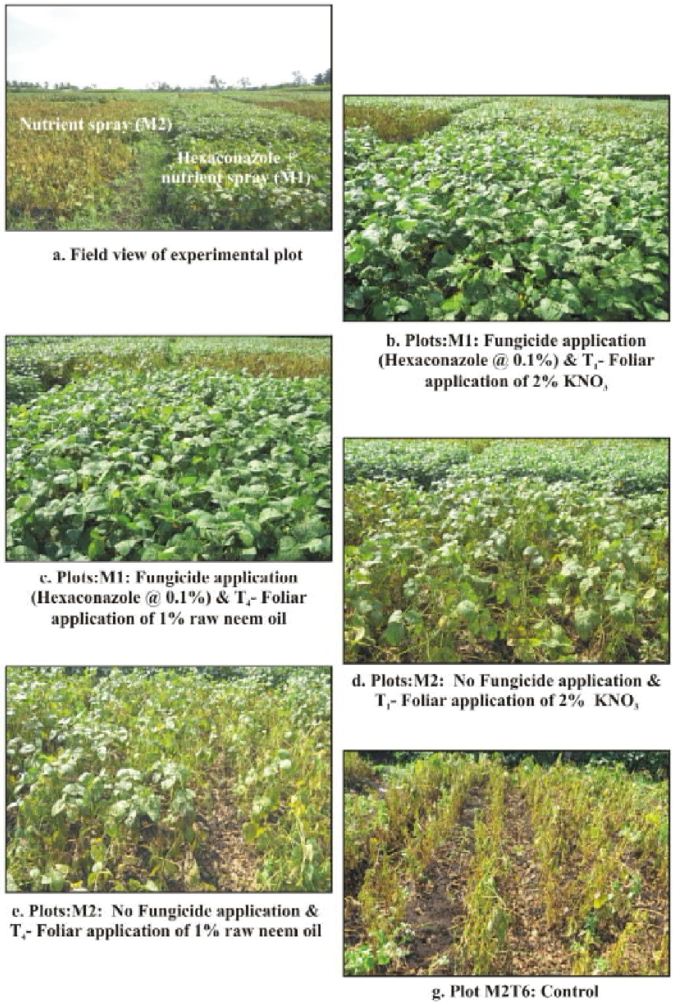
c. Plots:M1: Fungicide application (Hexaconazole @ 0.1%) & T_4- Foliar

d. Plots:M2: No Fungicide application & T_4- Foliar application of 2% KNO_3

e. Plots:M2: No Fungicide application & T_4- Foliar application of 1% raw neem oil

f. Plot M2T6: Control

Plate 1: Integrated management of soybean rust through fungicide and nutrients at Ugarkhurd at Dharwad



a. Field view of experimental plot

b. Plots:M1: Fungicide application (Hexaconazole @ 0.1%) & T_1- Foliar application of 2% KNO_3

c. Plots:M1: Fungicide application (Hexaconazole @ 0.1%) & T_4- Foliar application of 1% raw neem oil

d. Plots:M2: No Fungicide application & T_1- Foliar application of 2% KNO_3

e. Plots:M2: No Fungicide application & T_4- Foliar application of 1% raw neem oil

g. Plot M2T6: Control

Plate 2: Integrated management of soybean rust through fungicide and nutrients at Dharwad

disease severity 34.56 and 36.29 PDI was recorded in sub plot sprayed with 1% raw neem oil (S4) and 2% KNO_3 (S1), respectively, which were statistically on par with each other. On the other land highest severity (64.56 PDI) was observed in the plot without nutrient spray (S6). Interaction effect also differed significantly with respect to diseases severity. Treatment combination of hexaconazole (0.1%) + KNO_3 (2%) (M1S1) recorded the lowest severity (16.78 PDI) followed by 20.00 PDI recorded in hexaconazole (0.1%) + neem oil (1%) (M1S4), which are statistically on par with each other.

At Ugarkhurd, after two spray, significantly lower severity (22.68 PDI) was recorded in main plot sprayed with 0.1% Hexaconazole (M1) as compared to no fungicide (M2) sprayed plot (43.17 PDI). Similarly, lowest severity (34.56 PDI) was recorded in sub plot sprayed with raw 1% neem oil which was on par with 2% KNO_3 (34.83 PDI). On the other land highest severity (71.25 PDI) was recorded in plot without nutrient spray (S6). Interaction effect of foliar application of fungicide and nutrients also differed significantly with respect to diseases severity. The treatment combination of hexaconazole (@ 0.1%) and KNO_3 (@ 2%) recorded the lowest PDI (15.93) followed by hexaconazole with multinutrient spray @ 1% (20.70 PDI), which was on par with neem oil 1% (21.90 PDI).

Anahosur *et al*. (2000) observed that use of nimbecidine (0.5%) inter-mixed with hexaconazole (0.1%) sprays reduced the disease index and thereby increase the yield. The present study also revealed that two sprays of hexaconazole (0.1%) + neem oil (0.1%) reduced the disease severity both at Dharwad and Ugarkhurd. Though two sprays of hexaconazole alone has considerably reduced the disease severity to higher level but addition of neem oil, KNO_3 and

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Table 1: Integrated management of soybean rust through fungicide and nutrients at Dharwad

Tr. No.	Treatments	Percent Disease Index *					
		Dharwad			Ugarkhurd		
		M1	M2	Mean	M1	M2	Mean
S1	Foliar application of KNO_3 2%	16.78	36.29	26.54	15.93	34.83	25.38
		(24.18) **	(36.99)	(30.59)	(23.51)	(36.18)	(29.85)
S2	Foliar application of $MgSO_4$ 1%	20.49	44.93	32.71	22.20	40.72	31.46
		(26.91)	(42.10)	(34.51)	(28.11)	(39.66)	(33.89)
S3	Foliar application of multinutrients 1%	20.32	41.22	30.77	20.70	37.43	29.07
		(26.75)	(39.95)	(33.35)	(26.99)	(37.71)	(32.35)
S4	Foliar application of raw neem oil 1%	20.00	34.56	27.28	21.90	34.56	28.23
		(26.53)	(36.02)	(31.28)	(27.88)	(36.02)	(31.95)
S5	Foliar application of urea 2%	21.69	41.48	31.59	26.27	41.72	34.00
		(27.76)	(40.11)	(33.94)	(30.80)	(40.25)	(35.53)
S6	Check	21.00	64.56	42.75	29.07	71.25	50.16
		(27.25)	(53.49)	(40.85)	(32.63)	(57.60)	(45.11)
	Mean	20.05	43.85	-	22.68	43.17	-
		(26.56)	(41.49)	-	(28.32)	(41.10)	-
		S.Em.±	C.D. (P=0.05		S.Em.±	C.D. (P=0.05)	
	M	0.46	2.84		0.35	1.18	
	S	1.54	4.54		0.91	2.68	
	S x M	2.18	6.43		1.29	3.80	

*Mean PDI of 1st and 2nd spray, 80

**Figures are in parentheses are arcsine values, M1: Hexaconazole 0.1% spray, M2: No fungicide spray

other nutrients were found effective in reducing the disease severity to avoid problem of fungicidal resistance. The present results are strongly supported by Fixen *et al.* (2008); Jahagiradar *et al*. (2010); Jahagirdar *et al*. (2011); Jahagirdar *et al*. (2013), Jahagirdar (2014) in managing soybean rust in India.

Nutrients are important for growth and development of plants and also microorganisms and they are important factors in disease management. All the essential nutrients can affect disease severity (Huber and Graham, 1999). Graham and Webb (1991) described resistance in the host-pathogen relationship as the ability of plants to limit the penetration, development and/or reproduction of invading pathogens. Although both factors "tolerance and resistance" are genetically controlled, the environment and particularly plant nutrition status of the host can certainly have an impact. Hence, foliar application of nutrients with fungicide is one of the effective management strategies in integrated disease management.

These treatments also increased the seed yield, number of pods and 100 seed weight over unsprayed (Tables 2 and 3). At Dharwad, hexaconazole + neem oil helped in realization of maximum B:C ratio (Table 4a). However, at Ugarkhurd, maximum B:C ratio was recorded in

Table 2: Influence of different treatments on number of pods in IDM trial

Tr. No.	Treatments	Number of pods per plant					
		Dharwad			Ugarkhurd		
		M1	M2	Mean	M1	M2	Mean
S1	Foliar application of KNO_3 2%	39.90	36.93	38.42	40.20	35.93	38.07
S2	Foliar application of $MgSO_4$ 1%	34.73	32.27	33.50	36.57	32.60	34.59
S3	Foliar application of multinutrients 1%	33.53	35.40	34.47	34.20	34.90	34.55
S4	Foliar application of raw neem oil 1%	39.20	35.00	37.10	38.47	36.00	37.24
S5	Foliar application of urea 2%	35.40	32.73	34.07	36.07	33.07	34.57
S6	Check	34.20	32.00	33.10	35.20	31.67	33.44
	Mean	36.16	34.05		36.78	34.02	
		S.Em.±	C.D. (P=0.05)			S.Em.±	C.D. (P=0.05)
	M	0.32	1.05			0.31	1.12
	S	0.99	2.93			0.82	2.40
	S x M	1.41	NS			1.15	NS

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Table 3: Influence of different treatments on 100 seed weight in IDM trial

Tr. No.	Treatments	100 seed weight (g)					
		Dharwad			Ugarkhurd		
		M1	M2	Mean	M1	M2	Mean
S1	Foliar application of KNO_3 2%	14.03	12.67	13.35	14.7	12.93	14.42
S2	Foliar application of $MgSO_4$ 1%	13.86	11.97	12.92	13.97	11.80	12.89
S3	Foliar application of multinutrients 1%	12.77	11.90	12.34	12.43	11.50	11.97
S4	Foliar application of raw neem oil 1%	13.80	12.83	13.32	14.07	12.50	13.29
S5	Foliar application of urea 2%	12.57	11.97	12.27	12.57	12.00	12.29
S6	Check	12.32	10.37	11.35	12.17	10.47	11.32
	Mean	13.23	11.95		13.32	11.73	
		S.Em.±		C.D. (P=0.05)	S.Em.±		C.D. (P=0.05)
	M	0.11		0.69	0.21		0.90
	S	0.17		0.49	0.20		0.59
	S x M	0.24		0.69	0.28		0.83

Table 4a: Economics analysis in the management of soybean rust in Dharwad

Treatments	Cost of cultivation (1) (Rs)		Chemical cost (Rs)		Total cost (Rs) (1+2)		Seed Yield (q/ha)		Gross returns (Rs)		Net Income (Rs.)		B:C ratio	
	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2
S1	31250	31250	910	210	32160	31460	27.66	17.17	96810	60095	64650	28635	2.01	0.91
S2	31250	31250	868	168	32118	31418	23.95	16.62	83825	58170	51707	26752	1.61	0.85
S3	31250	31250	952	252	32202	31502	24.31	14.22	85085	49770	52883	18268	1.64	0.58
S4	31250	31250	798	98	32048	31348	28.42	17.20	99470	60200	67422	28852	2.10	0.92
S5	31250	31250	716	16	31966	31266	26.26	14.53	91910	50855	59944	19589	1.88	0.63
S6	31250	30500	700	0	31950	30500	25.06	13.60	87710	47600	55760	17100	1.75	0.56

Table 4b: Economics analysis in the management of soybean rust in Ugarkhurd

Treatments	Cost of cultivation (1) (Rs)		Chemical cost (Rs)		Total cost (1+2)		Seed Yield (q/ha)		Gross returns		Net Income (Rs.)		B:C ratio	
	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2
S1	31250	31250	910	210	32160	31460	29.87	18.46	104545	64610	72385	33150	2.25	1.05
S2	31250	31250	868	168	32118	31418	26.31	17.87	92085	62545	59967	31127	1.87	0.99
S3	31250	31250	952	252	32202	31502	26.56	15.95	92960	55825	60758	24323	1.89	0.77
S4	31250	31250	798	98	32048	31348	29.16	18.22	102060	63770	70012	32422	2.18	1.03
S5	31250	31250	716	16	31966	31266	27.33	15.33	95655	53655	63689	22389	1.99	0.72
S6	31250	30500	700	0	31950	30500	26.78	14.57	93730	51019	61780	20519	1.93	0.67

Note: Cost of the grain at Rs. 3500/q. Labour charges for spray = Rs. 150/-. Quantity of spray solution used per hectare: 700 lit. Cost of fungicides in Rs/ kg or litre. Hexaconazole (500), KNO3 (150), MgSO4 (120), Multi nutrients (180), Raw neem oil (70) and Urea (290).

hexaconazole + KNO_3 (Table 4b). This clearly indicated that spraying with fungicide and nutrients will be more useful not only in reducing cost of protection but also gave higher benefits as compared to only spray of hexaconazole. This also gave insurance against resistance development by the fungus against hexaconazole.

CONCLUSION

Persistent use of chemical fungicides to control Asian Soybean rust may lead to development of resistance in the pathogen. Further it is perceived that health of the plant may enhance the efficacy of fungicides. Therefore, an integrated disease management strategy involving fungicides and nutrients was developed. The study clearly indicated that spraying of fungicide along with nutrients was cost effective. It also provided insurance against resistance development in the fungus against hexaconazole.

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Detection of root-rot pathogens in seeds of cluster bean [*Cyamopsis tetragonoloba* (Linn.) Taub.]

Burhanuddin Bohra*, Kusum Mathur[1] and P.C. Trivedi[2]

Research Centre, Godrej Agrovet Limited, Pirojshanagar, Eastern Express Highway, Vikhroli (East), Mumbai-400 079, India.
[1]*Department of Plant Pathology, Rajasthan College of Agriculture, Udaipur-313 001, India.*
[2]*Department of Botany, University of Rajasthan, Jaipur-302 004, India.*
**Corresponding author: b.bohra@godrejagrovet.com*

ABSTRACT

Detection of the root-rot pathogens *Fusarium solani* and *Rhizoctonia solani* in cluster bean seeds, populanly known as guar seeds (*Cyamopsis tetragonoloba* (Linn.) Taub.), was attempted using standard blotter and agar plate methods. Blotter method seemed better, where 30 per cent seeds showed root rot pathogens, of these 17 per cent had colonies of *F. solani* and 13 per cent had *R. solani*. In agar plate method, 19 per cent seed showed root rot pathogens, and frequency of *F. solani* and *R. solani* was 10 and 9 per cent, respectively. The site of infection of both the pathogens was the seed coat. The sections of infected seeds of guar showed the presence of inter and intra-cellular mycelium of the two pathogens, and sclerotia of *R. solani* in seed coat and cotyledons.

Key words: *Cyamopsis tetragonoloba*, Cluster bean, Guar, Seed pathology, *Fusarium solani*, *Rhizoctonia solani.*

Seeds of cluster bean [*Cyamopsis tetragonoloba* (Linn.) Taub.] contain significant amount of galacto mannan gum, which counts for about 9 to 43% of the whole seed. Guar gum is the primary marketable product of the plant. In Asia, guar beans are used as a vegetable for human consumption, and as a green manure crop. The production and quality of guar seed are often hampered due to diseases, among which, root rot is the major threat. Root rot of guar is a complex disease, caused by *Fusarium solani* and *Rhizoctonia solani*. The disease is primarily soil borne, but the seed borne inoculum is responsible for dissemination of the pathogens into newer niches. The present study was conducted to determine the extent of seed infection by the two root rot pathogens in guar.

MATERIALS AND METHODS

Seeds of the root-rot susceptible guar cultivar Pusa Nav Bahar were analyzed for the presence of the pathogen by employing various methods (ISTA, 1985). Four hundred seeds of a sample were analyzed in the study. The seeds were surface sterilized with 0.1 per cent $HgCl_2$ for 3 minutes followed by 3 serial washing with distilled water for these studies.

Standard blotter method

Seeds (10 seeds /Petri plate) were placed in petri plates lined with three layers of moist blotter paper. These plates were incubated at 22±1°C under alternating cycles of 12 hrs light and 12 hrs darkness. The seeds were examined after 10 days of incubation under a stereo-binocular microscope. Cotton-blue mounts were prepared for observing fungal structures under the light microscope.

Agar plate method

Potato dextrose agar (PDA) medium was used as a basal medium for the isolation of pathogens. Ten seeds were placed at equidistance in each Petri plate. The plates were then incubated at 22±1°C for 10 days. The presence of the pathogens was confirmed by the formation of typical spores of *F. solani* and sclerotia of *R. solani*.

Component plating method

The various component of guar seed viz. seed coat, cotyledons and embryonal axis were examined by agar plate method. Infected guar seeds were rinsed with water and soaked for 30-45 minutes in water to facilitate removal of surface contaminants and seed coat from cotyledons. The seed coat and cotyledons were separated with the help of fine forceps. These were surface rinsed with sterile distilled water, blot dried and placed on PDA in Petri plates. The plates were then incubated for 10 days at 22±1°C. The proportion of seed parts showing presence of root-rot pathogens were recorded.

Histopathological study was carried out by following the techniques of component plating, whole mount preparation and microtome sectioning. For whole mount preparation, seeds were boiled in water for 2-3 hours, and dissected. Seed coat was cleared by boiling in 10 per cent

KOH for 5 min. while endosperm and embryo were boiled in lactic acid for 5-10 min. Components were stained in 1 per cent cotton blue. For microtomy seeds were softened by boiling in water for 5-10 min. and in lactic acid for 8-10 min. Usual micro technique methods were followed for paraffin embedding. Thin section (10-15 µm) were fixed on the microscopic slides, de-waxed in xylene, stained in safranin, and mounted in DPX.

RESULTS AND DISCUSSION

Both blotter and agar plate tests were found useful for detecting seed borne inocula of the two root rot pathogens, though the blotter test was more effective. Thirty per cent of the seeds incubated on moist blotters developed colonies of *F. solani* and *R. solani,* while in agar plate method only 19 per cent seeds exhibited these pathogens (Table 1).

Maximum infection of *F. solani* was observed in seed coat (15.0 per cent) followed by embryo (11 per cent) and cotyledons (9.0 per cent) (Table 2). Infection of *R. solani* was also more in seed coat (18.0 per cent), followed by cotyledons (10 per cent) and embryo (3.5 per cent). Brown to black, septate and knotty mycelium and minute, black sclerotia of *R. solani* and white septate mycelium and mico as well as macro conidia of *F. solani* were recorded on seed coat and cotyledons. Inter as well as intra cellular compactly interwoven dormant mycelium of *F. solani* and mycelium and micro-sclerotia of *R. solani* were observed in whole mount preparation of seed coat and cotyledons.

Table 1. Incidence of root-rot caused by *F. solani* and *R. solani* in cluster bean seeds (Pusa Nav Bahar)

Incubation Method	Per cent frequency on seed		Plant mortality (Per cent)
	Fusarium solani	*Rhizoctonia solani*	
Blotter plate	17.0	13.0	30.0
Agar plate	10.0	9.0	19.0

Sample size: 400 seeds per treatment

Table 2. Incidence of *F. solani* and *R. solani* in different component of cluster bean seeds (Pusa Nav Bahar)

Fungi	Percent component showed fungus*		
	Seed coat	Cotyledons	Embryo
Fusarium solani	15.0	9.0	11.0
Rhizoctonia solani	18.0	10.0	3.5

*Average of 100 seed components

The sections of infected seeds of guar showed the presence of inter and intra-cellular mycelium and sclerotia in seed coat and cotyledons. In all the infected seeds, mycelium and spores of *F. solani* and mycelium and sclerotia of *R. solani* occurred frequently in thin-walled region of seed epidermis. Parenchymatous middle layers were also severely invaded by the two pathogens and caused distortion of its cells. Accumulation of white to dark brown or black, branched, septate mycelium along with sclerotia and hyaline sickle shaped conidia was observed on the epidermis at micropylar end of the seed. Chitkara *et al.* (1986) also reported similar observations in case of chilli seeds infected with *R. solani.* In the wake of increasing cultivation of guar, there is a need to monitor seed health and provide disease free seeds for realizing high yields.

CONCLUSION

Thirty per cent of the seeds incubated on moist blotters developed calonies of *F. solani* and *R. solani*, whereas, in agar plate method only 19 per cent seeds exhibited these pathogens. Infection of *R. solani* was also more in seed coat followed by cotyledons and embryo.

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Host range of *Rhizoctonia solani* and *Fusarium solani* Causing Root-rot of Guar [*Cyamopsis tetragonoloba* (Linn.) Taub.]

Burhanuddin Bohra, P.C. Trivedi[1] and Kusum Mathur[2]

Research Centre, Godrej Agrovet Limited, Pirojshanagar, Eastern Express Highway, Vikhroli (East), Mumbai-400 079, India.
[1]Department of Botany, University of Rajasthan, Jaipur-302 004, India.
[2]Department of Plant Pathology, Rajasthan College of Agriculture, Udaipur-313 001, India.

ABSTRACT

Seven *kharif* crops, namely, maize, sorghum, cowpea, soybean, green gram, sesame and ridge gourd were evaluated for pathogenicity of *Rhizoctonia solani* and *Fusarium solani* causing root-rot of guar. Out of these, three, *viz.* soybean, green gram and sesame developed 36 to 51 per cent root-rot due to these pathogens and were considered susceptible, while others were resistant, and may be used for crop rotation to reduce the soil-borne inoculum of these pathogens.

Key words: Guar, *Cyamopsis tetragonoloba* (Linn.) Taub., Root rot, *Fusarium solani*, *Rhizoctonia solani*, Host range, Soybean, Green gram, Sesame, Maize, Sorghum, Ridge gourd

Guar [*Cyamopsis tetragonoloba* (Linn.) Taub.] is an important arid legume crop in India, particularly, in Rajasthan, which is the largest guar producing state. Guar crop is attacked by many fungal diseases. Among these, the recent occurrence of root-rot complex caused by *Fusarium solani* and *Rhizoctonia solani* is of great concern to the farmers. Both the pathogens are known to have a wide host range (Booth, 1971 and Sneh, *et al.*, 1991). Management of this disease is feasible through integrated strategy only and for that information on host range of the pathogens is required for successful crop rotation, which would be location specific. The present study was therefore, undertaken to study host range of the these two pathogens among the widely cultivated crops in the arid region.

MATERIALS AND METHODS

Eight plant species including guar were evaluated for host range studies of guar root-rot pathogens. Seeds of local land races of sorghum, cowpea, soybean, green gram, maize, sesame, ridge guard and cluster bean were procured from local market, surface sterilized with 0.1 per cent $HgCl_2$ for 2 minutes, rinsed with water and air dried. These were sown in 30 Cm diameter pots containing pathogen-infected soil. The pathogens *F. solani* and *R. solani* were separately multiplied on corn meal sand (1:1) medium at 25±1^{o} C for 10 days and the mixture of both pathogens was mixed with sterilized soil @ 20gm/kg soil. This inoculated soil was filled in pots. These pots were kept in green house for 7 days and were irrigated with sterile water to allow establishment of the pathogen. Surface sterilized seeds (0.1 per cent mercuric chloride solution for 2 minutes) of all the crops were sown in inoculated pots @ 10-15 seeds/pot, keeping 4 pots of each crop as 4 replications. For comparison with un-inoculated control, seeds of all the crops were sown in sterilized soil without pathogens. The pots were irrigated on alternate days with sterilized water to provide good moisture. The total number of germinated seedlings and root-rot plants were recorded after 10 and 30- 45 days of sowing, respectively.

RESULTS AND DISCUSSION

Germination of seeds was adversely affected due to pathogens in the inoculated soil as compared to the un-inoculated control in all the tested crops. But root-rot and plant mortality was observed only in soybean, green gram and sesame, where 36.1, 51.4 and 48.4 per cent disease was recorded, respectively (Table 1). The disease symptoms on these 3 crops were almost similar to that of guar root-rot.

Table 1. Host range studies of guar root-rot pathogens *Fusarium solani* and *Rhizoctonia solani*

Crop	Uninoculated pots		Inoculated pots	
	Per cent germination	Root-rot (%)	Per cent germination	Root-rot (%)
Sorghum	100.0	00.0	90.0	00.0
Maize	83.3	00.0	60.0	00.0
Soybean	66.6	00.0	40.0	36.1
Green gram	96.6	00.0	76.6	51.4
Cow pea	90.0	00.0	76.6	00.0
Sesame	73.3	00.0	38.3	48.4
Ridge guard	86.6	00.0	85.0	00.0
Cluster bean	83.3	00.0	73.3	83.7

*Average of 4 replications

The remaining 4 crops namely sorghum, cowpea, maize and ridge guard were found to be non-host of guar root-rot pathogens *F. solani* and *R. solani,* because there were no disease symptoms nor plant mortality was observed even after 60 days of sowing.

Both *Fusarium solani* and *Rhizoctoni solani* are wide spread and have been reported from rhizosphere soils of several crops, where these incite seedling rots and dry root-rot (Bilgramy *et al.* 1991). It is likely that different strains of these pathogens vary in their host range. In the present study, the guar isolates of *F. solani* and *R. solani* were found pathogenic on soybean, green gram and sesame but not on sorghum, maize, cow pea and ridge guard. The guar isolate of *R. solani* has been reported to be pathogenic to chilli and cotton also (Mathur *et al.* 2004).

CONCLUSION

It was observed that the germination of seeds were adversely affected due to pathogens in the inoculated soil as compared to the un-inoculated control in all the test crops. In the present study the Guar isolates of *F. solani* and *R. solani* were observed pathogenic on soyabean, green gram and sesame but not on sorghum, maize, cowpea and ridge gourd.

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Short Communication

Trichomes: The Real Hero in Natural Farming

S. Majeed Ahmed and *K.S. Bodeeshavali Vali

Assistant Director of Agriculture (R) Kadapa and Farmer, Respectively
Email: syedmajeed124@gmail.com

Abstract

Trichome is a small hair or other outgrowth from the epidermis of a plant, typically unicellular and glandular. In natural farming, this Trichome hairs are strong enough to defend sap sucking by sucking insects, avoid leaf eating by caterpillar and avoid spore germination of fungus. In chemical farming Trichomes are present on all above ground parts of the plants, but we can't remove them as they are very smooth. Due to application of urea and other chemical fertilizers, faster vegetative growth makes the natural defending mechanisms of the plants, i.e., Trichomes very smooth, so that they can't defend against sucking insect, leaf eating caterpillar and could also allow fungal spore to germinate.

Key words: Trichome, Natural farming, Chemical farming

The plants grown with the help of natural farming methods, with application of jeevamrutham, panchagavya, fish amino acid, egg amino acid, mulching are comparable with full grown baby born in ninth month with completely developed immune system. In plants Trichomes are the representives of immune system. We can feel the presence of Trichomes on all parts of plants above the ground level. The silica content in fully grown Trichomes is very high, which gives them the toughness. When trichomes are fully grown and hard they can resist sucking insects like trips, mite, jassid, mealy bug, aphids, whitefly, etc. from feeding on new flesh due to their hardness. The probosis of sucking insect will not reach leaf or stem, as Trichome length is more than length of the probosis. The leaves and stems are not hard enough to resist insect attack in chemical farming, as Trichomes are under developed and smooth. They will easily allow the probosis of sucking insect to reach growing leaf and stem.

The leaf eating caterpillar can not feed on leaves of plants growing under natural farming due to presence of high silica content in Trichomes, which are hard to chew. It will be like chewing sand in mouth of a caterpillar. Naturally, caterpillar will avoid such plants and move to plants grown with chemical farming, where Trichomes are very smooth and easy to chew.

Likewise a spore of fungal mycelium, will not germinate easily on leaf or stem substrate as trichomes which are fully developed in natural farming, will not allow fungal spore to reach leaf or stem substrate. In due course, the fungal spore will loose its viability and won't be able to germinate. In case of chemical farming, a fungal spore can germinate easily, as the natural immune system, i.e., Trichomes are very smooth, which will allow fungal spore to touch the substrate leading it to germinate and cause disease. The viral diseases are also very low in natural farming due to reasons that, the propagative agent, i.e., thrips, mites, aphids, etc. can't suck the sap from leaf or stem and can't translocate the virus to a healthy plant turning it into a unhealthy plant.

The presence of hard Trichomes can also be seen in kitchen garden plants, which grow naturally or plants, which grow by themselves wherever, moisture is available. The reason for immunity system in natural farming and chemical farming is in development of Trichomes. Hence trichomes are the real heros in natural farming.

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Obituary

First IRRI Entomologist and Director of Research and Training, passes away

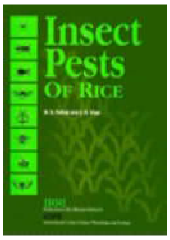
Mano Dutta Pathak
(1934 – 2019)

Dr. Mano Dutta Pathak, 85, passed away peacefully on 6 November 2019 at home with his family members in St. Peters, MO, USA. Born in 1934 in Sultanpur, Uttar Pradesh (U.P.), India, he worked in India, Philippines and the United States.

One of the key researchers, who ushered in the Green Revolution in rice, Mano was an internationally acclaimed scientist dedicated to improving crop production and agricultural education to eradicate hunger and poverty in the developing world. He joined the International Rice Research Institute (IRRI) in April 1962 as entomologist in the Plant Protection Department & stayed at IRRI for the next 27 years as an entomologist. In 1974, he was promoted to the position of Assistant Director of Research. He took over as the first Director of Research and Training in 1977, a title he held until he departed from IRRI in 1989.

He obtained his Ph.D. in entomology with a minor in genetics at Kansas State University in 1958 under the guidance of Reginald H. Painter, a world authority on controlling insects by developing resistant plant varieties.

In 1994, Mano co-authored with Z.R. Khan his book entitled *Insect Pests of Rice* that provided updated information with full-color photos on the biology, damage, seasonal history, abundance, and control measures of the major insect pests of rice, most of which is still relevant today.



Mano discovered that an Indian rice variety, TKM6, was consistently more resistant to stem borer attack than were most other varieties. One cross that turned out to be particularly successful was between TKM6 and Peta/ Taichung Native-1. Subsequently, working with IRRI, breeders and plant pathologists, he found that many of the selections from that cross in the F4 and F5 generations proved to be resistant to stem borer, leafhopper and diseases such as bacterial blight and tungro. In 1969, one of those selections was designated as IR20, which was the first IRRI-named variety that had a truly broad spectrum of resistance to both insects and diseases. IR20's disease and insect resistance and its superior grain quality made it a popular variety in South and Southeast Asia for several years. Indeed, it was a significant advance for IRRI, which paved the way for the development of even better rice varieties in the future.

After leaving IRRI in 1989, Mano returned to India to become the first Director General of the U.P. Council of Agriculture Research (UPCAR), Lucknow, India, which oversaw all government agricultural research and education programs for the entire state. At UPCAR, Mano recognized that U.P. had the largest concentration of sodic (sodium) lands in India, owned or operated by the most marginalized farmers. He was convinced that these problem lands could be reclaimed organically. Upon retirement in 1994, he founded the nonprofit Center for Research and Development of Waste and Marginal Lands in Lucknow, U.P., to address this issue.

Kind and generous, Mano participated in many philanthropic activities. Closest to his heart were the schools he built in U.P. and scholarships he provided to children in need. He believed that every person has possitive traits and never hesitated to give them a second chance.

Among his many awards, accolades, and offices, he received the Research Award of the International Year of Rice, Tokyo, Japan (2004), the Distinguished Alumni Award, Kansas State University (1992), D.Sc. *Honoris Causa*, Pantnagar University (1992), and the Borlaug Award of India (1973). He was honored for Leadership in Research and Development during the International Symposium on Insect Host Plant Resistance, Indianapolis (1992) and named a Fellow of the Indian National Academy of Sciences (1987). He was president of Doctors Agricultural and Horticultural Development Society, Lucknow, India w.e.f. 2007-2019 and took leading role in publishing the ***Journal of Eco-friendly Agriculture***.

Dr. Jagdish Chandra
Dr. D.K. Tondon
Prof. (Dr.) Ajay Verma

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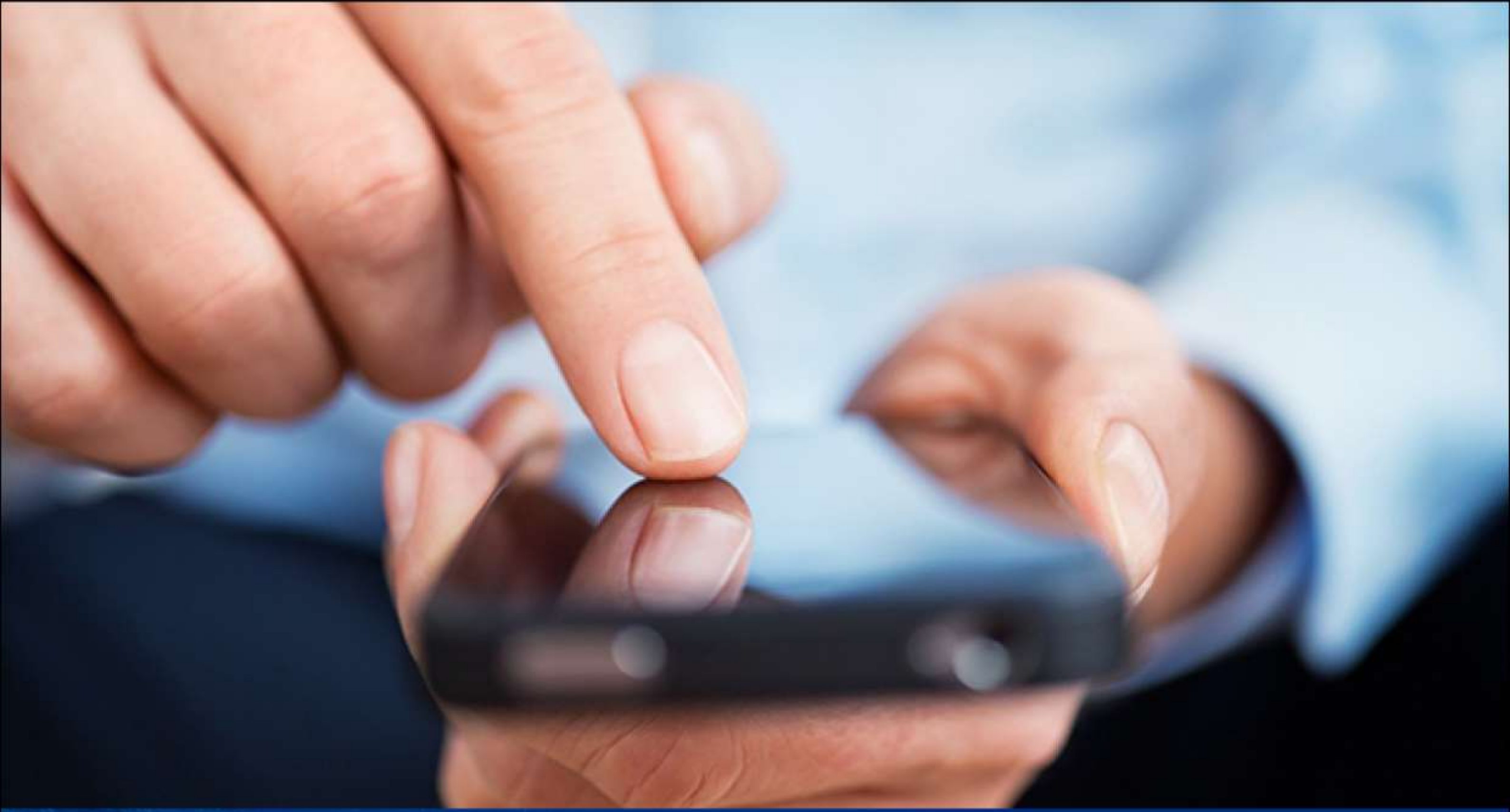

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