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Review Article

Nanotechnology applications in insect pest management- a review

Ms. Nimisha T. and Dr. Deepthy K.B.

College of Horticulture Vellanikkara, Thrissur, Kerala-680656, Kerala Agricultural University
Email: nimishadevadas33@gmail.com (corresponding author)

ABSTRACT

The great challenge of feeding ever growing human populations today is complicated by concerns about the risks of environmental pollution and human health associated with conventional pesticides. Among the recent technological advancements, nanotechnology shows considerable promise to combat these challenges. Most of the conventional pesticides are lost or decomposed while application itself and only 0.1 per cent finally reaches the target pests. Problems such as harmful solvents, poor dispersion, and drift losses can be very well addressed by nanotechnological interventions. Nanotechnology is defined as the branch of science which deals with the characterization, fabrication and manipulation of materials at nano scale,1-100 nm (Hanford *et al.*, 2014). Revolutionary changes in agriculture have been made with the introduction of nanofertilizers, nanopesticides and nanosensors which improved crop production and resource utilization efficiency, facilitate precise and safer application of pesticides as well as detection of pesticide residue in the produce. Important nanoformulations include nanoparticles, nanoemulsion, nanoencapsulation and nanogel. As far as pest management is concerned, these novel nano agricultural products will provide multiple benefits such as reduced use of chemical pesticides, lower environmental pollution and decreased pesticide residual contamination in food and other commodities.

Key words: Nanotechnology, pest management, nanopesticides, nanoparticles, nanogel, nanopheremone

Agricultural productivity is globally affected by insect pests and diseases. It is necessary to improve the systems for monitoring the environmental conditions and delivering nutrients as well as pesticides in appropriate way. Pesticides are important inputs for enhancing crop productivity and preventing major biological disasters. More than 90 per cent of pesticides are run off into the environment and residues are creating several menaces. In recent years, using nanotechnology to create novel formulations has shown great potential in improving the efficacy and safety of pesticides (Xiang *et al.*, 2017). The potential uses of nanotechnology are enormous. These include agricultural productivity enhancement involving nanoporous zeolites for slow release and precise dosage of fertilizer, nanocapsules for herbicide delivery, pest management and nanosensors for pest detection. Nano-encapsulated slow release fertilizers have been widely used to improve crop health (DeRosa *et al.*, 2010). Importance of nanoscale delivery system in agriculture is because of its improved solubility and stability to degradation in the environmental conditions. The nanoscale delivery mechanisms will improve efficacy by binding closely to the plant surface and decreases the amount of agrochemicals by preventing runoff into the environment (Johnston, 2010; Chen and Yada, 2011). Nanotechnology need to be explored to design and develop targeted pesticides with environmentally responsive controlled release via compound and chemical alterations has also shown great important in creating novel formulations (Huang *et al.*, 2018).

Materials, whether natural or of manufactured origin, that possess one or more external dimensions in the range of 1-100 nm are termed as nano-materials and are increasingly used in a broad range of technical applications due to its unique physical as well as chemical properties appearing at the nanoscale (Battacharya *et al.*, 2010). Major applications of nanomaterial can be found in the areas of electronics, energy, textiles, pharmaceutics, cosmetics, and biomedicine. Although nanoscience has recently emerged as a unique discipline of research, the technology is still in the infant stage and the field remains unexplored, presenting an opportunity to incorporate new concepts within the existing methodology. The future for the application of nanotechnology looks bright because of its efficiency and potential to contribute to clean products (Arivalagan *et al.*, 2011).

Nanotechnology applications in agriculture

There has been widely accepted interest in using nanotechnology in agriculture. The goals fall into several sections such as, increase in production rates and yield, improve efficiency of resource utilization, decrease waste production, nano-based treatment of agricultural waste and nanosensors. Specific applications include, Nano-fertilizers, nano-pesticide. Another promising application is with smart field system in which designed sensors that give increased sensitivity and earlier response to environmental changes and linked into GPS are practiced. These monitor soil

conditions and crop growth over wide areas. Such sensors have already been employed in US and Australia. Nanopesticides will provide many solution to the hazardous effects of conventional pesticides *i.e.* solubility of active ingredient, stability, controlled release and targeted delivery of active ingredient but still more research works has to carry out to understand the fate of nanopesticide in environment (Chhipa, 2017)

Nanotechnology applications in pest management

Conventional pesticide has got problem such as solvents and toxic ingredients directly leach into the water sources, act as pollutants in soil, results chemical residues in crops and food products and leads to potential threat to human health. These environmental problems and health risks has aroused the universal concerns (Zhao *et al*., 2017). The loss and decomposition rate of pesticide on crop foliage is typically up to 70 per cent, caused by run off, spray drift and rolling down during field application. Developing new advanced nano-based formulations that remain stable and active in the spray condition, penetrate and deliver at the target, prolong the effective duration and reduce the run-off in environment acts as the hotspots in the field of nano-technical agriculture applications (Ghormade *et al*., 2011).

Nanoparticles are loaded with pesticides and released slowly based on environmental triggers (Lauterwasser, 2005). Because of their high reactivity at nanoscale lesser quantity of nano pesicides show enhanced effect in crop protection (Debnath *et al*., 2011). Most of the pesticide active ingredients are poorly soluble, or even insoluble in water. One of the challenges associated with pesticide formulation is increasing their solubility and dispersion in aqueous solution. In addition, the most of crop leaf surfaces are highly hydrophobic which prevents liquid deposition. To overcome the lack of solubility addition of large amounts of organic solvents are required. Which increases costs, applicators exposures and environmental pollutants (Lawrence, 2006). Nano formulations will increase the solubility and dispersion of active ingredient in water, ensure uniform leaf coverage, biological efficacy and environmental compatibility, due to the small particle size, high surface area and elimination of organic solvents in comparison to conventional formulation (Anton *et al*, 2008).

Kah *et al*. (2012) have reviewed application of various nanoformulations used in enhancing the effect of pesticides such as microemulsion, nanoemulsion, nanodispersion, polymer-base nanoparticle, solid lipid nanoparticle, clay, porous hollow silica nanoparticles, layered double hydroxides and metal based nanoparticles for plant protection.

A study has been conducted by Armugham *et al*. (2016) for finding out the effectiveness of nano silica particle on pulse beetle (*Callosobruchus maculatus*) revealed a significant reduction in oviposition, adult emergence and seed damage potential. Debnath *et al*. (2011) attempted to determine the efficac y of surface functionalized silica nanoparticle against rice weevil *Sitophilus oryzae*. They found that silica nanoparticle treated stored rice was not affected by pest even after 2 months of treatment, they also concurred that amorphous form of nanoparticles were found to be highly effective in controlling this insect pest.

Another peculiarity of nanosilica particle is that it has got the capacity of shielding protection of insecticides from UV radiation. One such study was conducted by Li *et al.* (2007). In that experiment, shielding protection was given by self-prepared porous hollow silica nanoparticles (PHSN) to avermectin from degradation by UV light. It was demonstrated that PHSN have an encapsulation capacity and avermectin loaded into the inner core of the PHSN carriers was released slowly into the release medium for about 30 days following a typical sustained-release pattern. It thus appears that PHSN carriers have a promising future in applications requiring sustained pesticide release. Nano encapsulation of chemical such as an insecticide and pesticide for slow and efficient release allows the chemical to be properly adsorbed by plants (Scrinis and Lyons, 2007).

Apart from direct use of nano particle several other forms are also available. One such example is Nanoemulsions. These are oil-in-water (O/W) emulsions where the pesticides are dispersed as nano sized droplets in water, and the surfactant molecules localized at the pesticide-water interface. Nano emulsions improve the efficacy and safety effects of traditional pesticides, due to the small size effect, high dissolution rate and elimination of toxic organic solvent enhanced apparent -solubility and enhanced uptake/efficacy. Nano emulsion-based registered pesticides include Banner MAXX of Syngenta (Kookana *et al*., 2014). The study conducted by Nenaah (2014) suggest that the nanoemulsion may be useful to enhance water solubility of poor water soluble natural products with insecticidal activity. It was also obseeved that essential oils of *Achillea biebersteinii, A. santolina* showed considerable toxic and growth inhibitory activities against the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Another study conducted by Negahban *et al*.(2012) with essential oil of *Artemisia sieberi* Besser encapsulated by in-situ polymerization of oil/water emulsion in nano-scale. Then fumigant toxicity and persistence of produced nano-encapsuled essential oil (NEO) were examined against *Tribolium castaneum* (Herbst) and compared with pure

essential oil (PEO) (not encapsulated). The fumigant toxicity of nano-capsules (LC_{50}= 11.24 ppm) was significantly higher than that of PEO (LC_{50}= 15.68 ppm. Overall, it seems that nano emulsions are promising to manage pest attack.

Nanogel is an another advanced formulation and is successfully practiced as pheromone trap for fruitfly. This formulation upon entrapment and immobilization of methyl eugenol provide high pheromone retention capacity, enhanced shelf-life and protection of ME from environmental decompositions. This was utilized for the efficient pest management of *B. dorsalis* as a bait trap along with a technique to kill the pest (Bhagat *et al.,* 2013*).*

For enhancing the specific activity of nanopecticides agrochemicals companies are encapsulating active ingredients in nanocapsules designed to break open in certain conditions in an alkaline conditions in an insect's stomach. Another encapsulated product marketed under the name Karate ® ZEON, is a quick release microcapsulated product containing the active compound lambda-cyhalothrin which break open on contact with leaves. In contrast, the encapsulated product "gutbuster" only breaks open to release its contents when it comes into contact with alkaline environments, such as the stomach of certain insects (Prasad *et al.*, 2014). Shen *et al.*, (2017) formulated thermoresponsive emamectin benzoate microcapsules and it has got sustained and controlled release properties. Another constraint for the conventional pesticide is that loss of stability when exposed to UV radiation. The UV shielding can be provided by Porous silica nanoparticles (PSNPs). It will provide surface protection and it can be loaded them with a pesticide. One such example is biopesticide – Abamectin loaded Porous silica nanoparticles. Nanoparticles had a 320 nm diameter with pore size of 12 nm. The developed controlled release formulation improved the chemical stability and dispersity of Abamectin. (Wang *et al.,* 2014).

Nowadays, pesticide residue problems are increasing at an alarming rate. Even though pesticide residue analysis methods are available, most of them are costly and infrastructural facilities are needed. There comes the need for an easy to use alternate measure. The interventions of nanotechnology also finding solution for this problem by using smartphone as a measure to detect pesticide residues in food commodities. Smartphone based nanoparticles fixed filter paper used as test paper, and the blue luminescence on it would be quenched after additions of thiram through luminescence resonance energy transfer mechanism. These variations in light intensity will occur based on difference in concentration. That could be monitored by the smartphone camera, and then the blue channel intensities of obtained colored images were calculated to quantify amounts of thiram through a self-written androidprogram installed on the smartphone, offering a reliable and accurate detection limit of pesticide. The intensity of colour will be manifested as concentration of pesticide (Mei *et al*., 2016). Recently, Hua et al., (2015) reported that calcium carbonate nanoparticles can enhance plant nutrition and insect pest tolerance

Another measure for easy detection of pesticides can be achived through use of Nanosensors, a self contained portable equipment that has got a recognition element. The recognition element may be DNA/RNA/Enzyme/Antibody. Transduction element will help to convert biochemical signal to electrical signal. One such example is apta-nanosensors for detection and quantitative determination of acetamiprid (Verdian, 2017).

Bionanomaterials

The DNA tagged with nano particle are also a promising area in pest management. The efficacy of the DNA tagged gold nanoparticles on the major polyphagous pest, *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) was evaluated. Larval mortality data revealed that the particles were effective and caused 50 per cent larval mortality above 500 ppm. The study demonstrated that DNA tagged gold nanoparticles are effective against *S. litura* and would therefore be a useful component of an integrated pest management strategy This study clearly demonstrates that metal nano-particles could be a better alternative to synthetic insecticides, in addition to being a toxicant that inhibits biological and physiological systems of insects. (Chakravarthy *et al.*, 2012). Chandrashekharaiah *et al*. (2015) developed DNA-tagged nanogold, DNA-tagged CdS, nano-TiO2 and nano-Ag and were tested against *S. litura* third, fourth and fifth instar larvae. Results revealed that DNA-tagged nanogold caused 30.50, 57.50 and 75.00% mortality respectively on third, fourth and fifth instar *S. litura* larvae. Gold metal is a conductor of heat, but, when its size is reduced by one billion, it becomes insulator so that it can be used to deliver the toxicant to the target cells directly. This unique property will be of immense value in medical, entomological and allied sciences. It has been reported that gold nanoparticle has the ability to stimulate the different physiological enzymes (Biju, 2007). It may suggest that DNA-tagged gold nanoparticles can affect phosphorylation in relation to kinase activity which helps to inhibit the indirect effect of DNA functions and thus lysis of the insect pest tissue leads to death of the *S. litura*. DNA-conjugated-gold nanoparticles have an effect on kinase activity (Chakravarthy *et al.,* 2012). Nanoparticles loaded with neem (*Azadirachta indica*) extracts were

formulated as colloidal suspension and (spray-dried) powder and characterized by evaluating pH, particle size. The experimental data of the formulated products against *Plutella xylostella* showed 100 per cent larval mortality (Forim *et al*., 2013). Several attempts were made to manage mosquito by using plant derived materials coated with nano particle. Some of the sources of plantproducts carrying nanoparticles and their target pests are given in Table 1. Nano emulsion produced was thermodynamically stable, optically transparent and small droplet size.

Lagenidium giganteum, a mosquito larvicide registered with USEPA. Poor stability during storage & expensive storage requirements. Addition of hydrophobic silica NPs (7-14 nm) to water in oil emulsion reduced dessication.. Thickened formulation imparted >95% efficacy after 12 weeks of storage (Vandergheynst *et al*., 2007).

Nanopesticides were also formulated by using microorganism. The cell-free supernatant of *Photorhabdus luminiscens* was converted to nanoparticles (NPs) using a spray dryer fitted with ultrasonic nozzle. Nanoparticulated supernatant exhibited superior pesticidal property against serious sucking pests of cotton, viz. *Tetranychus macfarlanei* and *Aphis gossypii* (Ramesh *et al*., 2017).

Table 1: Biological nanopesticides: a greener approach towards the mosquito vector control

Nanopesticide	Source	Lethal indices (LC50) 24 h	Host insect	vector	References
AgNP	*Carissa carandas*	31.5 mg/L	*A. subpictus*		Govindrajan *et al.* (2016)
Neem nanoemulsion	Neem oil (*A. indica*	11.5 mg/L	*C. quinquefasciatus*		Anjali *et al.* (2012)
Eucalyptus nanoemulsion	Eucalyptus oil	250 mg/L	*C. quinquefasciatus*		Sugumar *et al.* (2014)

Limitations of nano agrochemicals

When considering all nanoproducts that will possibly emerge in the food and agriculture sectors, there is a widely accepted consensus that there is insufficient reliable data currently to allow a clear safety assessment. Exposure assessment relies on investigations into the environmental fate of a compound. There have been a limited number of studies investigating nano agrochemicals. It is also likely that fate and hazard endpoints are not adequately determined through the application of protocols that were developed previously for other types of chemicals (Kookana *et al*., 2014). Overall, the current level of knowledge appears to be largely insufficient for a reliable assessment of the risks associated with the use of nano agrochemicals.

However, prohibiting the application of nanopesticides until they are proven entirely safe is unrealistic, as all pesticides are inherently toxic (at least to the target pest) and, thus, associated with some risk.

It is also important to note that some nanopesticides may offer a number of benefits, including increased efficacy, reductions in application rates, exposure to non-target organisms or the development of resistances. In the scientific literature, the last couple of years have seen increasing incentives to use nanotechnology to develop products that may be less harmful to the environment relative to conventional agrochemicals. A fair assessment of nano pesticides should, thus, be looking at evaluating both the risks and benefits associated with their use relative to current solutions. While this may not be possible when considering all products discussed so far in literature, restricting the analysis to products that are likely to emerge in the next decade shows that a fair assessment may be possible.Nanoparticles are expected to diffuse at a slower rate that is influenced by humic substances and mucoproteins. In addition, Nanoparticles may get entangled with mucoproteins, leading to prevention/retardation of their uptake. The size of Nanoparticles precludes their uptake via ion or other transporters on the cell membranes. Furthermore, the Ca^{2}+- and Mg^{2}+-rich environment in the tight junctions between cells may trigger the aggregation of Nanoparticles, thereby reducing their diffusion. Such processes at biological surfaces have the potential to alter the absorption and distribution of nano pesticides in comparison to traditional forms, with resultant effects on tissue distributions and biomagnifications potential.

Future line

More studies are needed to explore the mode of action of NPs, their interaction with biomolecules , and their impact on regulation of gene expression in plants. Research on nanoparticles with respect to crop protection should be geared towards introduction of faster and ecofriendly nano formulations in future. Evaluation of nano materials for hazardous effects. Field level application of the nanopesticides .More concern on bio nano pesticides. UV shielding to entomopathogens can be provided.

CONCLUSION

Conventional farming practices are becoming increasingly inadequate, coupled with increasing demands of the terrestrial ecosystem. Adoption of new technologies is crucial if production is to be increased to match the demands for food. Safer and bio-degradable nanomaterials should be developed for nano pesticides production. As a most promising and attractive field of nanotechnology application

in agriculture, these novel agrochemical products will provide multiple benefits such as reduced use of chemicals and subsequently reduced water pollution and food product residual contamination, efficient use of agricultural produces. The use of agrochemicals is associated with some risks for human and environmental health (e.g., contamination of water resources, residues on food products). Many reports foresee that nanotechnology will allow the development of high-tech agricultural fields, equipped with a range of intelligent nano tools that allow for the precise management and control of inputs, including pesticides, fertilizers, and water. The development of such devices would certainly lead to a revolution in agricultural practices and could possibly contribute to an important reduction in the impact of modern agriculture on the environment and an improvement in both the quality and quantity of yield. However, because agriculture is a low profit industry, one must recognize that such applications do not fit within cur One of the main causes of losses in cultivations is the action of insects and other pests, which can be controlled by products derived from natural sources (such as botanical insecticides) as well as the use of nanotechnology to produce new formulations (Forim *et al*., 2013) economic reality and also face a high risk of early regulatory and social rejection. A well designed controlled-release system may enhance their target specificity, optimizing the action of the active ingredients and minimizing its residual impacts .Nano biotechnology offers great promise in this direction and nano technological formulations can be used to improve both the stability and effectiveness of these natural products (Ghormade *et al*., 2011). Different matrices can be used to produce nanostructured systems, including biodegradable polymers.

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Antimicrobial property of *amritpani*, cow pat pit, *jeevamrita* and *panchagavya* on some pathogens

R A Ram, Neelima Garg and Priti

ICAR-Central Institute for Subtropical Horticulture, Lucknow- 226 101
[1]Principal Scientist (e-mail: ra.ram@icar.gov.in), Divison 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

Antimicrobial property of bio-enhancers viz. *Amritpani*, *Panchagavya*, cow pat pit, *Jeevamrita* was tested against some selected pathogens in vitro conditions revealed significant reduction in the growth of *Aspergillus fumigatus* and complete growth inhibition of *Colletotricum gloeosporioides* and *Fusarium solani*.

Key word: *Amritpani*, *panchagavya*, cow pat pit, *Aspergillus fumigatus* and *Colletotricum gloeosporioides*

Use of organic liquid preparations had been an age old practice in India. *Amritpani*, *Panchagavya*, cow pat pit and *Jeevamrita* are used in different organic farming system viz; *Rishi krishi, panchagavya*, biodynamic and natural farming (Ram and Kumar, 2019, Vaish *et al*, 2019). *Jeevamrita* is a low cost bio-enhancer that enriches the soil with indigenous micro organisms required for mineralization of the soil (Ram and Pathak, 2019). *Cow pat pit, Panchagavya and Amritpani* is also cost effective preparations (Ram et al, 2019). These preparations are recommended for seed/seedling treatment, foliar and soil application in organic production of various crops (Ram and Pathak, 2019). Uma and Sujathamma (2014) have reported that replacement of chemical fertilizers by *Jeevamrita* is a better option in cultivation of rice varieties like Masura and Hamsa. The selected pathogens in this study cause various diseases in different crops. Cost of cultivation with use of recommended agro-chemicals arises at alarming stage. Attention to be paid to use an integrated disease management approach for managing various diseases in crops through utilization of resistant cultivars, minimizing fungicides use and alternative options to reduce the human health hazards (Ramadan and Nassar, 2005). Indigenous technical knowledge pertaining to disease management in different crops is available in biodynamic, *Panchagavya*, *Rishi Krishi* and natural farming (Ram and Pathak, 2019). In view of this, an attempt was made to record antimicrobial property of these preparations against some common pathogens under laboratory conditions.

Antimicrobial property of *Amritpani, cow pat pit, Jeevamrita and Panchagavya* was observed by plate assay method against pathogenic fungus *Colletotricum gloeosporioides, Fusarium solani* and *Aspergillus fumigatus.* Potato Dextrose Agar (PDA) was used to study the antagonistic activity since PDA was the suitable media for fungi growth. One ml from each samples (*Amritpani, Cow pat pit, Jeevamrita and Panchagavya*) were pour plated individually on sterile petri dishes. Approximately, a 5 mm mycelial plug was taken from the peripheral edge of five days old cultures of fungal pathogens and each placed at the centre of the plates and inoculated plates were incubated at 30°C for 3 days. Thereafter, the zone of inhibition (distance of the fungal mycelium measured in mm) was recorded after 3 days of growth (Zhang *et al.* 2015) and measured the colony size of fungi by Himedia colony size scale.

Table 1. Growth of various pathogens against bio-enhancers

Treatments	*Aspergillus fumigatus* colony size (mm)	*Colletotricum gloeosporioides* colony size (mm)	*Fusarium solani* colony size (mm)
Control	40	8	10
Amritpani	12	0	0
Jeevamrita	11	0	0
Panchagavya	20	0	0
Cow Pat Pit	10	0	0

Growth of *Aspergillus fumigatus* was 12 mm, 11 mm, 10 mm and 10 mm with Amritpani, Jeevamrita, Panchagavya and cow pat pit, respectively against 40 mm in control. *Colletotricum gloeosporioides* growth was recorded in control was 8 mm but no growth was observed with *Amritpani*, *Jeevamrita*, *Panchagavya* and cow pat pit. *Fusarium solani* showed no growth with *Amritpani*, *Jeevamrita*, *Panchagavya* and cow pat pit against 10 mm recorded in the control. Joseph and Sankarganesh (2011) has also reported the antifungal property of *Panchagavya*. These bio-enhancers are prepared with cow dung and cow dung contains several beneficial microbes which manage several diseases in various crops. Yangabi *et al.*, (2009) recorded cowdung slurry effect on antimicrobial property of medicinal crops. Swain *et*

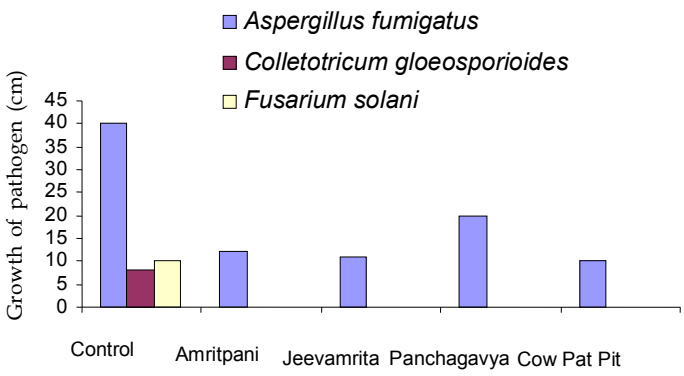

Fig. 1. Growth of various pathogens against bio-enhancers

al., (2008) have isolated *Baccillus subtilis* from cowdung which is used as bio control agent in several cases. Waziri and Suleiman (2013) also reported antimicrobial property of cow dung vapour against pathogen. Proctor (2008) has suggested seed/seedling treatment with cow pat pit for the management of soil born disease. Sumangala and Patil (2007) found that *Panchagavya*–an organic formulation evaluated in vitro for its antifungal activity against *Curvularia lunata* in rice, which was found to be dominant pathogen in causing grain discoloration. Selvaraj (2006) has reported that fermentative bacteria, *Lactobacillus* that develop in the solution, produce various beneficial metabolites such as organic acids, hydrogen peroxide and antibiotics, which are effective against other pathogenic micro-organisms. The short chain aldehydes are involved in hypersensitive response of plants against pathogens. The fatty acids constitute embryo development and seed filling. In another study, Utpal *et al*., (2013) reported that Panchagavya resulted in 86.30 per cent inhibition of mycelial growth and 95.9 per cent of spore germination of *Curvularia lunata*. They have concluded that Neemazol, *Trichoderma* and Jeevamrita can be used to manage of *P. sorghi* instead of fungicides which will be cheapest and eco-friendly way to manage the common rust of maize.

Seed treatment with Panchagavya further enhances the seed germination with 90.7 per cent and vigour index of 1036. Its regular use of 3 per cent solution has been found very effective in large number of crops pests and diseases such as leaf spot, blight, mildew, and rust of vegetables (Nagraj and Sreenivasa, 2009). Use of *Amritpani* as foliar and soil application has already been recommended by Deshpandey (2003) for organic production of various crops.

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Crop diversification and intensification through groundnut + sweet corn mix/inter cropping systems for enhancing farmers' income

V. P. Chovatia, R. K. Mathukia*, S. K. Chhodavadia and B. K. Sagarka

Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh-362001 (Gujarat, India)
**email: rkmathukia@jau.in*

ABSTRACT

For crop intensification and diversification as a strategy of doubling farmers' income, a field experiment was conducted during *kharif* season of 2016 and 2018 at Junagadh (Gujarat, India) to evaluate groundnut (*Arachis hypogaea* L.) + sweet corn (*Zea mays* L.var. *saccharata* Sturt) mix/inter cropping systems on medium black calcareous soil. Groundnut + sweet corn intercropping in row ratio of 1:1 (replacement series), 2:1, 3:1 and paired row in row ratio of 2:1 (additive series) and mix cropping in 90:10 per cent and 80:20 per cent were compared with sole groundnut and sole sweet corn. The pooled results over three years revealed that the paired row (45-75-45 cm) groundnut + sweet corn (2:1) additive intercropping recorded significantly the highest groundnut pod equivalent yield (GPEY)of 2210 kg ha^{-1} and land equivalent ratio (LER) of 1.42. The next superior treatments in this regard were groundnut + sweet corn (3:1) additive intercropping and groundnut (90%) + sweet corn (10%) replacement mix cropping having PEY of 1997 & 1765 kg ha^{-1} and LER of 1.32 & 1.12, respectively. Whereas, the sole sweet corn recorded the lowest GPEY (1191 kg ha^{-1}) and groundnut + sweet corn (1:1) replacement intercropping registered the lowest LER (0.97). The paired row (45-75-45 cm) groundnut + sweet corn (2:1) additive intercropping recorded maximum net returns of ' 72880 ha^{-1} and B:C ratio of 2.94, closely followed by groundnut + sweet corn (3:1) additive intercropping and groundnut (90%) + sweet corn (10%) replacement mix cropping, which gave net returns of ' 63497 and 55279 ha^{-1} and B:C ratio of 2.75 and 2.68, respectively.

Key words: Crop diversification, intercropping, farmer's income

Groundnut (*Arachis hypogaea* L.) is the pre-dominant *kharif* crop of the Saurashtra region of Gujarat state. Yield fluctuation under vagaries of monsoon, disease-pest and low market price are the major constraints in groundnut cultivation. Hence, during last few years most of the farmers switched over to Bt cotton cultivation. But further disease-pest problem and low market price of Bt cotton is now became the major constraint besides some production problems. Animal husbandry is an important and integral component of farming system in the Saurashtra region. The dominance of groundnut over the years is mainly ascribed to the haulm of groundnut, which serves as valuable fodder. This situation necessitates crop diversification, which should be remunerative and also provide fodder. As legume + cereal mixture is an ideal intercropping system, sweet corn can suitably be intercropped with groundnut (Kumar and Singh, 1992; Laxminarayana and Munda, 2004; Singh *et al.*, 2005; Thavaprakaash and Velayudham, 2007). Speciality corns (*viz.*, sweet corn, pop corn, baby corn, high-oil corn *etc.*) assume tremendous market potential not only in India but also in the international market. These specialty corns with their high market value are perfectly suitable to *peri*-urban agriculture. Thus, they promise higher income to maize growers. Out of the various speciality corns, sweet corn (*Zea mays* L.var. *saccharata* Sturt) has a big marketpotential. It is a hybridized variety of maize specifically bred to increase the sugar content. In addition, green fodder derived after harvest is an additional advantage of sweet corn. Being a C_4plant, sweet corn is also suited under climate change condition. The present experiment was therefore conducted to evaluate groundnut + sweet corn mix/inter cropping systems in various proportions.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) season of 2016to 2018 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat, India). Geographically, Junagadh is situated at 21.5^0N latitude and 70.5^0 E longitude with an altitude of 60 m above the mean sea level. The rainy season commences in the second fortnight of June and ends by September with an average rainfall of 1130 mm (average of last 10 years). Monsoon rainfall of 972, 804 and 789 mm was received in 41, 42 and 32 rainy days during the year 2016, 2017 and 2018, respectively. The experimental soil was clayey in texture and slightly alkaline in reaction with pH 7.6-7.8 and EC 0.32-0.43 dS/m. It was low in available nitrogen (221-241 kg ha^{-1}), available phosphorus (22-27 kg ha^{-1}) and high in available potash (281-323 kg ha^{-1}). The experiment comprised eight treatments*viz.*,T_1: Sole

groundnut, T_2: Sole sweet corn, T_3: Groundnut + sweet corn (1:1 replacement intercropping), T_4: Groundnut + sweet corn (2:1 additive intercropping), T_5: Groundnut + sweet corn (3:1 additive intercropping), T_6: Paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping), T_7: Groundnut + sweet corn (90:10% mix cropping), and T_8: Groundnut + sweet corn (80:20% mix cropping)were replicated three times in a randomised block design. The groundnut variety 'GG 20' and sweet corn hybrid 'Sugar 75' were sown on 28-06-2016, 03-07-2017 and 24-07-2018 and harvested according to maturity of respective crops. The gross plot size was 5.0 m x 4.8 m, and net plot size was 4.0 m x 3.6 m (except T_5) and 4.0 m x 2.4 m (T_5). The recommended fertilizer dose 12.5-25-0 kg N-P_2O_5-K_2O ha^{-1} for groundnut and 120-60-0 kg N-P_2O_5-K_2O ha^{-1} for sweet corn as per area occupied by the respective crop in different treatments were applied. The entire dose of phosphorus and nitrogen were applied to groundnut as basal application in form of urea and DAP just before sowing in the furrows. In sweet corn, entire dose of phosphorus and half dose of nitrogen were applied as basal application in form of urea and DAP and remaining half dose of nitrogen was top dressed as urea at 30 days after sowing (DAS). The crops were raised as per the standard package of practices.

Growth, yield and quality parameters of groundnut *viz*., plant height, mature pods/plant, 100-kernel weight, shelling percentage, oil content, pod yield and haulm yield, and that of sweet corn *viz*., plant height, cob length, cob girth number of grains per cob, fresh weight of cob, cob yield and fodder yield were recorded as per standard procedure. Land equivalent ratio (LER) was calculated as suggested by Willey (1979).

$$LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where; L_a and L_b are LER of crop a and crop b, respectively; Y_{ab} = yield of crop a in intercropping, Y_{ba} = yield of crop b in intercropping, Y_{aa} = yield of crop a in pure stand and Y_{bb} = yield of crop b in pure stand. LER of more than 1 indicates yield advantage, equal to 1 indicates no gain or no loss and less than 1 indicates yield loss. It can be used both for replacement and additives series of intercropping.

Pod and haulm yields of groundnut and cob and fodder yields of sweet corn were recorded from the net plot area and converted into quintal per hectare base. The gross realization in terms of rupees per hectare was worked out taking into consideration the pod/cob and haulm/fodder yields from each treatment and local market prices. The expenses incurred for all the cultivation operations from preparatory tillage to harvesting including the cost of inputs *viz*., seeds, fertilizers, pesticides, *etc*. applied to each treatment along with the treatment cost were calculated on the basis of prevailing local charges. Net return of each treatment was calculated by deducting the total cost of cultivation from the gross returns. The Benefit : Cost (B:C) ratio was calculated with the help of the following formula.

$$B:C = \frac{\text{Gross returns (₹ ha}^{-1})}{\text{Total cost of cultivation (₹ ha}^{-1})}$$

The data were subjected to statistical analysis by adopting appropriate analysis of variance (Gomez and Gomez, 1984). Wherever the F values found significant at 5 per cent level of probability, the critical difference (CD) values were computed for making comparison among the treatment means.

RESULTS AND DISCUSSION

Growth and yield attributes

Mean data of growth and yield attributes of groundnut are given in Table-1. The results indicated that sole groundnut recorded significantly the highest values of plant height (30.52 cm), mature pods $plant^{-1}$ (15.12), 100-kernel weight (54.53), shelling (72.86%) and oil content (49.68%), which remained statistically at par with the treatments groundnut + sweet corn (1:1 replacement intercropping), groundnut + sweet corn (90:10% mix cropping) and paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping). Whereas, the lowest values of these parameters were registered under groundnut + sweet corn (2:1 additive intercropping).

An appraisal of data presented in Table-2 showed that growth and yield attributes of sweet corn were significantly

Table 1: Effect of groundnut + sweet corn inter/mix cropping on growth, yield attributes and quality of groundnut (Pooled over three years)

Treatment	Plant height (cm)	Mature pods $plant^{-1}$	100-kernel weight (g)	Shelling (%)	Oil content (%)
T_1	30.52	15.12	54.53	72.86	49.68
T_2	-	-	-	-	-
T_3	30.13	14.91	53.76	71.63	49.16
T_4	25.26	8.46	42.13	63.73	45.13
T_5	26.40	9.32	47.88	65.16	45.28
T_6	28.73	13.98	50.92	69.35	47.66
T_7	29.65	14.51	53.20	70.26	48.54
T_8	27.06	10.11	49.11	67.04	45.28
S.Em.±	0.90	0.45	1.3	1.21	1.43
C.D. at 5%	2.58	1.32	3.9	3.56	4.19
C.V.%	9.56	10.94	8.01	5.31	9.08

influenced by different inter/mix cropping systems. Significantly the highest plant height (159.7 cm), cob length (21.90 cm), cob girth (16.83 cm), grains cob-1 (328.3) and fresh weight of cob (185.4 g) were recorded under groundnut + sweet corn (90:10% mix cropping), which found statistically comparable to groundnut + sweet corn (80:20% mix cropping) and paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) in pooled results. Whereas, significantly the lowest values of these attributes were registered under the sole sweet corn.

Table 2: Effect of groundnut + sweet corn inter/mix cropping on growth and yield attributes of sweet corn (Pooled over three years)

Treatment	Plant height (cm)	Cob length (cm)	Cob girth (cm)	Grains cob^{-1}	Fresh weight of cob (g)
T_1	-	-	-	-	-
T_2	144.1	14.64	14.46	265.2	150.4
T_3	156.3	17.04	14.68	276.9	155.0
T_4	145.4	17.92	15.00	282.3	166.3
T_5	148.2	18.40	15.33	297.4	171.7
T_6	154.4	20.32	15.71	312.5	175.0
T_7	159.7	21.90	16.83	328.3	185.4
T_8	156.6	20.60	16.22	319.6	179.3
S.Em.±	4.8	0.64	0.54	9.8	4.2
C.D. at 5%	13.8	1.88	1.58	28.7	12.3
C.V.%	9.47	10.27	10.48	9.88	7.45

Crop yields

The data furnished in Table-3 showed that different inter/mix cropping systems significantly influenced the pod and haulm yields of groundnut. The sole groundnut out yielded by producing significantly the highest pod yield of 1573 kg ha^{-1} and haulm yield of 2984 kg ha^{-1}, however it remained statistically at par with paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) having pod yield of 1525 kg ha^{-1} and haulm yield of 2890 kg ha^{-1}. Whereas, significantly the lowest pod (715 kg ha^{-1}) and haulm (1652 kg ha^{-1}) yields were registered under groundnut + sweet corn (1:1 replacement intercropping).

The data presented in Table-3 indicated that various inter/mix cropping systems exerted significant effect on cob and fodder yields of sweet corn. The sole sweet corn recorded significantly the highest cob yield of 4638 kg ha^{-1} and fodder yield of 13158. The groundnut + sweet corn (90:10% mix cropping) registered significantly the lowest cob yield of 1115 kg ha^{-1} and fodder yield of 3722 in pooled results.

In both the component crops, sole stand showed higher values for their respective yield attributes and yield. This is due to the fact that sweet corn has deep root system and vigorous plant growth, offered more competition both below and above ground for growth resources whereas, better root growth in sole groundnut facilitated more area for nodule formation and growth resulting higher yield attributes (Choudhary*et al.*, 2014). Whereas, in case of maize, the sole stand showed higher values of yield contributing characters and yield due to lesser competition for nutrients, light and space (Singh *et al.*, 2012). Adaniyan*et al.* (2007) also confirmed that yield reductions in intercropping are associated to inter-specific competition for nutrients, moisture or space.

The data (Table-3) indicated that different inter/mix cropping systems exerted significant effect on groundnut pod equivalent yield in pooled results. The paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) recorded significantly the highest GPEY (2210 kg ha^{-1}). The next superior treatments in this regard were groundnut + sweet corn (3:1 additive intercropping) and groundnut + sweet corn (90:10% mix cropping). Whereas, the sole sweet corn recorded the lowest GPEY (1191 kg ha^{-1}). Although, the yield attributes and yield of both the component crops showed a decreasing trend with intercropping compared to respective sole cropping, the GPEY increased with intercropping which leads to additional advantage of intercropping. Higher GPEY under intercropping systems was attributed to yield advantages achieved in intercropping system (Mandal*et al.*, 2015)). The difference in GPEY was mainly as a consequence of differences in the yield of groundnut, additional sweet corn yield and price of individual component crops.

Land equivalent ratio

The results (Table-3) showed that different inter/mix cropping systems exhibited their significant influence of LER in pooled results. Excluding sole crops and replacement intercropping, other inter/mix cropping systems recorded

Table 3: Effect of groundnut + sweet corn inter/mix cropping on yield and LER (Pooled over three years)

Treatment	Groundnut		Sweet corn		GPEY (kg ha^{-1})	LER
	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Cob yield (kg ha^{-1})	Fodder yield (kg ha^{-1})		
T_1	1573	2984	0	0	1692	1.00
T_2	0	0	4638	13158	1191	1.00
T_3	715	1652	2371	6359	1383	0.97
T_4	1074	2024	1604	6087	1598	1.04
T_5	1347	2552	2102	6350	1997	1.32
T_6	1525	2890	2030	8172	2210	1.42
T_7	1367	2512	1115	3722	1765	1.12
T_8	1294	2411	1150	4016	1701	1.09
S.Em.±	55	92	129	207	60	0.04
CD (p=0.05)	159	264	371	595	170	0.11

GPEY=Groundnut pod equivalent yield, LER=land equivalent area

LER > 1. The treatments comprising paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) and groundnut + sweet corn (3:1 additive intercropping), being statistically at par with each other, recorded significantly higher LER (1.42 and 1.32) in pooled results as compared to the other treatments. Whereas, groundnut + sweet corn (1:1 replacement intercropping) registered the lowest LER (0.97) in pooled results. The results indicate that 32 to 42 per cent area would be required by a sole cropping system to recover the yield of intercropping system. LER reflects the extra advantage of intercropping system over sole cropping system. While, LER for groundnut + sweet corn (1:1 replacement intercropping) was less than 1.0, it indicated disadvantage of replacement intercropping (Jacob *et al.*, 2014). On the other hand, LER of other inter/mix cropping systems was more than sole which showed an advantage of intercropping over sole system in terms of the use of environmental resources for plant growth. Mandal *et al.* (2015)also reported the higher land equivalent ratio with intercropping over sole cropping system.

Economics

Economics was worked out by using current market prices of produce and inputs used (Table-4). The mean data of three years indicated that maximum gross returns (' 110497 ha^{-1}) was recorded under paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping), followed by groundnut + sweet corn (3:1) and groundnut + sweet corn (90:10% mix cropping) having gross returns of ' 99837 and 88225 ha^{-1}, respectively. The paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) recorded maximum net returns of ' 72880 ha^{-1} and B:C ratio of 2.94, closely followed by groundnut + sweet corn (3:1 additive intercropping) and groundnut + sweet corn (90:10% mix cropping), which gave net returns of ' 63497 and 55279 ha^{-1} and B:C ratio of 2.75 and 2.68, respectively. Additional income from inter/mix crop resulted in higher net returns and B:C. These results also support the findings of Choudhary *et al.* (2014) and Mandal *et al.* (2015).

Table 4: Economics of groundnut + sweet corn inter/mix cropping systems (Pooled over three years)

Treatment	GPEY (kg ha^{-1})	Gross returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
T_1	1692	84607	32505	52102	2.60
T_2	1191	59538	36924	22614	1.61
T_3	1383	69144	34715	34430	1.99
T_4	1598	79885	37617	42269	2.12
T_5	1997	99837	36339	63497	2.75
T_6	2210	110497	37617	72880	2.94
T_7	1765	88225	32947	55279	2.68
T_8	1701	85039	33389	51651	2.55

CONCLUSION

In the light of the results summarized as above it could be concluded that crop intensification and diversification in form of paired row (45-75-45 cm) groundnut + sweet corn (2:1 additive intercropping) or groundnut + sweet corn (3:1 additive intercropping) or groundnut + sweet corn (90:10% mix cropping) could be adopted to achieve higher productivity and economic realization per unit area of land under south Saurashtra agro-climatic conditions of Gujarat.

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Response of drip irrigation on different tree architecture of mango cv. Dashehari for quality production

Manoj Kumar Soni[1] and V. K. Singh[2]

ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow - 226 101, India
[1]Research Associate; [2]Principal Scientist

ABSTRACT

A field experiment was conducted with an objective of improving the yield and quality of mango cv. Dashehari (15 year old) planted at 6.0 x 9.0 m spacing accommodating 185 plants per hectare. The experimental plot was irrigated with drip irrigation system having four emitters per plant of eight LPH capacity based on irrigation level of 80 per cent pan evaporation (PE) replenishment against ring basin irrigation methods used in control. The black polyethylene mulching (100µ thickness) was used to cover 40 per cent area of tree canopy. Recommended dose of fertilizer was applied at different phenological stages. The impact of different canopy shape viz. conical shape, flat top, open centre on light distribution pattern and gas exchange parameters along with flowering and fruiting pattern was studied. There were significant change in light distribution pattern among different shape being maximum diffused light (7777 mol m^{-2} s^{-1}) in open centre and minimum in flat top (4791 mol m^{-2} s^{-1}). Among gas exchange parameters photosynthesis rate (13.15 ì mol m^{-2} s^{-1}) was also found maximum in the open centre as compared to other shape (8.4 to 12.7ì mol m^{-2} s^{-1}) of canopy. Enhancement in flowering, maximum fruit yield in open centre (63.0 kg $tree^{-1}$) followed by flat top (59.6 kg $tree^{-1}$), conical shape (54.3 kg $tree^{-1}$) and minimum yield (48.6 kg $tree^{-1}$) in control was recorded. Maximum 'A' grade fruit (27%) was also observed in open centre with application of irrigation at 80 per cent PE per day per plant against minimum 'A' grade fruit (11%) recorded in the control.

Key words: Mango, Dashehari, Canopy shape, Irrigation level, Photosynthesis rate

In mango, canopy shape is very important for improving its quality production. Irrigation scheduling based on empirical value of crop coefficient greatly influences the production cost, crop yield and fruit quality. Intensive knowledge of the changes in water levels and its association with evapo-transpiration in mango is essential to improve upon the yield and fruit quality limiting factors. The economic development of country is dependent on the horticulture production because it provides more revenue per hectare in addition to nutritional security. Despite the exponentially growing population, food production is limited by land and water. Irrigation is a very important factor impacting growth, yield and quality of any crop. Mango is widely grown in India, whose production reached 15.03 million tones amounting to 21 per cent of the total fruit production. Uttar Pradesh contributes to 23.9 per cent in mango basket of the country. Although growing areas in India have shown increasing trend but the mean fruit yield has plateaued to nearly 6.5 ton ha^{-1} (NHB Database). As the water resources are becoming scarce day by day, appropriate water utilization must be ensured by adopting efficient irrigation management practices. It is observed that the application of a higher irrigation water volume does not result in higher yields of fruits (Azevedo *et al.*, 2003; Singh *et al.*, 2013; De bie, C.A.J.M., 2004). The empirical approach on irrigation of several subtropical and tropical fruit orchards suggests that if the amount of irrigation water is excessive it could lead to the leaching of applied nutrients and pesticides into the groundwater (Schaffer, 1998). Moreover, the surplus water may increase soil salinity and groundwater contamination. Irrigation scheduling based on empirical value of crop coefficient greatly influences production cost, crop yield and fruit quality. Intensive knowledge of the changes in water levels and its association with evapo-transpiration in mango is essential to improve upon the yield and fruit quality limiting factors (Zhang *et al.*, 2004; Allen *et al.*, 1998). In the present paper the impact of canopy shape on flowering and quality fruiting and irrigation requirement with respect to canopy modification in mango, grown in a subtropical environment based on standardized irrigation level of 80 per cent pan evaporation replenishment, has been studied.

MATERIALS AND METHODS

The field experiment was conducted at ICAR - Central Institute for Subtropical Horticulture, Lucknow in 15 years old mango cv. Dashehari planted at 6.0×9.0 m spacing accommodating 185 tree ha^{-1}, replicated thrice in randomized block design. The experimental plot had sandy loam soil and was irrigated with a drip irrigation system as having 4 emitters per plant of 8 lph capacity. The experiment has two irrigation levels with drip system, 80 per cent of pan evaporation (PE) replenishment and one basin irrigation with

100 per cent PE replenishment under mulch and non-mulch conditions along with four canopy shapes i.e. conical (central leader system), flat top (modified leader system), centre open (open centre system) and the conventional system (control). The drippers were placed equidistant at 50 per cent distance of canopy radius. The water received though rain was accommodated in irrigation schedule in successive days in all treatments but was neglected in control plants. The water requirement was determined by multiplying the canopy area (m^2 x pan evaporation (mm) x evaporation replenishment (%). One square meter canopy area with one ml evaporation replenishment was equal to one liter of drip irrigation water (Dinesh *et. al.,* 2008; Agarwal *et al.,* 2001; Singh *et al.,* 2015). The time of drip operation was determined by the total quantity of water required in liter divided by total discharge rate. The irrigation and fertilizer was applied as per schedule standardized earlier (Sivanappan, 1987; Srivastava *et. al.,* 1994; Anonymous 2018 pfdc Ann. Rep.) through drip irrigation (Table 1). UV stabilized black polyethylene mulching 100 micron thickness covering 40 per cent area of tree canopy was done during October-November. Observations on meteorological parameters viz., pan evaporation, temperature, relative humidity and plant growth viz., height (m), yield (kg plant $^{-1}$), fruit weight (g), and quality attributes viz., TSS (^{o}Brix), firmness (kg cm^{-2}) and cumulative physiological loss of weight (CPLW) (%) at appropriate stages were recorded.

Table 1. Monthly scheduling of fertigation and irrigation for mango

Month	16:46:00 (DAP)	46:00:00 (Urea)	0:00:50 (SOP)	Water requirement (liter plant^{-1})
January	0	0	0	330.08
February	0	0	150.0	347.79
March	0	0	250.0	478.45
April	300	0	350.0	743.72
May	0	0	450.0	932.78
June	0	0	250.0	0
July	0	450.0	150.0	0
August	400.0	250.0	0	0
September	0	450.0	150.0	0
October	400.0	250.0	150.0	607.90
November	0	425.0	100.0	492.13
December	0	0	0	311.58
Total	1100.0	1825.0	2000.0	4244.44

RESULTS AND DISCUSSION

Enhancement in flowering (90%), maximum fruit yield (63.0 kg tree^{-1}) in open centre followed by flat top (59.6 kg tree^{-1}), conical shape (54.3 kg tree^{-1}) against minimum flowering (72%) and yield (48.6 kg tree^{-1}) in the control was recorded. Maximum 'A' grade fruit (27%) was also observed in open centre with application of irrigation at 80 per cent PE per day per plant whereas minimum 'A' grade fruit (11%) was recorded in the control treatments. Improvement in the fruit quality in terms of higher TSS (25.4 °Brix), firmness (0.67 cm^{-2}) and reduced CPLW (6.10%) in centre open coupled with polythene mulching was recorded as compared to less TSS (20.9 °Brix), firmness (0.55 cm^{-2}) and high CPLW (6.80%) in control (Table 3, Fig 1, 2 & 3 A-G). The results are in conformity with the finding of Srinivas (2005) under Bangalore conditions, Dixit *et al.,* (2005) under Raipur conditions, Shirgure *et al.,* (2004) under Nagpur conditions. Singh *et al.,* (2015) reported maximum canopy volume and fruit yield with irrigation equivalent to 0.8 PE in sub tropical fruit under high density planting system. Drip irrigation provides a consistent moisture regime in the soil due to which root remains active through out the season resulting in optimum availability of nutrient and its proper translocation which accelerates the fruit growth and development in mango. Coelho and Borges (2004), Singh *et al.,* (2013) emphasized the importance of drip irrigation in fruit crops for better yield and quality. Leaf area index was maximum (1.734) in centre open shape and minimum in flat top.

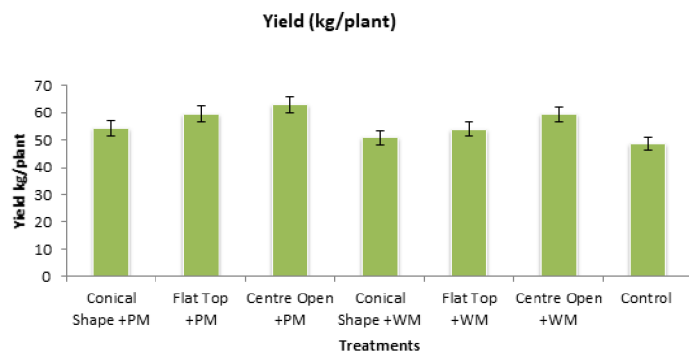


Fig. 1. Yield (kg plant^{-1}) pattern of mango cv Dashehari under different canopy shape cultured with and without black polyethylene

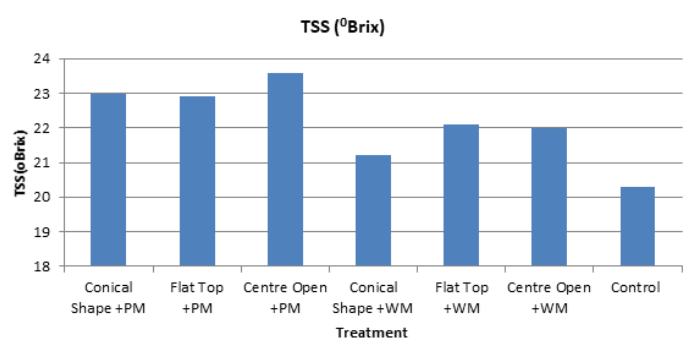
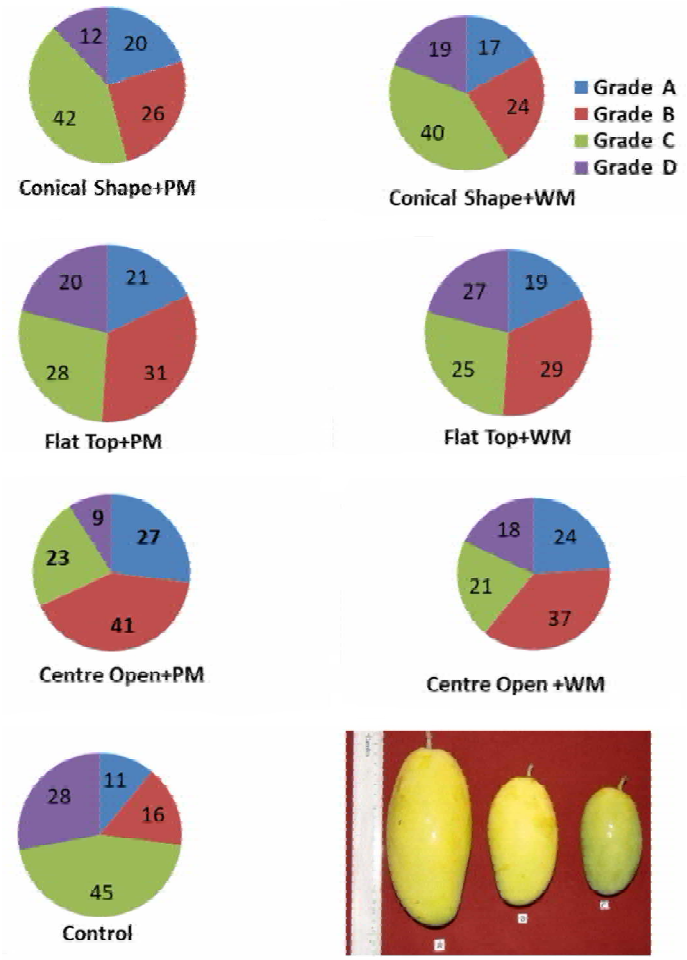


Fig. 2. TSS (0 Brix) pattern of fruits harvested from different canopy shape of mango cv Dashehari



Greading of fruit in different canopy shape (A > 300 g, B > 250-300 g, C > 150-250 g, D < 150 g)

Fig. 3 (A-G). Pattern of different grades of mango cv. Dashehari fruits harvested from different shape of canopy

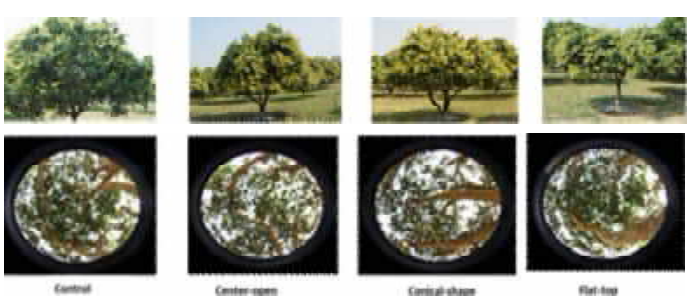


Fig. 4. Different canopy shapes and light distribution pattern

Significant changes in light distribution pattern, maximum diffused light being in open centre system was observed (Table 2). Uniform availability of water and nutrient through the fertigation in the root zone and reducing the water stress

Table 2. Variation in gas exchange attributes under different canopy shapes in mango cv. Dashehari

Canopy shape	gs	VPD	A	E	WUE
Centre open	198.50	2.21	13.20	4.13	3.19
Conical shape	195.00	1.98	9.58	3.68	2.60
Flat top	195.58	2.02	10.60	3.23	3.54
Control	249.40	1.58	11.42	3.65	3.15

*Mean of 10 branches

gs: Stomatal conductance (μ mol m^{-2} s^{-1}), VPD: Vapour pressure deficit, A: Photosynthesis (m mol CO_2 m^{-2} s^{-1}), E: Transpiration (μ mol m^{-2} s^{-1}) , WUE: Water use efficiency

pressure near the roots caused the extended harvesting period (Bankar *et al*, 1993). Similar results were also reported by Soni *et al.*, (2019a), Panigrahi *et al.*, (2010), Ghosh and Bauri, (2003), Pratibha and Goswami, (2013), Dixit *et al.*, (2003), Singh *et. al.*, (2007), Shirgure *et al.*, (2004) in different fruit crops. Soni *et al.*, 2019(b) also reported maximum (47.52%) water saving at 80 per cent pan evaporation among drip irrigation and polyethylene mulching as compared to control in guava. Irrigation through drip and fertigation increased the percent 'A' grade fruit with extended being maximum in open centre system.

Table 3. Response of different canopy shape in mango cv. Dashehari on flowering and fruit quality

Treatment	Flowering (%)	Firmness (cm^{-2})	CPLW (%)
Conical Shape (Central Leader System) +PM	83.0	0.61	6.22
Flat Top (Modified Leader System) +PM	86.0	0.63	6.17
Centre Open (Open Centre System) +PM	90.0	0.67	6.10
Conical Shape (Central Leader System) +WM	78.0	0.60	6.42
Flat Top (Modified Leader System) +WM	82.0	0.58	6.62
Centre Open (Open Centre System) +WM	85.0	0.62	6.71
Control (Conventional)	72.0	0.55	6.80
CD (0.05)	3.08	0.27	0.35

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Collective framework in saffron marketing and improvement of channels

Binish Qadri[1] and Mudaser Ahad Bhat[2]

[1]*Research Scholar, Department of Economics, Central University of Kashmir, Jammu and Kashmir, India. (Email id: qadribinish@gmail.com)*
[2]*Research Scholar, Department of Economics, Central University of Kashmir, Jammu and Kashmir, India. (Email id: mudaserahadbhat1990@gmail.com)*

ABSTRACT

The present study is a review based paper. It was undertaken to examine the role of organizations and committee in marketing in general and saffron in particular. Furthermore, it highlights the pros and cons of intermediaries in marketing. The study identifies less role of organizations and committee in saffron marketing. Almost all studies confirm the gain of intermediaries at the cost of growers. By eliminating the role of these middlemen, growers can manage to get a good price for their produce. But in a real sense these intermediaries actually indirectly gain at the cost of environment because high gains of intermediaries forced the saffron growers to substitute extensive cultivation for intensive cultivation in an ill-conceived manner and within a decade or so, this golden land lost its fertility. The outcome is that the notion of environmental sustainability has vanished from the minds of saffron growers because unhindered intensive cultivation failed to identify and then create a simulation of the real objects of the problem (either of saffron or of environment-related problems). By minimizing the role of these middlemen, growers can manage to get a good price for their produce and the notion of environmental sustainability can get its lost place back in the eyes of the growers. Review of literature shows that for preventing real problems of saffron market inside out and increasing the share of saffron growers in consumer's rupee there is a need of in-depth review of the production and marketing of saffron. In order to improve the over-all role of organizations and committee in saffron marketing and reduce the number of intermediaries who dominate saffron marketing thereby taking away major part of consumer's rupee, the present paper advances recommendations.

Key words: Saffron, marketing, organizations, cooperative marketing, intermediaries.

In the words of George Russell, "*membership of cooperative societies is a practical education in economics fitting men for public service and by its principles, it fosters the spirit of citizenship.*" According to the Reserve Bank of India, a co-operative marketing society "*is an association of cultivators formed primarily for the purpose of helping the members to market their produce more profitably than possible through the private trade.*" In general a co-operative marketing is a process of marketing of products which allow the growers to market their produce at better prices, followed by the objective of obtaining better marketing services and ultimately bringing improvements in not only the standard of living or richness of living of the members but quality of life or completeness of life as well. A Cooperative Society aims at promoting the economic welfare of its members in agreement with the canons of cooperatives. Cooperatives are the best hope of rural India because they are the best way to increase the income and output levels of agriculturists of this country. The cooperative set-up offers a body or organization, which protects the interests of small growers who are exploited by the intermediaries. Majority of the saffron growers in Pampore are small who have dearth of finance, post-harvest storage and marketing facilities and have poor or no knowledge about the demand and supply conditions at the terminal markets, with the result they incur heavy losses (Imtiyaz Ul-Haq & Sahina, 2014). And by cooperative framework channels of middlemen can be eliminated and the share of grower in consumer's rupee can be increased.

As saffron market is highly muddled and messy with no proper price and market mechanism, it is very imperative to understand the role of societies, associations, organizations, committees and intermediaries in the form of dalals and local traders, firms and retailers/wholesalers for the efficacious and successful marketing of saffron in Jammu & Kashmir.

Role of cooperatives, organizations and committees in marketing

Cooperative has growers as members and they dispose of their output collectively under cooperative framework to maximize their profits and output and minimize their cost and increase bargaining power. In AMUL's case marketing strategy and branding have been the mantras of success. And AMUL brand is one of the super brands of Indian market which has established its contract with customers, consistently displaying and showcasing its higher quality standards, right and justified pricing strategy & product accessibility in every part of India.

In the recent past Bora (1994) and Pathania (1998) observed that it is educated farmers who are more aware about cooperative management who utilize credit in a productive manner. According to Parihar (1993) the cooperative movement in Punjab picked up only after women's involvement. N.Lalitha (1996) & Arunbiswas and Vijay Mahajan (1997) found women empowerment through cooperatives. For Royer and Bhuyan (1995) cooperative marketing benefit members as well as non-members, particularly farmers and consumers. Gopalan (2000) evaluated the socio-economic impact of Agricultural Cooperative Marketing Societies in Tamil Nadu. The results revealed that agricultural cooperative marketing societies have made significant impact on the socio - economic conditions of members in particular and people in general.

From corner to corner, saffron growers are price-takers rather than price-makers. It is the lengthy chain of intermediaries rather than grower who control the marketing. Consequently, promising and guaranting remunerative price to the growers is very essential which can be given to them by offering them an efficient marketing system and a proper price policy. The best way available to the growers is forming an organization, association or committee of some sort to act on their behalf. Previously Pampore, the traditional saffron center had many saffron societies and organizations, particularly marketing societies, which governed production and marketing of saffron. They eventually collapsed due to lack of credit facilities and financial capital and support from government. With the result problems of saffron industry in general and post-harvest and marketing problems in particular got multiplied with every passing day (Munshi, 2002). For Khazaie (1998) export of saffron in Iran should be through a well-organized society or organization called the Saffron Export Box (SEB) in order to prevent fluctuations in saffron export prices which at present follow random walk series and improve marketing mechanism. Khorasan is a classic example of such a step in the contemporary times as it has successfully developed international saffron enterprises. In order to prevent actual problems of interior and exterior Iranian market and increase the profit of saffron growers there is a need of systematic and exhaustive review of the production and marketing of saffron. By using saffron box (SB) as a reference under the direction of members of government and saffron corporation members, in order to frame appropriate saffron policy (scrutinizing and guarding it) and reduce fluctuations in the prices, we may attain a symphonic and harmonious system in production, consumption and distribution of saffron in the market. Furthermore, with this, we may attain standardization in grading and packaging, boost exports and trouble-shoot saffron marketing. Regional marketing boards must be developed coupled with exchange market which can very well synchronize production, marketing, exports and maintain market segmentation (Ghorbani, 2008). Market research on saffron reveal that due to absence of solid marketing and export organizations, Iran is not only being heavily damaged by other more competitive saffron exporting countries (like Spain) but also creating negative externality on the global market price of saffron. Atibudhi (2008) explains the starring role which marketing committee plays in regulating mishandlings, malpractices and mismanagement and, raising producer's share in consumer's rupee.

The study concluded that strong producer's organization in the form of market boards and committee is both necessary as well as sufficient condition for raising the grower's share in consumer's rupee. With the help of such organizations we can definitely protect the interest of the growers and streamline better marketing system. The exploitation of farmers, particularly small and marginal farmers by dalals and local traders can be lessened by consolidating or strengthening the market committee. The Government must ensure that the functioning of these organizations is to be improved by providing proper marketing facilities, infrastructure and competent workforce and stringent enforcement of regulated market law. When growers combine and form an association or organization among themselves with the support of government and NGO's they can certainly get reasonable information about the market state of affairs (Karthikeyan, 2016), particularly, about the right marketing mix of product, price and promotion.

In the total marketing margin the share of wholesale and retail margin was maximum. Mean of wholesale, retail and marketing margins of one kilogram of saffron were estimated to be 4, 83,000, 4, 10,000 and 8, 93,000 Saudi Rials respectively. If marketing from the point of production to the point of consumption is undertaken by local buyers of saffron and packing companies the saffron grower will receive the benefits (Turkamani, 2001). But, Wyeth (2007) argues that growers who produce the saffron must be well informed about market prices and should control sales and distribution themselves by way of forming organizations and associations of their interest. He further argues that the Afghani market prices like Kashmiri saffron are apparently asymmetrical which is why we can't expect direct and proportional relationship between value and quality of saffron. In other words, high quality saffron under such circumstances is incapable of bringing high prices, but if growers are well educated and well informed about market conditions and

put in direct contact with growers in other saffron producing and exporting countries they will not only improve their own wellbeing but well-being of the entire saffron trade.

Ghabankandi (2006) examined capital market and the role played by the capital market in financing saffron industry through a case study of Iran. In order to improve agricultural products in both quantity and quality we need to expand agricultural commodity exchange as regional and specialized exchanges in the pivotal areas of production. In order to improve saffron production in both quantity and quality we need to expand saffron exchange as regional and specialized exchanges in the pivotal areas of production and marketing. Undoubtedly, saffron specialized exchange in the crucial areas of production, productivity and marketing can be a fundamental approach to improve saffron in both quantitative and qualitative standings. For that reason, the main recommendation for improving marketing of saffron is establishment of a saffron specialized exchange. Ghorbani (2008) emphasizes same but in other capacities and areas as well, particularly in the area of marketing and export.

One hopefulness and sanguinity found in saffron sector in Kashmir is that the growers, particularly large growers are now very inquisitive in re-establishing the integrity of the saffron business. They have made up their to mind registering themselves as farmer groups or societies which would go a long way in bringing developments and advancements in processing and marketing of Kashmiri saffron. The example of France is a classic example of grower cooperatives. For example, associations of saffron growers ("Les safraniers du Gâtinais" in 1987, and "Les Safraniers du Quercy" in 1999) were listed after periods of abandonment of the crop for its renewal (Fernandez, 2007). In Jammu and Kashmir organizations and associations of saffron growers are coming up for its recovery and revitalization.

Agriculture and intermediary network (s)

Agricultural experts and policy framers recognize intermediary or middleman as a fortune hunter who takes away larger proportion of profit from growers in general and small landholders in particular which leave them with little incomes, curtailing their expenditure and lowering their standard of living (Ellis, 1996). Dalals and traders, particularly local traders, and middlemen cheat farmers because they are unaware about the market conditions, demand and supply forces and overall market state of affairs. Intermediaries take advantage of the poor conditions of the growers, seasonal shortages of cash, insufficient infrastructure including poor storage and transport facilities in villages that contribute to their weak bargaining power rising from their illiteracy and low economic and social status (Thapa, Koirala and Gill, 1995; Lantican, 1997; Banskota and Sharma, 1999; Shrestha and Shrestha, 2000; Khushk, 2001).

Marketing of the saffron is concentrated in the hands of intermediaries because a common grower is incapable of directly selling his inadequate produce as he cannot grade, pack and store the produce at individual level (Zaki et al, 2002). The medium saffron growers have better socio-economic status than the small growers. The medium growers differ from the small growers in respect of economic, social and psychological attributes. The medium saffron growers depict a higher level of economic impetus, risk bearings, scientific orientation and ambition for adoption of scientific technologies as compared to small saffron growers. Furthermore, the medium growers differ from the small growers in terms of the ability to receive communications and messages related to agriculture through mass media. They have contacts with the development agencies; hence participate in the extension development programmes. While the small growers have less contact and exposure to mass media, low or no contact with the development agencies and have low or no participation in saffron training programmes. This happens because the small growers carry their activities mainly through dalals and local traders. In this manner they get exploited by the intermediaries (Kubrevi & Khare, 2006).

The marketing system in Jammu and Kashmir in the present times has an intrinsic tendency to pass on larger benefits to intermediaries at the cost of growers. The typical example is that of saffron and apple market where intermediaries are kings, taking major portion out of consumer's rupee. And it is interesting to note that the present-day marketing structure in apple is such that 87 per cent of the marketing functions are solely performed by these influential and persuasive intermediaries (Bhat, 2010).

Karthikeyan (2016) also observe and therefore, highlights somewhat same problems. According to him the intermediaries enjoy huge benefits at the cost of poor and illiterate Indian farmers. They take advantage of their incapacity, illiteracy and ignorance, with the result there are weak price signals. A small part of the prices paid by consumers reach the grower while the big part is consumed by the chain of intermediaries. Growers are suffering primarily in safeguarding reasonable price for their produce. He suggested that growers should start a super market/ Mega market in urban Centre with the support of other growers. Moreover, they should form an association among themselves with the support of government and NGO's to get fair information about the market situation. Supermarkets in India are a piping and boiling hot topic of national

discussion. The incidence of supermarkets in developing countries is on the level and distribution of income, output and employment of growers on one hand and welfare of consumers on the other hand.

Almost all studies on marketing of saffron in Jammu and Kashmir confirm that the maximum marketing margins are taken by the intermediaries leaving no possibility and opportunity for growers to progress (Munshi, 2002; Kubrevi & Khare, 2006; Wani, Saraf & Wani, 2006; Shah, Tripati & Hussain, 2009; Imtiyaz-Ul-Haq & Sahina, 2014 ; Ganie & Nusrath, 2016; Hamid, Kachroo, Bhat & Peer, 2017).

A number of studies were undertaken in the past on the production and marketing of saffron almost in all the saffron growing countries of the world. But, very little deliberation has been undertaken so far to enquire the role of organizations, associations and cooperatives in dealing with various problems experienced in saffron marketing across the world. Even in the state of Jammu and Kashmir, very limited studies on saffron marketing highlighting such significant roles to reduce problems and increase prospects of saffron marketing and give remedial measures has been done in the past. Adulteration has badly affected the saffron business. At national and international level Kashmiri saffron has lost its recognition because of lack of quality control, lack of standardization, certification and quality assurance. Afghani saffron is a simply an unbranded commodity which is why largely unknown (Wyeth, 2007). Literature review draws similarity between Afghani saffron and Kashmiri saffron. And Kashmiri saffron like Afghani saffron is largely unorganized, shambolic and unbranded in the national/international markets. There is lack of research and development, low capacity/Knowledge of saffron stakeholders and producers are not aware of the marketing channels and market structure of saffron. Consequently, with the decreasing price of saffron on account of it being adulterated, the dealers have started importing Iranian saffron which is available at cheap rates and mix it with the local product. This practice has badly affected the marketing of Kashmiri saffron. Extensive works are needed so as to protect the saffron industry from extinction. We find the traditional practices followed in saffron cultivation in Kashmir which are responsible for the decline in production and productivity levels. Available literature do mention different causes responsible for the downfall in the production and productivity levels of saffron in the Kashmir Valley (Wani, Saraf &Wani, 2006; Kubrevi & Khare, 2006). But, very few studies as such mention absence of cooperatives, committees and grower associations as the cause behind such a downfall and the need for cooperatives and grower's associations for revitalizing saffron industry in the state.

Part I has highlighted the role of organizations, committees and cooperatives in marketing. In Iran organizations, cooperatives and associations are present as far as marketing of saffron is concerned. During the last 2 decades various studies have been conducted on saffron, which mostly pertain to Iran that highlights the role of organizations and committees in marketing. No study has been conducted in Kashmir valley so far as the role of organizations and committees in saffron marketing is concerned. In this way the present study identified a big research gap. Saffron export should be through an organization called the Saffron Export Box (SEB). Khazaie's (1998) suggestion needs to be seriously taken up. Kashmiri saffron export should also be through an organization to control and improve saffron export prices. Like Khorasan, International saffron enterprises should be developed in Jammu & Kashmir. In order to control and improve saffron export prices, saffron marketing and export organizations can play a big role. No comprehensive work has been done that highlights the role of organizations, committees, associations in saffron marketing at micro or macro level. Similarly, in the state of Jammu and Kashmir such work is absent. Agricultural products are marketed in India still through traditional manner where the scope for middlemen participation is higher. In order to market goods and services on modern lines, India in general and Jammu and Kashmir in particular has to rebuild the cooperative marketing societies and develop grower associations and organizations. Cooperative set up has farmers as members who sell their output collectively under cooperative framework to maximize profits and increase bargaining power. Export prices is a function of the role of organizations. Cooperative set up always stands strong if it is democratic, participatory, and efficiently managed. Cooperative set up can be an integral part of economic growth in developing nations. It can help in the development of strong brand. The classic example being that of AMUL (Kashyup, 2009). Cooperatives can develop Geographical Indications with the support of Government. Hard work need to be undertaken in the state of Jammu and Kashmir for the development of strong cooperatives who can solve the marketing problems of agricultural commodities in general and legendary cash crop of Jammu and Kashmir "saffron" in particular. A handful of saffron growers in Pampore, Kishtwar, Pulwama and Budgam, have now eliminated the role of middlemen by joining hands as a cooperative, to ensure that the quality of Kashmiri saffron is maintained.

Part II highlighted the role of intermediaries. It has been found that intermediaries gain at the cost of producers.

Blaming the middlemen for downgrading the Kashmiri saffron by adulterating it with cheaper Iranian saffron, saffron farmers, argue as against the cost of Rs 200 per gram, the Iranian saffron is available for less than Rs100 per gram. By eliminating the role of these middlemen, they can manage to get a good price for their produce (Nehvi, Interview, June, 2016). Big saffron growers have more exposure to outside world which prevent them from exploitations. On the other hand, small growers due to their low economic and social status are less exposed to outside world and mass media which are the root causes of their exploitation by middlemen. However, National Saffron Mission (NSM) is found conducting awareness programmes of different kind that aim at bridging gap between small, medium and large farmers.

RECOMMENDATIONS

1. Saffron has evolved from an item of minor economic concern to one of major concern in today's economic systems. With the increased use of saffron and its products, the volume of saffron required has increased steadily but the quality of saffron has decreased more rapidly. Additionally, costs of saffron production and distribution have increased even more rapidly and as an environmental sustainability suffered adversely. With saffron products growing in scale, the number of intermediaries has been increased proportionately. Saffron industry and the government should realize that managing the development of huge saffron products and maintaining them is a difficult task, especially in the presence of such a large number of intermediaries. Saffron growers and saffron development projects in general and National Saffron Mission in particular frequently face the problems of cost overruns, low-quality saffron products etc. Moreover, use of progressive adulteration of saffron products which have sensitive applications, where cheating in saffron products can have severe and environment-life threatening consequences, require correctness and reliability of saffron products to be of very high degree. These quality and productivity demands for saffron products call for the introduction of systematic practices in the saffron industry. However, these systematic practices should be suitable to our operating environment.

2. Marketing and export of Kashmiri saffron should be through an organization in order to control and improve marketing and saffron export prices. Furthermore, the functioning of these organizations is to be improved by providing proper marketing facilities, infrastructure and competent team. Farmers should form an organization among themselves with the support of government and NGO's so that they can ensure rational, judicious and fair information about the market state of affairs. Development of international saffron enterprises in Khorasan is an example of such a step in recent years. Same should be developed in our state. With the help of saffron organization, who should be directed by the members of government and saffron experts and scientists, we may attain a harmonious system in production, packaging, distribution, exports of saffron.

3. Government should provide financial and technical assistance to young budding entrepreneurs coming from a saffron agri-business background who are seeking to provide consumers with quality saffron. Furthermore, government should develop organizations who collect quality saffron directly from experienced growers. This direct link will benefit the growers and prevent them from the exploitation of intermediaries.

4. National Federation of State Cooperative Banks (1986) revealed that cooperatives covered the small and marginal farmers and other weaker sections who aimed at raising income and output levels. By focusing on cooperative organizational set up and cooperative behavioral setup we can succeed in bringing positive changes in the economic status of small and marginal growers on one hand and weaker and down trodden sections on the other hand. Saffron in Jammu and Kashmir being dominated by small and marginal growers, cooperatives can play an important role for its revival.

5. All the marketing and cooperative societies, grower associations and other societies of same kind must appoint full time assistants or secretaries, particularly woman who may provide valuable suggestions pertaining to production, consumption and distribution of saffron along with marketing credits to their members regardless of the fact that they are growers or not.

6. Government should lend support to those who are behind the creation and development of cooperative marketing societies and honor the cooperatives and associations who are contributing to our knowledge of agriculture through different programmes, workshops, seminars and conferences.

7. Kashmiri saffron should be made known to the country's stock exchange where various saffron prices

will be announced and displayed at the time of its distribution in the stock exchange. In this manner government can control and fix saffron prices which at present follow random walk series and maintain its exports to a great extent. Saffron stock exchange will definitely go a long way in stabilizing, maintaining and preserving the interests of growers and all those associated with this trade directly and growing the country's export capacity. We should develop saffron exchange as regional and specialized exchange in the focal areas of production and marketing. Saffron specialized exchange in the vital areas of production, productivity and marketing can be a fundamental approach to improve saffron in both quantitative and qualitative terms. Creation of regional saffron marketing board besides saffron exchange market can very well harmonize and bring into line production, marketing, exports and maintain market section. The boards so established will primarily help in the stabilization or equilibrium of growers' prices in order to eradicate the seasonal price fluctuations of domestic and export produce. There are many other reasons also associated with the creation of regional saffron marketing board. They can provide resources for regional governments and lead to economic growth and development of the production and marketing areas of saffron and systematic and logical saffron research in agriculture which can put an end to a series of growers' complaints and improve of the quality of the saffron through the proper grading system.

8. The coverage of National Saffron Mission should be expanded to other areas of saffron cultivation and not confine to Karewas of Pampore. Effective measures are needed to reduce marketing losses at various stages of production and distribution of saffron. The National Saffron Mission should put emphasis on the strengthening of institutions, development of cooperative marketing societies, establishment of processing units, saffron spice parks cum research Centre and development of market infrastructure in all the major saffron growing villages/ Karewas so as to bring as much efficiency as possible.

9. Government should create local outlets at each saffron village where the farmers sell their stocks directly to the consumers or the authorized buyers at fixed prices. Intervention of grower's associations, committees and organizations in this network is essential to bring the fruits to the farmers.

10. Jammu and Kashmir economy is dual in nature as it has co-existence of traditional and modern industrial sectors. But, the modern industrial sector has its own limitations so far as its growth and development is concerned fundamentally due to the absence of large industrial sector. Consequentially, our state has to rest largely on its traditional industries for its growth and development signifying that traditional industries particularly silk textile, carpet-making and woolen textile, forest-based industries, agro-based industries, paper machie and horticulture form the backbone. And the primary horticulture produce with higher efficacy and market area is none other than saffron (Ganaie & Nusrath, 2016). Traditional industries are particularly important for the deprived and backward sections of the society. Government must focus on providing necessary support to this sector (traditional sector) in terms of access to finance, skill and knowledge building and appropriate know-how.

11. Government should take on lease the Karewa land which is suitable for saffron production and are kept fallow and barren so that growers as well as government is benefited immensely.

12. The growth and development of chain supermarkets in India may be constructive and beneficial to both producers, who supply high quality low priced food graded processed products, as well as consumers, who may have access to high quality low priced food products especially in the processed food categories. The growers can gain if they can manage to negotiate contracts with such big markets. Participation in the supermarkets supply chain will create positive externality to these growers. Need of the hour is to build super markets for horticultural crops who have greater efficiency and wide marketing arena such as apple and saffron. Majority of the growers in agriculture are small. Government should find ways and means to link more small growers to supermarkets and other emerging markets in developing countries in general and India in particular.

13. For increasing the grower's share in consumer's rupee and minimizing intermediary's margin, profit of firms, wholesalers and retailers must be restructured and rationalized through making and carrying out effective marketing guideline for commission rates.

Implications and future directions

The present study of exploratory nature opens door for future research to refine and further elaborate our findings. Implications of a research work recommend how the research

outcomes and conclusions may be significant for the future course of action, theory, policy, practice and following research works. Undoubtedly, implications of a research work are essentially the inferences that you draw from your research findings so as to be in a position to explain how the findings may have their direct bearing upon the plan, policy, theory or practice. Nevertheless, the implications necessitate authentication and validation by series of evidence. Two main areas of research work in cooperative marketing have evolved. First, how cooperatives are organized or structured? Second, how relationships in cooperative set-up are synchronized or coordinated in a communicative and behavioral sense? The present study can be extended in these two areas.

CONCLUSION

The intermediaries take a substantial proportion of the profit with both the growers as well as the end users being the losers in the saffron market. Consequently, there is a gap between farm-gate price and market price of saffron. Therefore, government and all the concerned departments in general and agriculture and horticulture department in particular should provide extensive support, financial as well as non-financial, particularly capacity and skill development and knowledge upliftment to saffron growers and all those associated with this trade directly so that their income will increase. By cooperative marketing the chains of middlemen can be eliminated and grower's share in consumer's rupee can be increased.

The fundamental question around which E.D. Domar builds his model can be stated as follows: Investment leading to an increase in productive capacity and income, what should be the rate of increase in investment which would equalize the increase in income and the increase in productive capacity, so that full employment is maintained. The fundamental Domar question reflects the importance of investment in an economy. Same should be realized by our economy. Investment in the formation of saffron organizations, cooperative marketing committees and societies will definitely improve income and production of the growers. Once cooperative marketing is regularized the demand would increase and the farmers will get better incentives and subsequently divert more land for the cultivation of this crop.

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Impact of different crop geometries and depths of planting on growth and yield of rice

Archana Rajput[1], Satyakumari Sharma*[2] and Sujit Singh Rajput[3]

[1]*Department of Agronomy, J.N.K.V.V., Jabalpur (M.P.), India*
[2]*Department of Agronomy, J.A.U., Junagadh (Gujarat), India*
[3]*Department of Food technology, J.N.K.V.V., Jabalpur (M.P.), India*
**email- satya.sharma77@yahoo.com*

ABSTRACT

An experiment was conducted during the *kharif* seasons of 2010-11 and 2011-12 at Krishi Nagar farm, Department of Agronomy, JNKVV Jabalpur to study the different crop geometries and depths of planting on growth and yield of rice in system of rice intensification. The results revealed that 30 cm × 30 cm planting geometry had superiority in various parameters, *viz,* growth and yield, and were significantly influenced by plant geometry and depth of planting. Rice variety MR-219 with shallow depth of planting (2.5 cm) was markedly superior in growth parameters, *viz*., number of tillers/m^2 at harvest. Almost all the yield parameters, *viz,* test weight, harvest index, grain and straw yields, were superior with the MR-219 variety and shallow depth of planting.

Key words: Varieties, yield, test weight, rice

Rice (*Oryza sativa* L.) is the most important cereal food crop of the developing world and the staple food of more than 3 billion people or more than half of the world's population. India is considered to be one of the original centers of rice cultivation covering 44.6 million hectares, producing 132 MT of rice with an average productivity of 2.96 t ha^{-1} (Pandian, 2009). Around 65 per cent of the total population in India eat rice and it accounts for 40 per cent of their food production. India is the world's second largest producer of white rice, accounting for 20 per cent of all world rice production. Rice-based production systems provide the main source of income and employment for more than 50 million households (IRRI, 2008). World production of rice has risen steadily from about 200 million tonnes of paddy rice in 1960 to over 678 million tonnes in 2009. Among different agronomic practices, planting geometry and depth of planting play a vital role in achieving higher yield levels of improved varieties of rice. It is because of the proper distribution of crop plant per unit area and efficient utilization of available nutrient and other resources as well as environment. Therefore, present experiment was conducted to study the optimum planting geometries, improved varieties under depths of planting for getting maximum yield of rice.

MATERIALS AND METHODS

The experiment was conducted at research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during *kharif* seasons of 2010-11 and 2011-12. The three different planting geometries, i.e., 20 × 20 cm^2, 25 × 25 cm^2 and 30 × 30 cm^2 between hills and rows were kept for growing the crop and to identify their effect on grain yield parameters. Three varieties of rice (MR-219, WGL-32100 and PS-3) and two depths of planting shallow (2.5 cm) and normal (5.0 cm) were studies. The layout of the trial was split-split plot design with three replications having planting geometry as main plots, varieties as sub plot treatments and depths of planting shallow and normal as sub-sub plot treatments. The area of each plot was 3×7 m^2. Seedlings were transplanted with an average of one seedling per hill in the SRI method of planting. Application of 10 t FYM/ha was given uniformly to all the plots before final puddling and leveling. Fertilizer with a uniform dose of N:P:K; 120:60:40 kg per hectare through urea, DAP and MOP was applied in all the plots. Half dose of nitrogen and full dose phosphorus and potassium were applied as basal application just before transplanting. The remaining half dose of nitrogen was applied in two split doses at tillering and panicle initiation stages.

RESULTS AND DISCUSSION

Effect on growth parameters

Plant density is an important agronomic factor that greatly influences the micro climate of the field and eventually the yield of agricultural crops. Planting geometry had significant influence on growth and yield of rice. Results showed that number of tillers/m^2 was significantly higher in wider spacing of 20 cm × 20 cm as compared to wider spacing of 25 cm × 25 cm and 30 cm × 30 cm. The significant reduction of dry weight of plant with increase in plant geometry might be due to higher mortality of tillers per hill. Some of the late emerged tillers were not well developed and

even died. Thus, a little reduction in number of tillers/hill was noted at maturity compared to its preceding stage.

Effect on yield and yield attributes

The 1000-grain weight was significantly higher in 30 cm × 30 cm in comparison to 20 cm × 20 cm and 25 cm × 25 cm. Similar results have also been obtained by Bari *et al.*, (1984). Rice MR-219 variety was markedly superior in various growth attributing characters, viz, test weight and more harvest index over WGL-32100 and PS-3. The growth parameters and yield attributes significantly greater under shallow depth of planting than deeper planting depth.

The grain yield was significantly influenced by planting geometries at harvest during both the years. Results showed that rice varieties had worked effectively on grain yield. Thus, the 25 cm × 25 cm planting geometries (6.86 t ha^{-1} and 7.00 t ha^{-1}) produced significantly higher grain yield in comparison to 20 x 20 cm planting geometry (6.34 t ha^{-1} and 6.51 t ha^{-1}) and 30 cm × 30 cm planting geometry (5.81 t ha^{-1} and 6.04 t ha^{-1}) during both the years and mean value of pooled grain yield was also higher in 25 cm × 25 cm planting geometry (6.93 t ha^{-1}) than 20 cm × 20 cm planting geometry (6.43 t ha^{-1}) and 30 cm × 30 cm planting geometry (5.92 t ha^{-1}) (Table 1). The grain yield was significantly higher at optimum spacing of 25 cm × 25 cm as compared to 20 cm × 20 cm and 30 cm × 30 cm, which might be due to the production per hill that developed better than higher tillers per hill and number of plants per m^2. Ultimately, 20 cm × 20 cm produced significantly higher straw (9.53 and 9.23 t ha^{-1}) yields over 25 cm × 25 cm (8.82 and 9.70 t ha^{-1}) and 30 cm × 30 cm (8.15 and 9.19 t ha^{-1}) during both the years.

Harvest index was significantly higher at optimum spacing of 25 cm × 25 cm as compared to 20 cm × 20 cm and 30 cm × 30 cm which may be due to higher mortality of tillers per hill in wider spacing and closer spacing which reduced grain ratio in total biological yield. Similar results have also been reported by Verma *et al.*, (2002). The cumulative effect of superior growth and yield attributes were finally reflected in terms of higher grain yield. Both grain and straw yields were also higher in the MR-219 over WGL-32100 and PS-3. Ultimately, MR-219 produced significantly higher grain (6.83 and 7.05 t ha^{-1}) and straw (9.46 and 10.71 t ha^{-1}) yields over WGL-32100 having grain yield of 6.22 and 6.41 t ha^{-1} and straw yield of 8.83 and 8.67 t ha^{-1} and PS-3 having grain yield of 5.95 and 6.08 t ha^{-1} and straw yield of 8.21 and 8.80 t ha^{-1}, respectively, during both the years.

The grain yield of rice directly correlated to the number of tillers per unit area, NAR and test weight and other physiological parameters. These growth attributing characters were significantly superior in MR-219 as compared to WGL-32100 and PS-3, which attributed to produce higher grain yield. Thus, rice MR-219 gave 9.94 and 9.98 per cent more grain yield over WGL-32100 and (14.78 and 15.98 per cent) over PS-3, during 2010 and 2011, respectively, and MR-219 gave 9.94 per cent more grain yield over WGL-32100 and 15.37 per cent over PS-3, during pooled average analysis. Straw yield of rice is directly related to growth parameter, *viz,* number of tillers per unit area, and

Table 1. Effect of planting geometries, varieties and depth of planting on growth and yield contributing attributes of rice in SRI

Treatments	Number of tillers/ m^2 at harvest			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index (%)			1000- grain weight		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Planting geometry															
S_1 - 20 cm x 20 cm	538	544	541	6.34	6.51	6.43	9.53	9.29	9.41	40.06	41.32	40.69	18.9	20.0	19.4
S_2 - 25 cm x 25 cm	499	504	502	6.86	7.00	6.93	8.82	9.70	9.26	44.14	41.97	43.05	21.0	22.1	21.6
S_3 - 30 cm x 30 cm	312	317	315	5.81	6.04	5.92	8.15	9.19	8.67	41.64	39.89	40.76	22.8	23.9	23.3
SEm ±	5.96	5.79	5.87	0.10	0.09	0.09	0.42	0.21	0.25	1.17	0.50	0.70	0.6	0.6	0.6
CD. at 5%	23.39	22.72	23.05	0.38	0.36	0.37	1.64	0.83	1.00	NS	NS	1.95	1.8	1.8	1.8
Variety															
V_1 - MR-219	511	516	513	6.83	7.05	6.94	9.46	10.71	10.08	42.12	39.74	40.93	23.2	24.2	23.7
V_2 - WGL-32100	448	453	450	6.22	6.41	6.31	8.83	8.67	8.75	41.45	42.55	42.00	19.1	20.2	19.7
V_3 - PS-3	391	396	394	5.95	6.08	6.02	8.21	8.80	8.51	42.26	40.89	41.58	20.5	21.5	21.0
SEm ±	7.68	7.59	7.64	0.09	0.08	0.08	0.22	0.21	0.14	0.61	0.70	0.50	0.6	0.6	0.6
CD. at 5%	23.66	23.39	23.52	0.26	0.26	0.26	0.69	0.65	0.43	1.33	1.53	1.09	1.3	1.3	1.3
Depth															
D_1 - Shallow Depth (2.5 cm)	455	461	458	6.49	6.68	6.58	9.11	9.61	9.36	41.79	41.07	41.43	21.5	22.6	22.1
D_2 - Normal Depth (5 cm)	444	449	447	6.18	6.36	6.27	8.56	9.17	8.87	42.10	41.05	41.58	20.3	21.4	20.8
SEm ±	5.27	5.26	5.26	0.08	0.08	0.08	0.19	0.15	0.13	0.83	0.44	0.59	0.4	0.4	0.4
CD. at 5%	NS	NS	NS	0.24	0.24	0.24	0.57	0.44	0.39	NS	NS	NS	0.7	0.7	0.7

this growth parameter was superior in MR-219 and may be responsible for the differences in straw yield in comparison to WGL-32100 and PS-3. Harvest index (HI) of rice was significantly influenced due to varieties during both the years. PS-3 (42.26 and 40.89%) had significantly higher HI as compared to MR-219 (42.12 and 39.74%) and WGL-32100 (41.45 and 42.55%), which may be owing to greater partitioning of photosynthesis towards the production of straw rather than the grain yield (Table 1). All the varieties might have high coefficient for partitioning of photosynthesis in production of grain out of the total crop biomass and accordingly the higher HI was obtained under it. Significantly higher grain yield of rice was obtained under shallow depth of planting (6.49 and 6.68 t ha^{-1}) as compared to normal depth of planting (6.18 and 6.36 t ha^{-1}) during both the years (Table 1). This may be ascribed to cumulative effect of growth. Significantly higher values of growth attributing characters, viz, functional leaves/hill, dry weight of plant/hill, test weight, and more harvest index under shallow depth of planting than normal depth of planting. The shallow depth of planting did not show significant effect on straw yield and harvest index (HI) during 2010 but during 2011 significantly higher straw yield was obtained under shallow depth of planting (9.61 t ha^{-1}) as compared to normal depth of planting (9.17 t ha^{-1}).

CONCLUSION

The results revealed that growth parameters, viz., number of tillers/m^2at harvest was superior at 20 cm × 20 cm planting geometry as compared to other planting geometries. All growth parameters were significantly superior in MR-219 which resulted in production of more 1000-test weight and sterility percentage and higher yield in comparison to WGL-32100 and PS-3. MR-219 (6.94 t ha^{-1}) proved significantly superior to WGL-32100 (6.32 t ha^{-1}) and PS-3 (6.02 t ha^{-1}) with regard to grain yield, when planted at shallow depth with 25 cm × 25 cm plant geometry. Interaction between varieties and planting geometry on the grain yield was found significant. The variety MR-219 had significantly more grain yield at 25 cm × 25 cm, straw yield at 20 cm × 20 cm and 1000-test weight at 30 cm × 30 cm compared to other planting geometries.

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Effect of pinching on flowering and yield in different varieties of marigold (*Tagetes spp)*

A.A. Patade, K.V. Malshe and V.V. Sagvekar

Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri - 415712 (MS)
(E-mail : kvmalshe@rediffmail.com)

ABSTRACT

The field experiment conducted during *Rabi* season of the year 2017-18, to study the response of marigold varieties (Pusa basanti gainda, pusa arpita and yellow 09) to different levels of pinching (Control-No pinching, pinching after 3 weeks of transplanting, pinching after 5 weeks of transplanting and double pinching - Pinching after 3 and 5 weeks of transplanting), showed that the earliest initiation of flowering (38.00 DAT) and minimum days for 50 per cent flowering (53.00) was recorded in control (no pinching) in Yellow 09. The double pinching in Yellow 09 recorded significantly maximum numbers of pickings (7.15). The longest crop duration (flowering period) and highest yield of 27.54 days and 176.16 q ha^{-1}, respectively in Yellow 09 variety with double pinching was recorded.

Key words: *Marigold, variety, pinching, yield*

Marigold is one of the most important commercial loose flower extensively used for making garlands for religious and social functions. It is native to Central and South America, especially Mexico, from where it spread to different places during early part of the 16th century. Its wide adaptability, round the year production with easy cultivation practices, wide spectrum of attractive colours, shapes, size and good keeping quality has made it a popular flower crop that attracted the attention of many amateur and commercial flower growers in India. Several varieties of marigold have been evolved with unique phenotypic characters and varying performance in different agroclimatic conditions and cultural practices.

The climatic conditions of Konkan region are suitable for various seasonal flower crops like Marigold, Aster, Gaillardia, etc. With improvements in standard of living, the tendency of society towards purchase of flower crops is also increasing. There is high demand for these flowers especially during festivals, religious ceremony as well as family functions. With the increase in area under irrigation its cultivation has become more remunerative than any other agronomical crop. Hot and humid climate favours its vegetative growth. Adoption of practices like pinching has produced higher yield in many flower crops. As no specific recommendation regarding variety and package of practices for this region has been done so far, evaluation of various varieties of marigold as well as standardization of pinching intensity for its yield maximization was urgently needed. Hence, response of different varieties of marigold (*Tagetes spp.)* to pinching was studied.

MATERIAL AND METHODS

The field experiment was laid out during *Rabi* season of the year 2017-18 at Department of Horticulture, College of Agriculture, Dapoli, Dist. Ratnagiri, (Maharashtra state) in the split plot design. The treatments comprised of three varieties (Pusa Basanti Gainda, Pusa Arpita and Yellow 09) as main plot treatments and four levels of pinching (Control-no pinching, pinching after 3 weeks of transplanting, pinching after 5 weeks of transplanting and double pinching - pinching after 3 and 5 weeks of transplanting) as sub-plot treatments in three replications. The flat beds of 2.7×1.8 m size were prepared. The seedlings were transplanted at the spacing of 45×45 cm. The polythene mulch films were cut in the size of 2.7×0.45 m and laid between the two rows of seedlings covering the entire area between two rows. The recommended cultural practices were followed for raising the crop. The pinching treatments were given to each plot as per the sub-plot treatments. The observations on flowering and flower yield were recorded. The data were analyzed by standard method of analysis of variance described by Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

The data on days of initiation of flowering and requiring 50 per cent flowering presented in table 1 shows that the varieties, pinching and their interaction significantly altered the initiation of flowering and days for 50 per cent flowering. The minimum days for initiation of flowering (46.83 DAT) was recorded in Yellow 09, followed by Pusa Basanti Gainda (48.58 days). The delayed initiation of flowering (53.58 DAT) was observed in Pusa Arpita (53.6). In pinching, significantly minimum days for initiation of flowering (44.00) was recorded in control (no pinching) followed by pinching after three weeks and five weeks of transplanting, respectively, while, maximum days (55.11)

in double pinching treatment. The data of interaction between varieties and pinching revealed earliest initiation of flowering (38.00 DAT) in control (no pinching) in variety Yellow 09 and maximum (56.67) in Pusa Arpita in double pinching.

The time required for days taken to first flower emergence is an important genotypic character in marigold that might be primarily governed by the genetic makeup of the genotypes. The results observed were in line with the findings of Beniwal and Dahiya (2012). Early flowering was recorded in no pinching treatment (Control) whereas late flowering was recorded in double pinching. (Baskaran *et al.*, 2017). The delayed flowering in pinching treatments might be due to elimination of vegetative growth by cutting the growing tip and thereafter the additional time taken to attain the physiological maturity of the crop for induction of flowering.

The shortest period for 50 per cent of flowering (59.08 DAT) was observed in Pusa Basanti Gainda and maximum days (66.00) in Pusa Arpita followed by yellow 09. The days required for 50 per cent flowering differed significantly due to pinching treatments and minimum days for 50 per cent flowering (55.22) was recorded in control (no pinching) followed by pinching after three and five days after transplantation. The maximum days for flowering (72.67) was recorded in double pinching. In interaction between varieties and pinching, significantly minimum days (53.00) for 50 per cent flowering was recorded in control (no pinching) in Pusa Basanti Gainda and no pinching in Yellow 09, respectively. These were followed by Pusa Basanti Gainda with pinching after three weeks of transplanting, Pusa Basanti Gainda after five weeks of transplanting and yellow 09 with pinching after three weeks of transplanting. The maximum days for 50 per cent flowering (76.67) was recorded in Pusa Arpita in double pinching. The flowering phenomenon varied in different varieties is associated to the genetic character of the particular variety and also subjective to the environmental conditions of particular location. The delay in flowering in pinched plants might be due to the fact that new shoots which emerged after pinching entered into vegetative phase and took time to become physiologically mature to bear flowers. (Sehrawat *et al.*, 2003).

Table 1. Effect of pinching and different varieties on days required for initiation of flowering and 50 per cent flowering of marigold

Treatment	Initiation of flowering (days)*				Days for 50 per cent flowering*			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
P_1	42.33	42.33	51.67	38.00	53.00	59.67	53.00	55.22
P_2	47.00	47.00	54.67	45.33	57.00	65.33	63.00	61.78
P_3	50.67	50.67	51.33	49.67	61.00	68.33	72.00	67.11
P_4	54.33	54.33	56.67	54.33	65.33	76.67	76.00	72.67
Mean	48.58	48.58	53.58	46.83	59.08	67.50	66	64.19
S.Em.± (V)	0.10				0.12			
C.D. at 5%	0.29				0.35			
S.Em.± (P)	0.13				0.16			
C.D. at 5%	0.39				0.47			
S.Em.± (VXP)	0.40				0.48			
C.D. at 5%	1.18				1.42			

(* Days after transplanting)

The data regarding number of pickings revealed significant variation in number of picking of flowers among the varieties, pinching treatments as well as their combination (Table 2). The highest number of pickings (5.33) was recorded in Yellow 09 followed by Pusa Basanti Gainda and the lowest number of pickings (3.20) was in Pusa Arpita. Significantly maximum number of pickings (5.51) was recorded in double pinching treatment followed by pinching after three weeks of transplanting. The minimum number of pickings (2.62) was observed in control. Among the treatment interactions, double pinching in Yellow 09 recorded significantly maximum numbers of pickings (7.15) over remaining interactions. The numbers of pickings was lowest (2.18) in Pusa Basanti Gainda with no picking.

In case of flower crops, the number of flower picking (harvesting) depends upon the yield potential and flowering span of that particular crop. The number of pickings might vary from variety to variety because of its genetic vigour for yield and span. Such trend was reported earlier by Khanvilkar *et al*. (2003). The pinching practice induces the plant to produce large number of axillaries shoots which eventually bears more number of flowers leading to more number of picking. The findings of Pushkar and Singh (2012), Badge *et al*. (2014) are in conformity to these results.

Table 2. Effect of pinching and different varieties on number of picking and flowering duration of marigold

Treatment	No. of pickings				Flowering period (Days)			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
P_1	2.18	2.52	3.15	2.62	18.03	9.80	21.89	16.57
P_2	3.71	3.22	4.68	3.87	19.50	10.73	24.10	18.11
P_3	5.32	3.51	6.33	5.05	21.01	13.02	26.39	20.14
P_4	5.81	3.56	7.15	5.51	24.57	13.95	27.54	22.02
Mean	4.26	3.20	5.33	4.26	20.78	11.88	24.98	19.21
S.Em.± (V)	0.02				0.04			
C.D. at 5%	0.05				0.13			
S.Em.± (P)	0.02				0.06			
C.D. at 5%	0.06				0.17			
S.Em.± (VXP)	0.06				0.17			
C.D. at 5%	1.18				0.50			

The data regarding flowering period (days) presented in table 2 revealed significant variation among the varieties, pinching treatments and their interaction. Among varieties, the longest flowering period (24.98 days) was observed in Yellow 09, followed by Pusa Basanti Gainda and the shortest flowering period (11.88 days) in Pusa Arpita. In pinching treatments, significantly maximum flowering period (22.02 days) was recorded in double pinching followed by pinching after five days and three days of transplanting. The shortest flowering period (16.57 days) was observed in control (no pinching). In interaction between varieties and pinching, significantly maximum days of crop duration (27.54) were recorded in double pinching in Yellow 09 and the minimum days for flowering period (9.80) with no pinching in Pusa Arpita.

The overall performance indicates that irrespective of pinching treatments, the shortest crop duration was in Pusa Arpita variety. The pinching treatments enhanced the flowering duration leading to availability of flowers for market.

There was significant variation in number of flowers per plant and yield per plant among the varieties, pinching treatments and their combination (Table 3). The significantly maximum number of flowers (45.71 plant^{-1}) was recorded in Yellow 09 followed by Pusa Basanti Gainda (29.40 plant^{-1}) and the lowest number of flowers per plant (23.59) in Pusa Arpita. Among the pinching treatments, significantly maximum flowers (37.21 plant^{-1}) were harvested in double pinching treatment followed by pinching after five and three days of transplanting. The minimum number of flowers per plant (25.60) was in control (no pinching). Among the treatment interactions, double pinching in Yellow 09 recorded significantly maximum numbers of flowers per plant (53.51) and it was at par followed by variety yellow 09 in pinching after five weeks of transplanting. The numbers of flowers was lowest (19.75) in Pusa Arpita with no pinching.

The increased number of flowers per plant in a specific variety may be attributed to the genetic makeup of the cultivars and vigour for higher yield. Similar results have also been reported by Singh and Singh (2006) and Narsude *et al*. (2010). Increase in number of flowers in pinching treatments may be due to the fact that pinched plant induces production of large number of axillaries shoots resulting in well-shaped bushy plants bearing more number of uniform flowers. Pushkar and Singh (2012), Badge *et al*. (2014) and Meena *et al*. (2015) also reported similar findings in African marigold.

In case of varieties, high range yield variation was noticed where the highest flower yield per plant (323.4 g) was recorded in Yellow 09 followed by Pusa Basanti Gainda. The lowest flower yield (99.93 g) was received in Pusa Arpita. Among the pinching treatments, significantly highest flower yield per plant (214.11 g) was recorded in double pinching, followed by five and three weeks of transplanting control (no pinching) treatment registered the lowest flower yield (171.79 g plant^{-1}). In interaction between varieties and pinching, significantly maximum flower yield (357.59 g plant^{-1}) was recorded in double pinching in Yellow 09, followed by rest of the pinching treatments. The minimum yield (95.10 g plant^{-1}) was recorded with no pinching in Pusa Arpita.

The wide range of variation in relation to flower yield per plant might be due to difference in genetic potential of any genotype/variety and environmental situation where it grown. The present finding is in agreement with the observation made by Khanvilkar *et al*. (2003). The high productivity is the most important qualitative character of the particular variety. The increased number of flowers per plant might be due to cell elongation and rapid cell stimulation. Similar results were also noticed by Choudhary *et al*., (2014), Bharathi and Jawaharlal (2014) in African marigold. The flower yield per plant was maximum in double pinching i.e., 24.64 per cent yield increment over control (non-pinching). The increase in flower yield per plant under pinching treatment might be due to gain of extra energy in the production of more number of flowers per plant and ultimately surge in flower yield. The present results are in conformity with the findings of Singh *et al.* (2015) and Prakash *et al.,* (2016) in marigold.

The yield on hectare basis presented in Table 3 also showed the similar trend as per the yield per plot. The significantly highest yield per hectare (159.54 q) was recorded in Yellow 09, followed by Pusa Basanti Gainda (83.08 q). The lowest yield (49.30 q ha^{-1}) was in Pusa Arpita. Among the pinching treatment, double pinching registered significantly highest yield (105.55 q ha^{-1}) against, the lowest yield per hectare (84.73 q) recorded in control. The interaction between varieties and pinching showed significant difference in yield per hectare and highest yield (176.16 q) was recorded in double pinching in Yellow 09 pinching after five and three weeks of transplanting and no pinching (control). The lowest yield (46.91 q ha^{-1}) was recorded with no pinching in Pusa Arpita.

The maximum yield of flowers observed in Yellow 09 may be due more number of flowers, prolonged flowering span and more picking having direct positive relation with yield. The differences in flower yield may be due to variation

Table 3. Effect of pinching and different varieties on flower yield of marigold

Treatment	No of flowers plant^{-1}				Flower yield (g plant^{-1})				Flower yield (q ha^{-1})			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
P_1	23.67	19.75	33.38	25.60	158.23	95.10	262.04	171.79	78.04	46.91	129.22	84.73
P_2	31.47	22.70	47.31	33.83	163.13	99.03	326.42	196.19	80.47	48.86	161.11	96.82
P_3	29.58	26.67	48.65	34.97	173.36	99.70	347.70	206.92	85.54	49.19	171.68	102.14
P_4	32.88	25.26	53.51	37.21	178.84	105.90	357.59	214.11	88.25	52.25	176.16	105.55
Mean	29.40	23.59	45.71	32.69	168.39	99.93	323.44	197.25	83.08	49.30	159.54	97.31
S.Em.± (V)	0.22		0.07		0.20				0.03			
C.D. at 5%	0.66		0.22		0.50				0.10			
S.Em.± (P)	0.30		0.10		0.23				0.05			
C.D. at 5%	0.88		0.29		0.70				0.14			
S.Em.± (VXP)	0.90		0.29		0.07				0.14			
C.D. at 5%	2.64		0.86		0.20				0.41			

P_1, P_2, P_3 and P_4 denotes no pinching (control), pinching after three weeks five weeks and double pinching after 3 and three weeks of transplanting, respectively; V_1, V_2 and V_3 denotes varieties namely, Pusa Basanti Gainda, Aisa Arpita and Yellow 09, respectively.

in flowering characters and yield potential of the particular variety that is determined by the genetic potential and inheritance characters. The results are analogous with the earlier findings of Khanvilkar *et al*. (2003) in marigold. Besides this, the increase in yield of flowers under pinching treatments may be due to the fact that pinching checked the apical dominance and diverted extra metabolites into the production of more number of flowers. The present findings are in conformity with the report of Rathore (2007) and Prakash *et al*. (2016) in marigold.

CONCLUSION

The present investigation concludes that adoption of double pinching practice in Yellow 09 marigold is beneficial in producing highest yield with longest commercial flower duration.

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Feasibility of flower crops under coconut based cropping system in coastal ecosystem of Maharashtra State

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

ICAR-All India Coordinated Research Project on Palms, Regional Coconut Research Station, Bhatye, Ratnagiri (M.S.), India
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-415 712

ABSTRACT

Field experiment carried out at ICAR-AICRP on palms at Regional Coconut Research Station Bhatye, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (MS) during 2013 to 2015 with flower crop combinations of T_1- coconut alone *(monocrop)*, T_2- coconut + *Jasminum sambac,* T_3- coconut + *Jasminum multiflorum,* T_4- coconut + *Lily spp.,* T_5- coconut + *Heliconia spp.* and T_6 - coconut + *Michelia champaka,* according to two years of data, showed that the lily flower recorded 1683811 numbers of spikes ha^{-1}, *Jasminum multiflorum* recorded 48656 kg ha^{-1}, *Heliconia spp.* recorded 96982.5 number of spikes ha^{-1}, *Jasminum Sambac* recorded 1123.2 kg ha^{-1} follwed by *Michelia champaka* with only 12690 number of flowers only. In respect of economics, coconut +*Lily spp.* system recorded the highest gross return of Rs. 12,19,962/- ha^{-1} followed by Rs. 7,63,197/- in coconut + *Jasminum multiflorum system.* Coconut +*Heliconia spp.* recorded Rs. 6,37,495.25, coconut +*Jasminum sambac* Rs. 553102.53 and coconut +*Michelia champaka* the minimum gross return of Rs. 255672.00. The gross income realised in the monocropping of coconut was of Rs. 195300.00. The coconut nut yield realised during 2014-15 in the intercropping garden was 165 nuts palm^{-1} year^{-1} whereas in monocropping it was 96 nuts palm^{-1} year^{-1}.

Key words : *Coconut, intercropping, flower crops, lily, heliconia*

The establishment of more sustainable cropping system is need of today's era. Multispecies and multistoried cropping system ensures maximum utilization of resources for higher yield per unit area. There are many coconut based cropping systems in various countries and states of the nation. Effective and efficient utilization of available resources for higher yield is the modern concept of cropping system. Merely growing coconut crop as monocrop is not the most efficient way for the exploitation of natural recourse (Ghosh and Bandopadhyay, 2011). Adoption of coconut based commercial flower cropping system emerges as the most profitable way for improving the economic status of coconut farmers. Improvement in the soil properties and biological activities in the rhizosphere due to intercropping results in the modification of soil environment for the benefit of the plant growth (Maheshwarappa *et al*., 1998). The studies revealed that natural resources i.e. soil water, air space and solar reclamation are not fully utilized under the spacing schedule 7.5 m x7.5 m. Further in India, coconut is primarily a crop of small and marginal farmers (Rethinam, 1990). Many of the coconut workers have reported that a well designed high density multispecies crop model suited to a given agro-climatic situation generates returns biomass output, yields, more economic returns and higher total income, additional employment opportunities for family labours and meets diversified needs of the coconut farmers, such as food, fruit, vegetables, fuel etc. (Retinam, 1990; Ghosh and Hore, 2007; Hore *et al*., 2007, Ghosh *et al*., 2008). Flowers are good source of economic returns. It has great use in daily activities for religious and felicitations programmes. Now a day's demand for flower are increasing tremendously. *Jasminum sambac, Jasminum multiflorum, Lily spp., Heliconia spp., Michelia champaka etc.* are the most demanded flowers in domestic market. Hence these flower crops are included in present study during the year 2013-15. The flowers were supplied to the market and the feedbacks from the buyers were documented. The flower crops were selected as per the demand from the flower market of Ratnagiri. All five types of flowers are most important in state and also in India. The present investigation was undertaken to find out the suitable flower crop based model for coconut based multiple cropping system for maximization of returns per unit area.

MATERIALS AND METHOD

Field experiment was carried out in 29 years old coconut hybrids (COD x WCT) plantation of AICRP on palms at Regional Coconut Research Station, Bhatye, Ratnagiri under Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (M.S) during the year 2013-15. The research station is situated at 17.00 ^{0} N latitude and 73.40 ^{0} E longitude with altitude of 3 m above the mean see level. Farm is situated on the creek of Bhatye village facing towards Arabian Sea. The soil of the experimental plot was sandy loam in texture, well drained with medium fertility status. The hybrid coconut palms were spaced at 7.5 x 7.5 m recommended by CPCRI for tall verities. The study was based on five flower types

which are mostly commercial and has year round demand in the market. The flower species used are scented, heliconea is exotic type and has demand for decoration in various function. The T_1: coconut alone *(monocrop)* T_2:coconut +*Jasminum sambac,* T_3:coconut + *Jasminum multiflorum,* T_4:coconut +*Lily spp.,* T_5 coconut +*Heliconia spp.* and T_6 coconut +*Michelia champaka.* The experiment was started in 2012. The flower crops were planted keeping 2 m free space from the base of palm. The experimental plots were prepared thoroughly by repeated ploughing to get fine tilth, well rotten FYM (10t ha^{-1}) was applied and mixed thoroughly during land preparation. The regular need based irrigation was applied to intercrop and monocrop except during rainy season. The plant protection measures were taken as and when necessary for all crops. Schedule of management practices were followed in coconut under both intercropped and monocroped block. Nutrient management and cultural aspects of different intercrop are presented in Table 1. The benefit or net return: cost ratios of different cropping models were calculated on the basis of cost of cultivation, gross return and net return [Table 4]. The economic assessment was carried out considering the cost, inputs and market rates of the produce during the period of investigation.

RESULT AND DISCUSSION

Flower crop yield, nut equivalent yield ha^{-1} and coconut yield

The crop wise nut yield ha^{-1} $year^{-1}$ and flower crop yield in respect of kg and numbers ha^{-1} are presented in table 2. Maximum mean nut yield (23801.56 nut ha^{-1}) was recorded with the lily crop as compared to monocrop (16275 nuts ha^{-1}). It was second with *Jasminium multiflorm* (22359.89 nuts ha^{-1}) followed by with in *Heliconia* (21306.25 nuts ha^{-1}) and *M. champaka* (20278.12 nuts ha^{-1}). Lowest yield among the different flower crop was recorded with *Jasminium sambac* (20172.33 nuts ha^{-1}). The net equivalent yield ha^{-1} for an intercrop was maximum with lily (77861.91 nuts) followed by *J. multiflorum* (41239.75 nuts) [table 3 and fig. 1].

Impact on plant nutrient status in soil

Nutrient status of the soil from different plot under different flower crops are given in Table 5. Total nitrogen and available phosphorus and potassium content was

Table 1: Agronomical and horticultural details and nutrient management of intercrops under different flower crop models

Treatments	Model No.	Crops	Variety	Planting time	Plants	Spacing (cm)	FYM (Kg)	NPK (g $plant^{-1}$)
T_1 (coconut-m*onocrop*)	Model-I	Coconut	COD x WCT	June, 1988	175	750 x 750	25	1000:3000:2000
T_2 (coconut +*J. sambac)*	Model-II	*J. sambac*	Madan ban	Dec. 12	88	120 x 120	0.5	20:10:10
T_3 (coconut + *J. multiflorum*)	Model-III	*J. multiflorm*	Local	Dec. 12	61	120 x 120	0.5	20:10:10
T_4 (coconut +*Lily spp*)	Model-IV	*Lily spp.*	Local	Dec. 12	133	100 x 100	0.5	20:10:10
T_5 (coconut +*Heliconia spp*)	Model-V	*Heliconia spp*	Sexy Pink	Dec. 12	133	100 x 100	0.5	20:10:10
T_6 (coconut +*M. champaka*)	Model-VI	*M. champaka*	Soundarya	May. 13	32	240 x 240	3.00	100:50:100

Note: Fertilizers are applied in two (June, Sept.) splits doses for intercrop and three splits for coconut.

Table 2: Intercrop and coconut yield under coconut base cropping system *(Pooled data)*

Treatments	Model No.	Intercrop	Intercrop Yield ha^{-1}	Intercrop Yield ha^{-1} (Rs.)	Coconut yield (nuts ha^{-1})	Coconut yield ha^{-1} (Rs)
T_1 (coconut -*monocrop*)	Model-I	Coconut	-	-	16275.00	195300
T_2 (coconut +*J. sambac)*	Model-II	*J. sambac*	1123.2 kg	311034.53	20172.33	242068
T_3 (coconut + *J. multiflorum*)	Model-III	*J. multiflorum*	48656 kg	494877.00	22359.89	268320
T_4 (coconut +*Lily spp*)	Model-IV	*Lily spp.*	1683811 nos spike.	934343.00	23801.56	285619
T_5 (coconut +*Heliconia spp*)	Model-V	*Heliconia*	96982.5 nos	381803.25	21306.25	255672
T_6 (coconut +*M. champaka*)	Model-VI	*M. champaka*	12690 nos	12690.00	20278.12	243336

Table 3: Nut equivalent yield per hectares for an intercrop under coconut base cropping system *(Pooled data)*

Treatments	Model No.	Intercrop	Coconut yield (Nut)	Intercrop Yield ha^{-1}	Flower yield (Rs)	Nut equivalent yield (Nuts)
T_1 (coconut-m*onocrop*)	Model-I	Coconut	16275.00	-	-	62385.00
T_2 (coconut +*J. sambac)*	Model-II	*J. sambac*	20172.33	1123.2 kg	311034.53	25919.54
T_3 (coconut + *J. multiflorum*)	Model-III	*J. multiflorum*	22359.89	48656 kg	494877.00	41239.75
T_4 (coconut +*Lily spp*)	Model-IV	*Lily spp.*	23801.56	1683811 nos spikes.	934343.00	77861.91
T_5 (coconut +*Heliconia spp*)	Model-V	*Heliconia*	21306.25	96982.5 nos spike	381803.25	31816.93
T_6 (coconut +*M. champaka*)	Model-VI	*M. champaka*	20278.12	12690 nos	12690.00	1057.50

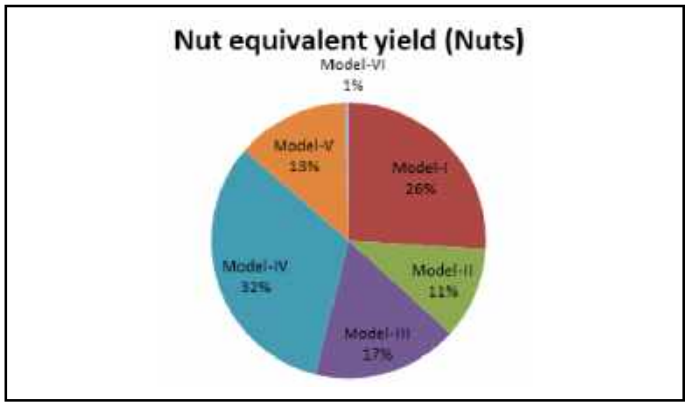

Fig 1: Percentage of nut equivalent yield per hectares for an intercrop under coconut base cropping system

maximum with the crop lily (277.10, 19.44 and 288.24 kg ha^{-1}, respectively) followed by *Jasminum multiflorum* (274.11, 19.20 and 280.16 N, P_2O_5 and K_2O kg ha^{-1}). Minimum values for the nitrogen, phosphorus and potassium were observed in monocropping plots. NPK contents under different cropping system increased over the initial status indicating that addition and recycling of organic matter added considerable amount of nutrients in to the system which was also recorded earlier (Maheswarappa *et al.*, 1998; Ghosh and Bandopadhyay, 2011). The nitrogen phosphorus and potassium content of each plot decreased with soil depth in all flower crops including monocrop which may be due to lower leaching losses or fixation than higher uptake of N, P_2O_5 and K_2O by crops (Sharma and Chowdhury, 2002; Bopaiah and Shetty, 1991) also reported the higher phosphatase enzyme activity in the coconut mixed farming plots favored the release of fixed phosphorus. The nitrogen fixers and phosphate solubliizing bacteria were more in mixed farming system as compared to coconut monocropping. The soil enzymes activities and soil microbial biomass were higher in coconut based mixed farming as compared to coconut monocropping.

Economics of different coconut based flower cropping models

Five flower cropping models along with the coconut monocropping were being compared to identify the best performance [table 4]. Cost of cultivation and net returns from one hectare of monocropped coconut were Rs. 56719.75 and Rs. 138580.25, respectively. The maximum cost of cultivation was incurred in the lily intercrop which was (Rs. 116794.0) followed by *J. multiflorum* (Rs. 94720.75), *J. sambac* (Rs. 85373.00) *M. champaka* (Rs. 74171.50) and *Heliconia spp*. (Rs.74171.0). Economic assessment of different flower intercrop models revealed that out of five models the model IV (consist of coconut + *Lily*) was more remunerative showing highest net return of Rs. 1103168/- followed by model III (Rs. 668476/-). The present findings very well corroborate to the findings of Sairam *et al.,* (1997) who obtained a net profit of Rs. 24000/-, 20,500/- and Rs. 11000/- from ginger, turmeric and elephant-foot yam grown as intercrop. Sharma and Chowdhury, (2002) obtained gross return of Rs. 1, 25,285/- and Rs. 73,545/- from one hectare coconut based cropping system with cost:benefit ratio of 1:1.4. In another

Table 4: Economic evaluation of different intercrops under coconut base cropping system *(Pooled data)*

Treatments	Model No.	Intercrop	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	Net Returns: Cost of cultivation
T_1 (coconut-m*onocrop*)	Model-I	Coconut	56719.75	195300.00	138580.25	2.44
T_2 (coconut +*J. sambac)*	Model-II	*J. sambac*	85373.00	553102.53	467730	5.47
T_3 (coconut + *J. multiflorum*)	Model-III	*J. multiflorum*	94720.75	763197.00	668476	7.05
T_4 (coconut +*Lily spp*)	Model-IV	*Lily spp.*	116794.00	1219962.00	1103168	9.44
T_5 (coconut +*Heliconia spp*)	Model-V	*Heliconia*	72590.00	637495.25	564905	7.78
T_6 (coconut +*M. champaka*)	Model-VI	*M. champaka*	74171.50	255672.00	181501	2.44

Note: Selling rates for coconut @ Rs 12/-, *J.sambac* @Rs 273 kg^{-1}, *J. multiflorum* @Rs.100/-, Lily @Rs 5 10 no^{-1}, *Heliconia* and *champaka* @Rs 1 flower^{-1}.

Table 5: Soil nutrient statues under different cropping systems

Treatments	Model No.	Intercrop	Pre–experimental (kg ha^{-1})			Post-experiment (kg ha^{-1})		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1 (coconut-m*onocrop*)	Model-I	Coconut	248	17.6	221.11	267.14	18.22	274.26
T_2 (coconut + *J. sambac)*	Model-II	*J. sambac*	248.14	17.8	221.12	269.26	18.86	279.10
T_3 (coconut + *J. multiflorum*)	Model-III	*J. multiflorum*	253.16	17.4	222.16	274.11	19.20	280.16
T_4 (coconut + *Lily spp*)	Model-IV	*Lily spp.*	259.10	17.9	221.18	277.10	19.44	288.24
T_5 (coconut + *Heliconia spp*)	Model-V	*Heliconia*	251.16	17.7	221.14	271.82	18.30	282.24
T_6 (coconut + *M. champaka*)	Model-VI	*M. champaka*	250.10	17.5	221.16	270.68	18.58	278.18

system studied by Girijadevi and Nair, (2003) the net return of Rs. 2,74,808/- was realized from coconut + banana + elephant-foot yam and Rs. 1,13,644/- from coconut + banana + turmeric per year in one hectare plantation.

CONCLUSION

It is concluded that the inter cropping system under coconut is more feasible and profitable than the monocropping which, promises the farmers a lot besides generating additional employment opportunity. The result findings clearly indicate the economic viability of companion cropping system with coconut under littoral sandy soils of Maharashtra. In the coconut based cropping system (Model IV) preferring flower crop, the intercropping of lily with coconut was found best under Konkan coastal areas of Maharashtra.

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Effects of irradiation stages on male reproduction in the sweet potato weevil, *Cylas formicarius* (Coleoptera: Brentidae)

Satoshi Hiroyoshi[1,2,3], Takayuki Mitsunaga[4], Tsuguo Kohama[1,2] and Gadi V.P. Reddy[5]

[1]*Okinawa Prefectural Plant Protection Center, 123 Maji, Naha, Okinawa, 902-0072 Japan.*
[2]*Okinawa Prefectural Agricultural Research Center, 820 Makabe, Itoman, Okinawa, 901-0336 Japan.*
[3]*202 Corpo Mankyu, Nodamachi, Kawagoe, Saitama 350-1115, Japan.*
[4]*Central Region Agricultural Research Center, National Agriculture and Food Research Organization, 2-1-18 Kannondai, Tsukuba, Ibaraki 305-8666, Japan*
[5]*Montana State University-Bozeman, Western Triangle Agrcultural Research Center, 9546 Old Shelby Rd., P.O. Box 656, Conrad, MT 59425, USA*
Corresponding author; Satoshi Hiroyoshi
E-mail address: satoshi_hiroyoshi@yahoo.co.jp

ABSTRACT

The sweet potato weevil, *Cylas formicarius* (Fabricius) (Coleoptera: Brentidae), is a notorious pest of sweet potato, *Ipomoea batatas* (L.), over tropical and subtropical countries. The eradication program for this weevil using female sex pheromone (male annihilation) and sterile insect technique (SIT) has been undertaken in Okinawa and Amami islands in Japan. The effect of the timing of irradiation on reproduction of adult male of this weevil applied with 100 Gy of radiation either 3 days before adult emergence or 1, 5, or 9 days after emergence was investigated. The survival rate in the control (no treatment) group was 100 per cent throughout the observation period (day 10 to 20 of adult life), while survival rates of irradiated groups were reduced to approximately 30 per cent by just a few days after the start of the observation period. Irradiated individuals showed reduced mating rates for several days before their death, suggesting that the mating period ended before death. The earlier the stage that was irradiated, the lower the total sperm production was recorded. However, the main factor driving decreased insemination rates in irradiated individuals reduced mating rates due to decreased sexual behavior and earlier death, rather than disruption of spermiogenesis. Since mating ability decreased several days before death, irradiation at an early stage shortened mating periods by shortening lifespan. Therefore, the release of adult males immediately after irradiation would appear to be an effective means of flooding the field with sterile males and thus suppressing populations of this pest.

Key words: Accessory gland, mating, radiation, SIT, spermiogenesis, sweet potato

The Sterile Insect Technique (SIT) was first proposed by Knipling (1955) and its initial application resulted in the successful eradication of the target pest, the screwworm, *Cochliomyia hominivorax* (Coquerel) (Diptera: Calliphoridae), through the use of gamma radiation on Curaçao in the Caribbean (Lindquist 1955, Baumhover et al. 1955, Knipling 1955). Since then, many pest insects have been targeted for control, suppression, or eradication with SIT, especially tephritid fruit flies (Knipling 1982, Alphey 2002, Koyama et al. 2004, Weldon et al. 2010, Rempoulakis et al. 2015). Irradiation at an early life stage requires rearing the insects for a relatively long time between their irradiation and release. If reproductive development, including spermiogenesis, continues to occur over time in the adult stage, the decline of mating with age should be taken into consideration if irradiated insects are subjected to long term storage. To counter any reduction in the mating activity of released males, SIT programs rely on the mass production and release of large numbers of sterile males to achieve a high sterile: wild male ratio (Shelly et al. 2007). Moreover, significantly higher doses of radiation are needed to achieve full sterility in males than in females (Calvitti et al. 1997, Rempoulakis et al. 2015). In studies of female re-mating behavior in the Queensland fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) (Collins et al. 2012) and the sapote fruit fly, *Anastrepha serpentina* (Widemann) (Diptera: Tephritidae) (Landeta-Escamilla et al. 2016), it is found that if sterile males are unable to inhibit females from remating, the efficiency of the SIT program would be reduced.

The sweetpotato weevil, *Cylas formicarius* (Fabricius) (Coleoptera: Brentidae), is a serious pest of sweet potato, *Ipomoea batatas* (L.), in tropical and subtropical areas (Kohama 1990). In Japan, this weevil was first recorded on the subtropical island of Okinawa in 1903 and from there it had spread to neighboring islands (Kohama 1990). In Okinawa Prefecture, a program for eradicating this pest using a combination of a synthetic female sex pheromone and SIT has been underway since 1994 (Yasuda 1995, Moriya 1997, Moriya and Miyatake 2001). These efforts have recently met with initial success on Kume Island (Kohama 2010). To

successfully expand the eradication to other islands, basic information about reproduction, especially the mating ability of released sterile insects, is needed. Although the effects of larval and pupal irradiation on survival and spermatogenesis have been examined (Dawes et al., 1987, Iwamoto et al., 1990, Ito et al., 1993, Hayashi et al., 1994, Sakurai et al., 1994, Sharp 1995, Sakurai et al., 1998), the effects of adult irradiation on sperm production and sperm transfer are less understood in this weevil. However, survival, fertility, mating propensity, or mating competiveness are examined (Dawes et al., 1987, Sharp 1995, Halllman 2001, Kumano et al., 2008, Kumano et al., 2010, Kumano et al., 2011). In our earlier study, we have demonstrated the effects of radiation dose on sperm production, insemination, and mate mating possible period (Hiroyoshi et al., 2018).

The present study aimed at to clarify the effects of age and stage at the time of irradiation used on male reproductive abilities, including adult survival, mating rate, sperm production, development of male reproductive organs, and number of sperm ejaculated by irradiated males compared to non-irradiated controls. Although our facility has been using 200 Gy for the complete sterilization since 2000, 100 Gy was adopted in this study.

MATERIALS AND METHODS

The colony of *C. formicarius,* used in this study, was established with adults collected from Yomitan (26°23'N, 127°44'E) on Okinawa Island and reared continuously at the Okinawa Prefectural Plant Protection Center on sweet potatoes at 25 ± 1ºC and a 14L10D photoperiod until used in experiments in 1999, after approximately 8 to 13 successive generations of successive laboratory rearing. Approximately, 500 two to six week old female and male adults were placed in plastic containers (14.5 l) to which 600 g of sweet potatoes were added as food and an oviposition substrate. Sweet potatoes were changed twice each week and infested tubers were held in plastic containers (14.5 l) to rear new weevils. Due to logistical restraints, weevils life stages inside tubers could not be used as the target stage for large scale irradiation. Given that adults of this weevil remain inside the tuber for 4 to 6 days after adult emergence (Sugimoto et al., 1996), irradiation of newly emerged adults was considered impractical. For this reason, adults after leaving their natal tubers, when they seem to 4 to 6 days old, were irradiated.

Approximately 5 weeks after the oviposition, most progeny weevils reached the pupal stage. Pupae were collected by breaking sweet potato tubers into pieces small enough to hold in plastic cups until adult emergence. Adult weevils were designated as 0-day-old on the day of their adult emergence. Individuals were sorted by sex from the morphology of antenna within two days of adult emergence and reared in groups of 20 to 30 with sweet potato (about 40 g) pieces, which were replaced twice a week.

Mating ability was examined to assess if reproductive activity of males differ in the stage of irradiation. Mating in sweet potato weevils takes place at night (Sakuratani et al., 1994). Consequently, to periodically check the mating status of females, pairs of weevils were confined separately in glass petri dishes (9 cm diam) during the scotophase. Approximately 16 h later, the females were dissected to check for the presence of sperm in their spermatheca, which was considered an indication of successful mating. Based on earlier studies, we judged that matings without sperm transfer were unlikely to occur (Hiroyoshi et al., 2016).

Sperm counts in males, to evaluate the effectiveness of SIT programs in the laboratory and in the field (Seo et al., 1990), were carried out with established methods (Yamagishi and Tsubaki 1990, Tsubaki and Yamagishi 1991, Hiroyoshi et al., 2018). Male *C. formicarius* have a pair of testes and one seminal vesicle (collectively, the "testes-seminal vesicle complex" or TSC), with free sperm in both areas. To determine the number of sperm, the male reproductive organ was dissected out in a 0.9 per cent salt (NaCl) solution under a stereomicroscope. The reproductive tract was then placed in a 0.1 per cent triton X solution (Kishida Chemical & Co. Ltd., Japan), and the fat body carefully removed with a piece of tissue paper and forceps. The TSC was then transferred into 500 µl of deionized water on a glass petri dish and the tissues were torn into small pieces. The deionized water containing the free sperm was stirred 20 times with a pair of forceps to homogenate the sample, and 10 µl of this solution was collected per sample with a microsyringe, spread onto a glass microscope slide, and allowed to air dry. Sperm were counted with a video apparatus (VM-60, Olympus, BR-S925, Victor and VY-VP20, Hitachi) attached to a microscope and the sperm count multiplied by 50 to determine the total sperm per weevil.

To determine the number of sperm transferred to females during mating, the female reproductive organ were dissectioned out in 0.9% salt solution, the spermathecae isolated and transferred into 100 µl of deionized water.

Determination of mating status of newly emerged control females

To determine if weevils were sexually mature immediately upon emergence from sweet potato tubers, new females seen outside the tubers were dissected the day after their emergence every day until no further weevils in a rearing group emerged. The sex of all individuals was determined

from the morphology of the antenna and the presence of sperm in the spermatheca of all females was assessed to determine mating rates of young females (1-day after adult emergence from tubers). The experiment was replicated three times in different blocks.

Effect of radiation on weevil stages on survival, mating rate and ejaculate quantity

To determine the effects of weevil life stage or age on the efficacy of irradiation, irradiated groups of several weevils in its four different ages: (1) pupae 3 days before adult emergence (3BA), (2) 1-day-old adults (A-1), (3) 5-day-old adults (A-5), and (4) 9-day-old adults (A-9) were irradiated with 100 Gy from Co^{60} to determine the efficacy of were of stages and the ages on tradition. Non-irradiated insects were used as controls. After irradiation, each male from each treatment was paired with a 20-day-old or older, non-irradiated sexually mature virgin female with similar body size (mating rate>75%) (Hiroyoshi et al., 2016), and each pair was confined in a glass petri dish (9 cm diam) with a piece of sweet potato (40 g). Over an 11-day observation period (from day 10 to 20 after weevil adult emergence), each pair of weevils was observed daily and the rates of male survival, male mating, and the number of ejaculated sperm per mated male were recorded. Females paired with experimental males were replaced daily over the 11 days observation period. Females paired with irradiated or control males for a night were dissected to determine mating rate and number of sperm transferred. Presence of sperm in the female spermatheca indicated that the female was mated. The number of sperm found in a female's spermatheca was considered to be the number ejaculated by the male. After the 11-day observation period, the total number of ejaculated sperm were summed across all observation days. As excess ejaculated sperm cannot enter a full spermatheca, the number of sperm counted in the present study was assumed to be an under estimation of the total produced (Hiroyoshi et al., 2016). Rates of survival and mating and the ejaculated sperm number per living mated male were checked daily for the observation period.

After selecting active individuals, groups of 14 (control) or 15 (irradiated) insects were used in the experiments to determine male survival, mating rate, and ejaculate quantity. To assess the impact of weevil age on the efficacy of irradiation on male sperm production, a separate group of 20 irradiated or control males was selected for each weevil age treatment, and the number of sperm in the male's TSC was counted on days 1, 5, 9, 11, 13, 17, or 21 after adult emergence. Feeding was confirmed from the presence of weevil frass or feeding holes in the piece of sweet potato.

Effects of radiation stage on male reproductive development

To determine the influence of weevil age, at the time of irradiation, on the impact of radiation on the development of the male reproductive organs, males were irradiated with 100 Gy at each of four weevil ages: 3 days before adult emergence and at 1, 5, or 9 days after adult emergence. Non-irradiated males were held as controls. To characterize male reproductive development, the length and width of the testis, the width of the seminal vesicle, width of the free sperm mass in the seminal vesicle and the width of the accessory gland were measured at 1, 5, 9, 13, 17, and 21 days after adult emergence under a stereomicroscope. Twenty individuals were tested for each weevil age group except for A-5 (adults irradiated 5 days after adult emergence), for which 18 weevils were tested.

The data on the total number of sperm ejaculated by males irradiated at each life-stage or age, the size of each male reproductive organ, the number of sperm ejaculated per mating during the observation period and the number of sperm in the TSC of males were compared by ANOVA to evaluate the effects of irradiation in conjunction with life stage or age. If necessary, pairwise comparisons using Tukey's HSD test were performed (R Development Core Team, 2009). Data generated from the data on survival or mating rates were analyzed by logistic regression analysis to estimate the effects of stage of irradiation or the stage at which it took place. An overall test was first performed follwed by a pairwise test with a Bonferroni correction for survival and mating rate. When necessary, pairwise comparisons using *G*-test weighted by a Bonferroni-Holm correction were also performed. The data at each point was presented in average±standard deviation (SD).

RESULTS AND DISCUSSIONS

Mating status of newly emerged control females

Most of the females (56.7%) mated on the first night of their emergence from tubers (Fig. 1). Because females bored out of tubers earlier than males, mating rates were lower early in the observation period due to a lack of mates (Fig. 2).

Effect of male weevil age on survival, mating rate and ejaculate quantity

Significant differences in survival rates were found between weevils of different stages age groups, the controls, post-irradiation time period and in the interaction of age and ejaculate (Fig. 3, Table 1). Survival rates during the observation period were significantly different between the control and various life-stages: 3BA, A-5 and A-9. In addition, significant differences existed between 3BA and A-9. All

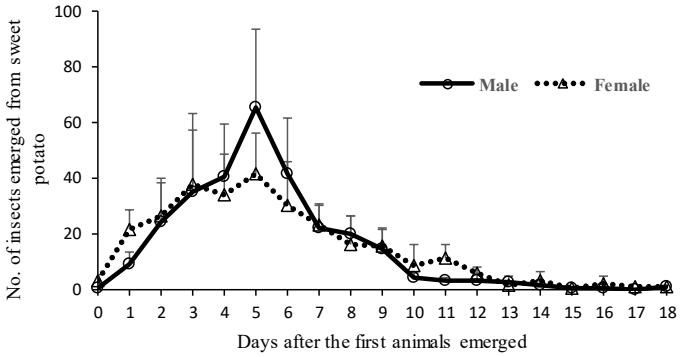

Fig. 1. The daily emergence of non-irradiated *Cylas formicarius* from sweet potatoes, over three trials. The data are expressed as mean±SD.

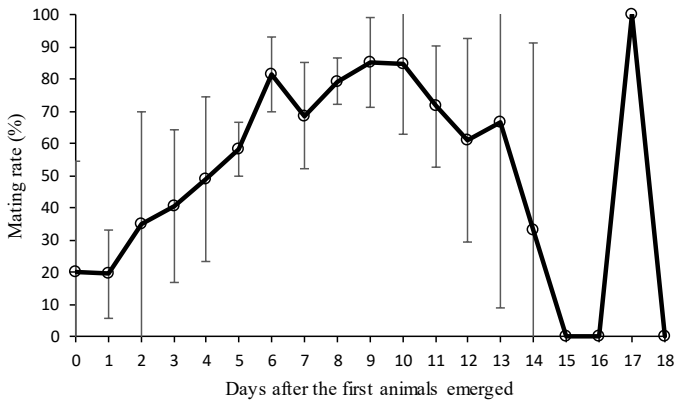

Fig. 2. The daily mating rate of non-irradiated *Cylas formicarius* from sweet potatoes, over three trials. The data are expressed as mean±SD.

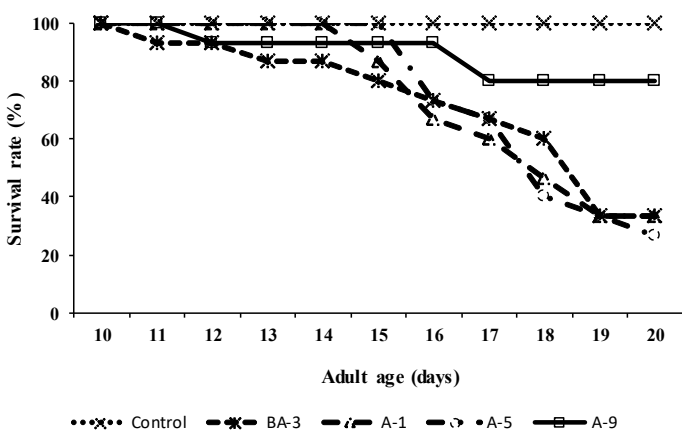

Fig. 3. Survival rate of *Cylas formicarius* males irradiated at different stages from 10 to 20 days of adult life.

Table 1. The results of logistic regression analysis on the effects of irradiation age on the survival rate of *Cylas formicarius*.

Factor	Parameter	df	Likelihood rate χ^2	P-value
Overall test				
Irradiation stage	4	4	28.93439	<0.001*
Age	1	4	67.66188	<0.001*
Irradiation stage×age	4	4	23.37743	0.0001*
Pairwised test				
Control vs BA-3				
Irradiation stage	1	1	25.5818256	<0.0001*
Age	1	1	7.89470723	0.0050*
Irradiation stage×Age	1	1	7.89470723	0.0050*
Control vs A-1				
Irradiation stage	1	1	14.3614053	0.0002*
Age	1	1	12.97175	0.0003*
Irradiation stage×Age	1	1	12.97175	0.0003*
Control vs A-5				
Irradiation stage	1	1	10.1203702	0.0015*
Age	1	1	15.3171697	<0.0001*
Irradiation stage×Age	1	1	15.3171697	<0.0001*
Control vs A-9				
Irradiation stage	1	1	6.51990148	0.0107*
Age	1	1	1.82690935	0.1765
Irradiation stage×Age	1	1	1.82690935	0.1765
BA-3 vs A-1				
Irradiation stage	1	1	1.02934744	0.3103
Age	1	1	85.2654923	<0.0001*
Irradiation stage×Age	1	1	1.42690513	0.2323
BA-3 vs A-5				
Irradiation stage	1	1	2.2741418	0.1315
Age	1	1	91.5347428	<0.001*
Irradiation stage×Age	1	1	2.74780628	0.0974
BA-3 vs A-9				
Irradiation stage	1	1	7.02325436	0.0080*
Age	1	1	31.2070238	<0.001*
Irradiation stage×Age	1	1	3.22709545	0.0724
A-1 vs A-5				
Irradiation stage	1	1	0.24411041	0.6213
Age	1	1	109.279446	<0.0001*
Irradiation stage×Age	1	1	0.22125595	0.6381
A-1 vs A-9				
Irradiation stage	1	1	2.18113069	0.1397
Age	1	1	42.5601052	<0.0001*
Irradiation stage×Age	1	1	7.94851995	0.0048*
A-5 vs A-9				
Irradiation stage	1	1	0.83209081	0.3617
Age	1	1	47.2176956	<0.0001*
Irradiation stage×Age	1	1	10.3329929	0.0013*

For pairwised tests, asterisk indicates the significant difference (P<0.05/10) with a Bonferroni correction.

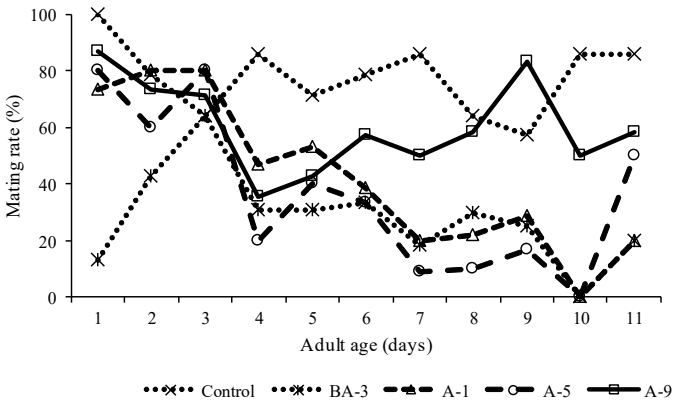

Fig. 4. Mating rate of *Cylas formicarius* males irradiated at different stages from 10 to 20 days of adult life. Mating rate was calculated from the number of mated males divided by alive males at each treatment.

control males survived the observation period. A-9 males exhibited a higher survival rate during the observation period, while male adults irradiated at stages 3BA, A-1, or A-5 showed a sharp reduction in survival during the latter half of the observation period.

Significant differences in the mating rate among groups of weevils irradiated at different stages or adult ages, the post-irradiation time period and the interaction of the two factors were observed (Fig. 4, Table 2). Specifically, there were significant differences in mating rates between the control and 3BA, A-1, A-5, and A-9, as well as between 3BA and A-1 or A-9. A high mating rate was observed in the control throughout the observation period after a slow start for the first two days. In male adults irradiated at the pupal stage, mating rate decreased with age, especially during the latter half of the observation period. In A-1, A-5, or A-9 age groups, mating rate was relatively high during the first three days of the observation period and then declined. Interestingly, the mating rate of A-9 males increased again thereafter.

During the observation, several mating patterns were found in irradiated male adults. More than half of A-9 males mated almost every day, some mated during the first several days of the observation period and finally died, some did not mate for some time but copulated once and died soon after while some never copulated at all.

The total number of sperm ejaculated in the control was 2- to 5-fold that of irradiated male adults (Table 3). The number of ejaculated sperm was underestimated because only the spermathecae were examined. Actual ejaculated sperm number would be greater than this value, since excess sperm (more than the spermatheca can hold) cannot enter the spermatheca (Hiroyoshi et al., 2016). However, excess sperm seems unlikely to affect fertilization, because they are expelled from the female's reproductive organs shortly after mating (Hiroyoshi et al., 2016). In irradiated weevils, the

Table 2. The results of logistic regression analysis on the effects of irradiation age on the mating rate of *Cylas formicarius*.

Factor	Parameter	df	Likelihood rate χ^2	P-value
Overall test				
Irradiation stage	4	4	105.470077	<0.001*
Age	1	1	39.5087226	<0.001*
Irradiation stage×Age	4	4	26.3051541	<0.0476*
Pairwised test				
Control vs BA-3				
Irradiation stage	1	1	80.5362301	<0.0001*
Age	1	1	1.46861228	<0.2256
Irradiation stage×Age	1	1	0.16142294	<0.6878
Control vs A-1				
Irradiation stage	1	1	36.1010224	<0.0001*
Age	1	1	17.870682	<0.0001*
Irradiation stage×Age	1	1	11.5196586	0.0007*
Control vs A-5				
Irradiation stage	1	1	61.7005706	<0.0001*
Age	1	1	20.285233	<0.0001*
Irradiation stage×Age	1	1	13.6887886	0.0002*
Control vs A-9				
Irradiation stage	1	1	14.2646301	0.0002*
Age	1	1	1.57799997	0.2090
Irradiation stage×Age	1	1	0.10674963	0.7439
BA-3 vs A-1				
Irradiation stage	1	1	9.52804761	0.0020*
Age	1	1	19.0760127	<0.0001*
Irradiation stage×Age	1	1	7.71457792	0.0055*
BA-3 vs A-5				
Irradiation stage	1	1	1.56771359	<0.2105
Age	1	1	21.4714059	<0.0001*
Irradiation stage×Age	1	1	9.55100224	0.0020*
BA-3 vs A-9				
Irradiation stage	1	1	30.4886531	<0.0001*
Age	1	1	2.50791733	0.1133
Irradiation stage×Age	1	1	0.01546958	0.9010
A-1 vs A-5				
Irradiation stage	1	1	3.0448512	0.0810
Age	1	1	56.1437111	<0.0001*
Irradiation stage×Age	1	1	0.16730325	0.6825
A-1 vs A-9				
Irradiation stage	1	1	6.19161374	<0.0128*
Age	1	1	22.9265816	<0.0001*
Irradiation stage×Age	1	1	10.8332484	0.0010*
A-5 vs A-9				
Irradiation stage	1	1	18.989469	<0.0001*
Age	1	1	25.4981469	<0.0001*
Irradiation stage×Age	1	1	13.0391269	0.0003*

For pairwised tests, asterisk indicates the significant difference (P<0.05/10) with a Bonferroni correction.

Table 3. Differences of total number of sperm ejaculated by irradiation stages in *Cylas formicarius*.

Irradiation stage	No. of insects used (Average ± SD)	Total number of sperm ejaculated
CT	14	11411.0 ± 4858.6a
BA-3	15	1906.1 ± 239.1b
A-1	15	3252.4 ± 2461.7bc
A-5	15	4144.3 ± 3782.0bc
A-9	15	6006.7 ± 4480.4c

BA-3, A-1, A-5, and A-9 indicate 3 days before adult emergence, 1-day-old adult, 5-day-old
Adult, 9-day-old adult, respectively. Different letters indicate the significant differences.

earlier the stage exposed to irradiation, the smaller the total number of sperm ejaculated.

The number of sperm ejaculated per mating from control weevils was slightly higher than that from irradiated males, especially during the second half of the observation period (Table 4). In general, the earlier the stage exposed to irradiation, the smaller the number of sperm ejaculated per mating (Table 4). Non-irradiated males transferred a more sperm than irradiated males, suggesting negative effects on insemination from irradiation.

Examination of sperm production on 1, 5, 9, 13, 17 and 21 days after adult emergence showed that 13 days and thereafter, the number of sperm in the TSCs of control insects tended to be larger than in irradiated males (Table 5), indicating that irradiation inhibited spermiogenesis to some degree.

Impact of male life-stage and post-irradiation duration on damage from radiation to male reproductive development

The data summarized in table 6 reveals that at day 1 post-irradiation, there was a significant difference between control and pupae 3 days before emergence (3BA) males in the testis (TS) length (z-value = 2.681, P <0.05). At day 5 post-irradiation, there was a significant difference in the testis length between control weevils and those irradiated as pupae (3BA) or 1- or 9-day-old (A-1 or A-9) males (z-value = 2.723, P <0.05; z-value = 3.710, P <0.001; z-value = 2.718, P <0.05). At day 9 post-irradiation or thereafter, the testis length of control (CT) males tended to be longer than that in other

Table 4. Change of the number of sperm ejaculated per mating in *Cylas formicarius* males irradiated with different stage during 10 to 20 days of adult life.

Adult age (days)	No. of sperm ejaculated per day (Average ± SD)				
	Irradiation stage				
	CT	BA-3	A-1	A-5	A-9
10	64.5 ± 1411.9a	177.4 ± 192.1b	502.9 ± 657.6ab	1218.4 ± 1436.3a	1298. ± 1208.8a
11	58.1 ± 526.5a	402.4 ± 637.1a	566.5 ± 1188.9a	844.1 ± 884.4a	364.6 ± 680.6a
12	48.9 ± 790.0a	127.0 ± 192.9a	308.2 ± 358.1a	817.1 ± 1478.1a	608.0 ± 672.2a
13	39.8 ± 2045.3a	206.2 ± 483.7b	379.8 ± 512.5b	152.2 ± 311.8b	241.8 ± 366.2a
14	38.7 ± 792.5a	398.7 ± 838.2a	376.0 ± 551.9a	476.6 ± 791.4a	493.3 ± 700.5a
15	996.1 ±953.9a	177.4 ± 415.7a	586.3 ± 1158.6a	362.1 ± 686.4a	419.2 ± 654.5a
16	986.4 ± 1032.8a	332.6 ± 846.8ab	246.3 ± 681.3ab	0.7 ± 2.1b	418.1 ± 700.1ab
17	670.6 ± 751.9a	176.1 ± 445.0a	253.8 ± 560.6a	141.0 ± 445.9a	701.2 ± 809.4a
18	882.2 ± 1287.6a	567.6 ±1593.0a	165.7 ± 300.7a	255.0 ± 624.6a	1000.1 ± 1497.0a
19	1711.1 ± 1307.2a	0 ± 0b	0 ± 0b	0 ± 0b	240.5 ± 1163.2b
20	1215.1 ± 1021.2a	18.2 ± 40.7a	282.0 ± 630.6a	0.3 ± 794.8a	409.6 ±801.8a

Different letters indicate significant differences at each age.

Table 5. Change of the number of sperm in the testis and seminal vesicle in *Cylas formicarius* males irradiated with different stage each adult age.

Adult age (days)	No. of sperm ejaculated per day (Average ± SD)				
	Irradiation stage				
	CT	BA-3	A-1	A-5	A-9
1	25 ±50a	75 ± 134a	89 ± 121a		
5	873 ± 6436a	3615 ± 3183b	1201 ± 1002a	2523 ± 4142ab	
9	6858 ± 3783a	5008 ± 4124a	5184 ±3130a	4333 ± 2703a	5835 ± 4843a
13	27120 ± 18914a	14103 ± 10462b	8101± 5657b	11700 ± 5949b	13228 ± 6613b
17	33170 ± 14130a	31843 ± 67690a	21038 ± 9842a	24365 ± 11278a	28450 ± 10471a
21	41298 ± 14671a	23958 ± 10398b	31291 ± 10714.3ab	30378 ± 15245ab	30650 ± 13182zab

Different letters indicate significant differences at each age.

Table 6. Effects of irradiation stage on development of male reproductive organs of *Cylas formicarius*.

Adult age (days)	Stage of Irradiation	Testis length (μm) (Average ± SD)	Testis width (μm) (Average ± SD)	SV width (μm) (Average ± SD)	SV width (μm) (Average ± SD)	Ag width (μm) (Average ± SD)
1	CT	383.6 ± 35.89a	235.0 ± 26.36a	173.3 ± 14.99a	0 ± 0a	124.9 ± 14.37a
	3BA	349.8 ± 44.79b	204.1 ± 30.80b	162.5 ± 18.17a	0 ± 0a	116.1 ± 16.38a
	A-1	374.4 ± 38.28ab	216.1 ± 23.63ab	146.0 ± 13.59b	0 ± 0a	123.3 ± 20.80a
5	CT	436.2 ± 46.78a	252.5 ± 18.36a	173.2 ± 15.77a	89.7 ± 22.05a	176.8 ± 25.55a
	3BA	390.1 ±60.43b	239.4 ± 20.10a	161.9 ± 20.62ab	74.0 ±20.01ab	147.6 ± 27.62b
	A-1	378.5 ± 44.80b	227.3 ± 21.21b	149.4 ± 16.79a	58.4 ± 28.72b	154.4 ± 22.47b
	A-5	393.9 ± 42.54b	228.7 ± 26.35b	157.8 ± 12.34bc	59.6 ± 38.56b	169.5 ±21.71ab
9	CT	411.2 ± 38.24a	222.0 ±26.42ab	168.2 ± 29.13a	91.1 ± 91.08a	181.4 ± 27.64a
	3BA	346.3 ± 42.75b	205.9 ± 29.71a	163.2 ± 18.61a	83.4 ± 30.01a	178.9 ± 26.52a
	A-1	383.1 ± 36.63ab	225.7 ± 27.42ab	184.7 ± 43.36a	95.5 ± 28.55a	188.8 ± 18.83a
	A-5	362.1 ± 50.16bc	225.0 ± 25.89ab	167.1 ± 21.91a	87.7 ± 26.41a	181.6 ± 31.29a
	A-9	397.6 ± 47.82ac	243.7 ± 18.87b	181.3 ± 28.69a	95.2 ± 19.11a	189.0 ± 24.27a
13	CT	431.7 ± 59.05a	215.0 ± 35.45ab	169.4 ± 15.67a	99.2 ± 26.10a	186.5 ± 22.34a
	3BA	358.0 ± 33.18bc	203.9 ± 24.51b	168.2 ± 21.17a	99.3 ± 26.15a	179.8 ± 21.68a
	A-1	366.9 ± 42.86bc	228.2 ± 24.20a	176.0 ± 27.80a	100.6 ± 28.55a	180.8 ± 27.84a
	A-5	350.2 ± 46.15b	221.8 ± 29.58a	173.7 ± 25.89a	123.2 ± 19.40b	176.4 ± 23.51a
	A-9	387.5 ± 26.67c	236.7 ± 22.58ab	176.0 ± 16.77a	99.2 ± 17.73ac	189.9 ± 21.18a
	CT	384.0 ± 56.13a	236.1 ± 36.72a	185.7 ± 20.33a	125.4 ± 26.00a	193.4 ± 19.07a
	3BA	320.6 ± 55.93b	192.7 ± 31.97b	178.8 ± 31.45ab	120.6 ± 33.25a	178.2 ± 20.11a
	A-1	339.7 ± 33.72bc	214.9 ± 29.30ab	162.1 ± 17.27b	112.3 ± 30.80a	183.6 ± 20.22a
	A-5	368.4 ± 32.74ac	217.3 ± 24.21ab	175.0 ± 19.67ab	111.6 ± 20.89a	179.4 ± 30.13a
	A-9	355.1 ± 32.69ab	219.1 ± 23.49a	179.5 ± 17.25ab	124.3 ± 18.80a	186.1 ±33.34a
21	CT	367.3 ± 31.92a	209.8 ± 27.06a	172.8 ± 15.92ab	123.7 ± 11.70a	185.2 ±17.18a
	A-1	374.3 ± 72.31a	203.9 ± 26.36a	162.4 ± 27.12a	101.1 ± 26.78b	186.6 ±39.14a
	A-5	369.6 ± 45.29a	205.0 ± 22.82a	174.9 ± 25.88a	108.6 ± 36.12ab	192.3 ± 26.69a
	A-9	228.0 ± 28.47b	221.8 ± 21.44a	163.8 ± 25.63a	115.8 ± 17.94ab	188.0 ± 26.30a

Sample size was 18 to 20. CT, 3BA, A-1, A-5, and A-9 indicate control, 3 days before adult emergence, adult 1, adult 5 and adult 9 at the irradiated stage, respectively. Different letters indicate significant differences at each age.

treatment groups. However, at 21-days post-irradiation, 9-day-old (A-9) males had a considerably smaller testis length.

At 1 and 5 days post-irradiation, the testis (TS) width of control males tended to be larger than that of weevils irradiated as pupae (3BA) or as 1- or 5-day-old (A-1 and A-5) males. At day 9 post-irradiation, the testis width of all experimental groups was similar, except between weevils irradiated as pupae (3BA) and 9-day-old (A-9) males (z-value = -4.608, P <0.001). At day 13 post irradiation, the testis width of A-9 males was the largest. At day 17 post irradiation, there were significant differences between the pupal (3BA) and the control (CT) groups or A-9 group (z-value = 4.646, P <0.001; z-value =-2.824, P <0.05). At day 21 post irradiation, there were no significant differences among any experimental insect life-stage groups. These results for the testis width are similar to those for the testis length in which testis development was suppressed by irradiation during early adulthood.

At 1 and 5 days post irradiation, the width of the seminal vesicle (SV) of control males tended to be greater than in weevils irradiated as pupae (3BA) or 1- or 5-day-old (A-1 and A-5) males. At days 9, 13, and 21 post-irradiation, there were no significant differences among any experimental insect life-stage groups. At day 17 post irradiation, the width of the seminal vesicle of control males was significantly greater than that of A-1 males (z-value = 3.416, P <0.01). These results indicate that the width of the seminal vesicle of control males tended to be larger than that of other experimental insect life-stage groups until day 5.

The width of the free sperm mass (SM) in the seminal vesicle on day 1 was 0 in control (CT) weevils or weevils irradiated as pupae (3BA) or 1-day-old males (A-1), indicating no sperm storage in the seminal vesicle. At day 5 after irradiation, the width of SM of control males was significantly greater than that of A-1 and A-5 males (z-value = 3.460, P <0.01; z-value = 3.324, P <0.005). At day 9 post irradiation, there were no significant differences in the width of SM among any of the experimental life-stage groups. At day 13 post irradiation, the width of SM of A-5 males was significantly larger than that of 3BA, A-1, and A-9 males (vs. 3BA, z-value =-3.376, P <0.01; vs. A-1, z-value = 3.185, P <0.05; vs. A-9, z-value = -3.386, P <0.01). At day 17 post

irradiation, there were no significant differences among any experimental life-stage groups. At day 21 post irradiation, there was a significant difference between the control and 1-day-old males (A-1) (z-value = 2.872, P <0.05). Generally, sperm storage in control weevils tended to be greater than in irradiated groups, for all life-stages.

The width of the accessory gland (AG) of control weevils, pupae (3BA), and 1-day-old (A-1) males showed no significant differences 1 day post irradiation. At days 5 post-irradiation, the width of the accessory gland of the controls was significantly larger than that of 3BA or A-1 weevils (vs. 3BA, z-value = 3.462, P <0.01; vs. A-1, z-value = 2.928, P <0.05). At day 9 post-irradiation or thereafter, there were no significant differences among any of the experimental life-stage groups. These results indicate that accessory gland development was suppressed by irradiation during early adulthood.

Analysis of effects of the number of days after irradiation for each time point post-irradiation and insect life-stage at the time of irradiation on subsequent development of on male reproductive organ development (Table 7) indicated that factors of irradiation stage and age had significant differences in the testis length, testis width, seminal vesicle width, sperm mass width in the seminal vesicle and the width of accessory gland. Pairwised test indicated that age had significant differences in the testis length, sperm mass width and accessory gland width between BA-3 and control, A-1 and control, or A-5 and control. There were significant differences in the testis length, sperm mass width, and accessory gland width with age between A-9 and control, A-1 and A-9, and A-5 and A-9. Finally, significant differences in testis length, testis width, seminal vesicle width, and sperm mass width with age between BA-3 and A-1, and BA-3 and A-5 was recorded, although significant differences in the testis length, sperm mass width accessory gland width between BA-3 and A-9 with age seminal vesicle width, sperm mass width and accessory gland width between A-1 and A-5 was found.

Sperm production of control males tended to be larger than that of irradiated males from day 13 post-irradiation, especially compared with weevils irradiated as pupae (3BA (at 5 days post-irradiation, z-value = -3.237, P <0.01; at 13 days post irradiation, z-value = 3.834, P <0.001; at 17 days post irradiation, z-value = 4.553, P <0.001; at 21 days post irradiation, z-value = 4.219, P <0.001) (Fig. 5).

Feeding of irradiated individuals

Irradiated males showed feeding activity whenever they were active irrespective of the weevil life-stage subjected

Table 7. The results of general linear model on the effects of irradiation age on subsequent growth of male reproductive organs.

Factor	Testis length	Testis width	SV width	SM width	AG width
Overall test					
Irradiation stage	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Age	<0.001*	<0.001*	0.047*	<0.001*	<0.001*
Irradiation stage×age	<0.001*	0.4068	0.009*	<0.001*	<0.001*
Pairwised test					
Control vs BA-3					
Irradiation stage	<0.001*	-	0.0686	−0.5939	0.0202
Age	<0.001*	-	<0.001*	<0.001*	<0.001*
Irradiation stage×age	0.5947	-	0.1288	0.0321	0.0506
Control vs A-1					
Irradiation stage	<0.001*	-	<0.001*	0.0033*	0.1508
Age	<0.007*	-	0.0247	<0.001*	<0.001*
Irradiation stage×age	0.4974	-	0.2468	0.4088	0.5882
Control vs A-5					
Irradiation stage	<0.001*	-	<0.001*	0.8837	0.6458
Age	0.0145	-	<0.001*	<0.001*	<0.001*
Irradiation stage×age	0.6260	-	<0.001*	0.0014*	0.0229^
Control vs A-9					
Irradiation stage	<0.001*	-	0.2179	0.1851	0.0170
Age	<0.001*	-	0.0899	<0.001*	0.0015*
Irradiation stage×age	<0.001*	-	0.0081*	<0.001*	<0.001*
BA-3 vs A-1					
Irradiation stage	0.0028*	-	0.1427	0.0410	0.4247
Age	0.0043*	-	0.0027*	0.001*	<0.001*
Irradiation stage×age	0.2556	-	0.7693	0.0887	0.0858
BA-3 vs A-5					
Irradiation stage	0.0016*	-	0.7013	0.4617	0.0114
Age	0.0075*	-	<0.001*	<0.001*	<0.001*
Irradiation stage×age	0.3475	-	0.8745	<0.001*	<0.001*
BA-3 vs A-9					
Irradiation stage	<0.001*	-	0.0140	0.0709	<0.001*
Age	<0.001*	-	0.6955	<0.001*	<0.001*
Irradiation stage×age	<0.001*	-	<0.001*	<0.001*	<0.001*
A-1 vs A-5					
Irradiation stage	0.8297	-	0.2143	<0.001*	0.0915
Age	0.0522	-	<0.001*	<0.001*	<0.001*
Irradiation stage×age	0.9152	-	0.6520	0.0085*	0.0064*
A-1 vs A-9					
Irradiation stage	0.3772	-	<0.001*	<0.001*	<0.001*
Age	<0.001*	-	0.5570	<0.001*	<0.001*
Irradiation stage×age	<0.001*	-	<0.001*	<0.001*	<0.001*
A-5 vs A-9					
Irradiation stage	0.1238	-	0.0726	0.2007	0.0634
Age	<0.001*	-	0.7896	<0.001*	0.2646
Irradiation stage×age	<0.001*	-	<0.001*	0.2991	0.1258

For pairwised tests, asterisk indicates the significant difference (P<0.05/10) with a Bonferroni correction and hut indicates non-significant but suspected difference. SV, SM, and AG indicate seminal vesicle, sperm mass, and accessory gland, respectively.

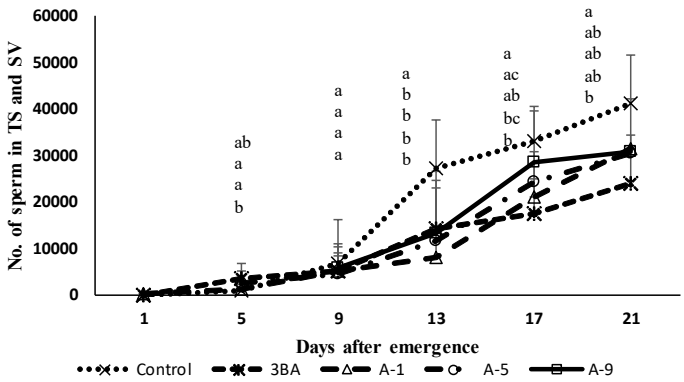

Fig. 5. The number of sperm in a pair of testes and seminal vesicles of *Cylas formicarius* males irradiated at different stages on days 1, 5, 9, 13, 17, or 21 of adult life. The data are expressed as mean±SD. Different letters indicate significant differences.

to irradiation. However, they stopped feeding 3 or 4 days before death, while control males continued to feed throughout the entire observation period. Male adults irradiated at the pupal stage stopped feeding earlier than other treated groups. This indicates that irradiation of the weevils affected feeding behavior, as a side effect, which would damage midgut cells.

The effectiveness of SIT depends on rendering the sperm abnormal by utilizing the differences in sensitivity to irradiation between germ cells and the more tolerant somatic cells. Irradiation also induces abnormalities in midgut cells (Sakurai et al., 1998) reducing normal feeding behavior activity several days later after irradiation, causing death by starvation. The present study indicated that 100 Gy of irradiation provoked strong abnormality in feeding behavior of *C. formicarius* within a week after irradiation. Moreover, the survival rate of irradiated weevils was high for 4 or 5 days immediately after irradiation at this dose, after which survival rates declined quickly (Fig. 3). The later in their lifecycle weevils were irradiated, the higher their survival rate during the observation period (from day 10 to day 20 of adult life) (Fig. 3) was recorded. This suggested that the stage and age of irradiation influences the possible mating period. Kumano et al. (2008) find that the survival and mating rates of male adults of *C. formicarius*, irradiated at 10 to 14 days after adult emergence, are high for one week after irradiation with 200 Gy and then declined greatly, a result similar to present study.

Although males irradiated as pupae showed low mating rates during the observation period, those irradiated 1 or 5 days after emergence mated with relatively high frequency during the first 3 days of the observation period, at rates similar to the controls. In this period, irradiated adults seemed to show normal behavior. Thereafter, irradiated adults became moribund but not death feigning (Miyatake 2001a, b), and died within two days. Moribund individuals could not copulate. Even if irradiated male adults survived the entire observation period, most could not mate during the latter half of the observation period, and relatively large numbers of sperm were found in the seminal vesicles of irradiated male adults. Moreover, while the stage that was irradiated did have an effect on sperm production (Table 5), it is unlikely that males experienced sperm depletion after several matings due to inhibition of spermiogenesis from irradiation. It seems likely that mating ability decreased as male adults starved due to a side-effect of irradiation to midgut cell, resulting in decline of mating ability and a shortened mating period. This explains why the mating period was shorter than survival period.

The effects of irradiation stage on male reproductive organ development in *C. formicarius* was also examined (Tables 6 & 7). Generally, irradiation suppressed the development of male reproductive organs (testis, seminal vesicle and accessory gland) to some degree during the early phase of adulthood compared to controls, but did not seriously damage the development of male reproductive organs nor interfere with mating, including the transfer of sperm and accessory gland substances. In the Mediterranean fruit fly, *Ceratitis capitata* Wiedemann, 100 Gy of irradiation completely stops spermatogenesis (Anwar et al. 1971). In contrast, the present study demonstrated that weevils irradiated as adult had a higher total number of sperm available than weevils irradiated as pupae. Furthermore, we found that pupal irradiation shortened the possible mating period of *C. formicarius.* Therefore, irradiation of sexually mature adults was recommended to extend the possible mating period of this weevil.

It took approximately five days for more than half of female adults of *C. formicarius* to emerge from sweet potatoes (Fig. 1) and become sexually mature (Fig. 2), as suggested by Sugimoto et al., (1996). Thus, male adults irradiated at the pupal stage are active for almost an entire week before they have the chance to become sexually active, but can seldom mate after this time, making pupal irradiation unsuitable for SIT. One of the most essential requirements of the sterile male technique is the ability of an irradiated male to compete with a normal male for mating with wild females (Saour & Makee 1997). As the possible mating period of male adults is shortened by irradiation, whether male adults are able to efficiently mate during the first week after irradiation is very important for the success of the eradication program. There is a balance, however, because the later the irradiation takes

place, the higher the dose needed for complete sterilization, which in turn decreases possible mating period. Conversely, if the irradiation dose is too low, the insects released will not be sufficiently sterile, which would be disastrous for control programs (Collins & Taylor 2011). Furthermore, older males produce more sperm, resulting in an increase of fertile sperm, if the irradiation dose is too low to achieve sterilization. Therefore Okinawa Prefecture has used 200 Gy of irradiation for complete sterilization (Kuriwada 2013). Kumano et al., (2011) suggested that fractionated-dose irradiation can be highly advantageous for eradication of this weevil because the effective copulation period is prolonged. By exposing insects to 100 Gy of radiation at two successive times, damage to midgut somatic cells reduced that would produce fitter weevils useful for the eradication program.

The study concludes that adult weevils should be irradiated soon after their emergence from sweet potatoes and be released frequently into the field to maximize the sterile male's mating ability.

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Population dynamics of fruit fly, *Bactrocera* spp. (Diptera: Tephritidae) in Lucknow region of Uttar Pradesh, India

Rajesh Kumar and RP Shukla

Former Research Associate, Department of Crop Protection, CISH, Lucknow. Former Head Department of Crop Protection, CISH, Lucknow.

ABSTRACT

Annual monitoring of the population dynamics of the oriental fruit fly *Bactrocera spp* Hendle (Diptera: Tephritedae) in Lucknow region of Uttar Pradesh, India was conducted by bottle trap and wooden block trap in 2004 and 2005 and factors including temperature, rainfall and host species with respect to the population fluctuation were analyzed systematically. The results showed that the fruit fly was present all the year round in Lucknow region of Uttar Pradesh. In Lucknow destrict, the first catch in bottle trap was in the 7th standard week in both year 2004 and 2005 at an average of 10.53 and 9.67 flies/trap/week, respectively. However, trap catch were observed in the wooden block traps in the 3rd standard week in 2004 and 2005 (14.50 and 3.67 flies/trap/week, respectively). The peak average population of *Bactrocera* spp. was 420 and 1499 flies/trap/week in 25th standard week in bottle and wooden block traps, respectively in the year 2004. The weathe parameters during 25th standard week showed the average maximum and minimum temperatures of 37.7°C and 25°C respectively, maximum and minimum relative humidity was 89°C and 73 per cent respectively and the total rainfall was 19.4 cm during the first year of experiment. The peak average population (399 and 1398 flies/trap/week) during the year 2005 was attained in the 26th standard week in bottle trap and wooden block trap, respectively. In the corresponding 26th standard week of the second year, the maximum and minimum temperature relative humidity and the total rain fall was 42 and 25.7°C, 61 and 41 percent and 51 mm., respectively.

Key words: *Bactrocera* spp, Population dynamics, Lucknow district of UP

Batra (1953) while observing the fruit fly activity throughout the year on mango and guava, with peak periods in July–October, stated that the population build up of any insect is intimately associated with the weather parameters prevailing during preceding and corresponding periods. The pest status does not remain static throughout the year but changes according to abiotic conditions, like temperature, relative humidity (RH), rainfall and light, etc. Bess and Haramoto (1961) recorded that little variation in temperature between winter and summer affects the peak abundance of *B. dorsalis*. Patel (2013) studied fluctuation of fruit fly oriented damage in mango in relation to major abiotic factors. Mann (1980) studied population dynamics of *B. dorsalis* in various seasons and found its highest population in September-October. Bagle and Prasad (1983) recorded that fruit fly population was high during March, April, May and June in Karnataka during 1975 to 1978. They studied the population dynamics by weekly counts of males caught in traps with 100 ml of an emulsion containing 0.1% methyl eugenol (4-allyl-1, 2-dimethoxybenzene-carboxylate) and 0.25% malathion. Vargas *et al.,* (1983) reported *B. dorsalis* as most abundant and widely distributed fruit fly on Kauai at low and high elevations. Drew *et al.,* (1984) recorded the peak trap catches of *Bactrocera* spp. at the peak fruiting time of major hosts. Shukla and Prasad (1985) studied the population fluctuation of *B. dorsalis* in two guava orchards in Bangalore during 1980-1981 using methyl eugenol traps. Two distinct population peaks during March to June and September to October each year were recorded. Su (1986) recorded the peak population of fruit fly during August to November in Chiu-jun area of Taiwan and identified temperature as the major regulating factor followed by rainfall, humidity and sunshine hours. Abbas and Srivastava (1989) reported that the population of fruit fly was nil from January to March in north Indian conditions. The emergence started from April and maximum population was recorded in May, June and July. The population again declined slowly in August to September and remained nil in October, November and December. Gupta and Verma (1990) recorded seasonal incidence of *B. zonata* and *B. dorsalis* in semi isolated peach, plum and apricot orchards located in the mid hill regions of Himachal Pradesh during 1986–87 and found that the traps baited with methyl eugenol and malathion captured maximum males of both the species from the second week of April to second week of November during both the years. Gupta *et al.* (1990) recorded peak adult activity of *B. zonata* in the 3rd week of June on apricot, 4th week of June on plum and 2nd week of July on peach. Chaudhry and Jamal

(2000) noticed that the activity of adult males of *B. dorsalis* and *B. zonata* reached a peak from August to October (1995) in Rawalpindi, which coincided with the maturity of guava crop. Sarada *et al.,* (2001) recorded seasonal bundance of *Bactrocera* spp. in Andhra Pradesh and found peak fly population in mango orchards from May to July. Roy *et al.,* (2018) in a pilot study of area studied the management of fruit fly by the male annihilation technique (MAT). With this technique the population of fruit fly population was reduced in protected area.

Rashid Ahmad Khan and Muhammad Naveed (2017) reported occurrence and seasonal abundance of fruit fly, *Bactrocera zonata* Saunders (Diptera:Tephritidae) in relation to meteorological factors. Shukla and Kumar (2006) found that the fruit flies (*Bactrocera* sp.) were earlier not so active during winter months but currently they are observed throughout the year in Lucknow Kamla Jayanti (2019) reported male annihilation techniques (MAT) to control fruit fly *B. dersalis* population. Her studies suggested that kariromenes would facilitate the development of lures based on synthetic female attractant. These kairomones affect the population fluctuations in Saharanpur regions of U.P. The numbers of adult fruit flies caught in methyl eugenol traps kept in mango and guava orchards maintained organically since 2000 was monitored at Lucknow, U.P. during 2004-2006. Among the fruit fly species observed in the traps, the maximum population was that of *B. zonata* (98%), while only less than 2 percent was of *B. dorsalis*. Mohammed *et al.,* (2000) evaluated soaked-wooden blocks to replace the plastic traps use in male annihilation technique (MAT) of fruit flies in mango orchards in Pakistan. Each block killed nearly twice as many flies as a trap and lasted nearly twice as long and was preferred to traps for on-farm fly control in all cases. Oblong plywood traps caught slightly more flies than other shapes, and catch size appeared positively associated with the block edge. Duniel Brhane *et al.,* (2019) reported that fruit fly infestation was observed in 89 per cent of trees. The variation in percentage infestation was inversely proportional with the management practices. Relatively spongy date wood caught more flies than other harder woods but did not last as long. Most flies caught were *B. zonata* and up to 10 percent *B. dorsalis* was also found. Shukla *et al.,* (2005) made catches of *Bactrocera* spp. by unreplenished soaked wooden block containing approximately 2 ml of lure and weekly replenished water traps containing 0.1 ml of lure in mango orchards near Lucknow and reported widely differing results during two different years period. Stonehouse *et al.,* (2007) used MAT at village and farm levels and reported that a guild of fly pests are largely responsive to methyl eugenol lures, with reference to a mean infestation rate in unprotected orchards of 13 percent. Farm-level control showed improvements at 71 per cent, village-level control at 96 per cent and both together at 99 per cent levels.

MATERIAL AND METHODS

The experiments were conducted at four locations (Rehmankhera, Gulabkhera, Budharia and Pathakganj) situated near Division of Crop Protection, Central Institute for Subtropical Horticulture, Lucknow during 2004 and 2005. Seasonal incidence studies were conducted from January 2004 to December 2005, while the studies on seasonal distribution were conducted during the fruiting season.

Geographically, the Lucknow district is situated at an elevation of about 110 m above sea level between 20′81° north latitude and 80′54° east longitude and falls in semi-arid and subtropical zones of extreme type. It experiences an average rainfall of about 807.3 mm during monsoon with a few showers in the winter season. Saharanpur district is situated at an elevation of about 270.50 metres above sea level between 29′58° north latitude and 77′33° east longitude and falls in semi arid zone. The observations on various meteorological parameters, *viz.* temperature, relative humidity (%) and rainfall (mm) were recorded at weekly intervals in the meteorological observatories situated at 4th Block of CISH, Rehmankhera, Lucknow.

Bottle trap

Fruit fly traps were constructed using a 250 ml wide mouth bottle (9.5 x 4.5 cm; Plate-2). An aluminium canopy was attached to the bottle neck and a thread hooked through the canopy to enable these to be hung from the trees. The bottle was filled with a solution of methyl eugenol (0.2 ml), dichlorovos 76 per cent (0.26 ml) and 200 ml water. The solution was changed every week. Weekly observations on the number of fruit fly trapped were made from January 2004 to December 2005. The corresponding mean weekly data of weather factors such as, temperature, relative humidity and rainfall were also recorded. The data obtained were subjected to simple correlation analysis.

Wooden block trap

Wooden block trap of size 5x5x1 cm were made from poplar wood because of its high absorption capacity (Plate-3). These blocks were soaked in solution of ethanol, methyl eugenol and malathion (EC) in the ratio of 6:4:1 for 48 hrs. Wooden blocks were kept in used plastic mineral water bottles provided with four holes on top of bottle for entry of flies. These traps were hung on mango trees at a density of 10 traps per hectare. Fly population trapped was recorded at weekly intervals year and traps were replaced after every two months.

RESULT AND DISCUSSION

There were no catches in bottle traps up to 6th standard week (1 st standard week = 1 st week of January and so on) in both the years of experimentation. In bottle traps, catches started from 7th standard week at an average of 10.53 and 9.67 flies trap^{-1} week in 2004 and 2005, respectively (Table 1). However, trap catches were observed in the wooden block traps in the 3rd standard week in 2004 and 2005 (14.50 and 3.67 flies trap^{-1} week^{-1}, respectively (Table 1). The peak average population of *Bactrocera* spp. was 420 and 1499 flies trap^{-1} week^{-1} in 25th standard week in bottle and wooden traps, respectively in the year 2004 (Table 1). The weather parameters during 25th standard week showed that the average maximum and minimum temperature was 37.7°C and 25°C, respectively, maximum and minimum relative humidity was 89 and 73 per cent, respectively and the total rainfall was 19.4 cm during the first year of experiment (Table 1). The peak average population (399 and 1398 flies trap^{-1} week^{-1}) during the year 2005 was attained in 26th standard week in bottle trap and wooden block traps, respectively (Table 1). In the corresponding 26th standard week of the second year, maximum and minimum temperature was 42 and 25.7°C, maximum and minimum relative humidity was 61 and 41 per cent, respectively, and the total rain fall was 51mm (Table 1). The population fluctuations of fruit flies (*Bactrocera* spp.) have been graphically shown in figures- 1, 2, 3 and 4 for the years 2004 and 2005.

There was abundant population of fruit flies in the entire crop season during 15-38 standard weeks in 2004. Three peaks of fruit fly population were observed at 25th (420 flies trap^{-1} week^{-1}), 28th (410 flies trap^{-1} week^{-1}), and 27th (404 flies trap^{-1} week^{-1}) standard weeks in bottle trap and 25th (1499 flies trap^{-1} week^{-1}), 26th (1460 flies trap^{-1} week^{-1}), and 24th weeks (1390 flies trap^{-1} week^{-1}) in wooden block trap in 2004 (Table 1). While in 2005, peaks of fruit flies populations were recorded in 26th (399 flies trap^{-1} week^{-1}), 27th (389 flies trap^{-1} week^{-1}), and 28th (379 flies trap^{-1} week^{-1}) standard weeks in bottle traps and 26th (1398 flies trap^{-1} week^{-1}), 27th (1371 flies trap^{-1} week^{-1}), and 25th (1342 flies trap^{-1} week^{-1}) standard weeks in wooden block traps (Table 1). It was observed that the maximum number of fruit flies was recorded during the month of June (in 25th and 26th standard week) in both the years (2004 and 2005) which coincided with maturity of the fruits. Traps catches were higher in wooden block traps as compared to bottle traps in the both years of investigation. The fruit fly trap catch during 2004 and 2005 was found to be dependent upon abiotic factors.

Temperature played an important role in regulating the population buildup of fruit flies in both the years. In the year 2004 in Lucknow district, the average temperature was statistically significant and was positively correlated to the population of fruit flies in both bottle (r= 0.741; P<0.001) and wooden block (r=0.680; P<0.001) traps (Table 2). Similar correlations between temperature and population of fruit flies was found in the bottle (r=0.262; P<0.01) and wooden block traps (r=0.296; P<0.01; Table 2).

Results revealed that the prevailing relative humidity did not influence the population of fruit flies in either of the two years of sampling in Lucknow.

Though positive correlations were obtained between relative humidity and population of fruit flies in both the bottle (r= 0.155; P>0.05) and wooden block (r= 0.212; P>0.05) traps during 2004, they were statistically non-significant (Table 2). During 2005, statistically insignificant negative correlations were obtained between the two parameters of relative humidity and population of fruit flies in both bottle (r= -0.126; P>0.05) and wooden block traps (r=-0.208; P>0.05; Table 2).

The total rain fall showed significant positive correlations in bottle and wooden block traps in the years 2004 (r= 0.452; P<0.005 and r=0.362; P<0.005, respectively) and 2005 (r= 0.316; P<0.005 and r=0.387; P<0.005, respectively; (Table 2). The study on seasonal incidence of fruit fly, *Bactrocera* spp. was conducted in Lucknow and Saharanpur districts of the state of UP, India during 2004 and 2005 using bottle traps and wooden block traps. In the Lucknow district the first catch in bottle trap was in the 7th standard week in both years 2004 and 2005 at an average of 10.53 and 9.67 flies trap^{-1} week^{-1}, respectively. However, trap catches were observed in the wooden block traps in the 3rd standard week in 2004 and 2005 (14.50 and 3.67 flies trap^{-1} week^{-1}, respectively). The peak average population of *Bactrocera* spp. was 420 and 1499 flies trap^{-1} week^{-1} in 25th standard week in bottle and wooden traps, respectively in the year 2004. The weather parameters during 25th standard week showed that the average maximum and minimum temperature was 37.7°C and 25°C, respectively, maximum and minimum relative humidity was 89 and 73 per cent, respectively and the total rainfall was 19.4 cm during the first year of experiment.

The peak average population (399 and 1398 flies trap^{-1} week^{-1}) during the year 2005 was attained in 26th standard week in bottle trap and wooden block traps, respectively. In the corresponding 26th standard week of the second year, maximum and minimum temperature was 42 and 25.7°C, maximum and minimum relative humidity was 61 and 41 per cent, respectively, and the total rain fall was 51 mm.

Table 1: Average of mateorological data and population of fruit flies, *Bactrocera* spp. population trapped in bottle and wooden trap during 2004 and 2005 in Lucknow district

Std. week	2004					2005				
	Average Temp (%)	Average Humidity (%)	Total rainfall (mm)	Bottle Trap	Wooden block trap	Average Temp °C	Average Humidity (%)	Total rainfall (mm)	Bottle Trap	Wooden block trap
1	11.15	85	0	0	0	13.3	68.6	0	0	0
2	10.85	81	0	0	0	14.5	68	2	0	0
3	14.65	86	0	0	14.5	14.2	69.5	7	0	3.67
4	14.5	85	0	0	15.83	14	75.5	4	0	9.67
5	15.5	77	41.1	0	21.17	13.9	75.5	40	0	11.3
6	15.9	68	0	0	23.5	17	68.5	0	0	13.2
7	18.65	68	0	10.53	30.17	19.5	60	0	9.67	22.2
8	19.85	62	0	13.3	22.83	16.6	57	0	10.1	25.2
9	21.7	59	0	15.8	35.33	18.5	57.7	0	13.5	28.3
10	22.3	60	0	17.1	40.83	21.5	51	0	13.1	35.7
11	25.55	61	0	27.7	50.5	22.7	64	5.4	23.7	43.8
12	27.8	47	0	36.8	61.33	22.4	58.5	0	23.5	53.3
13	26.95	44	0	46.8	100.8	24.7	46.8	0	51.7	67.2
14	27.1	48	0	52.4	178.5	23.8	34.5	0	53.3	173
15	30.9	48	0	144	259.8	25.2	30.5	0	107	236
16	31.55	48	0	125	335.3	25.7	29.5	0	124	347
17	28	67	2	192	585.2	28.4	24.5	0	191	591
18	27.1	69	2.1	128	822.7	30.1	43	0	123	753
19	31.95	57	0	204	997.3	29.8	79	20	203	914
20	35.01	47	0	241	1085	30.2	39	14	235	1043
21	32.31	71	32.9	263	1203	30.2	43	0	274	1162
22	31.9	70	0	363	1305	32.2	45	0	317	1167
23	30.05	78	4	349	1380	31.8	33.3	0	346	1324
24	28.45	82	28	396	1390	33.1	41.5	0	357	1279
25	31.35	81	194	420	1499	34.7	39.5	0	326	1342
26	31.3	70	54	399	1460	33.9	51	39	399	1398
27	29.9	84	24.2	404	1364	30.8	77	38.9	389	1371
28	28.8	85	419	410	1169	29.3	81	16.5	379	1172
29	31.2	81	14	370	1011	29.8	82.5	87	369	1042
30	31.9	88	101	387	851.5	30.3	85.5	61.6	320	882
31	29.4	87	10	355	661.8	30.9	81.5	11.1	336	737
32	29.5	87	8	209	565.2	30.7	80	0	212	636
33	29.15	83	14.7	181	487.3	30.7	71.5	0	183	566
34	28.5	81	35.1	181	346.7	189	80.5	23	179	403
35	29.8	78	7	154	272.7	30.9	83.9	78	152	288
36	30.45	70	0	116	195.5	31	66.2	0	90.3	191
37	31.25	81	0	125	165	31.2	78.6	49.7	125	173
38	27.7	81	196	119	120.8	30.7	81.3	131	119	120
39	28.25	70	0	78	118	27.3	82.2	5.5	74.4	108
40	27.95	77	24.3	114	126.5	28.9	79.2	0	111	125
41	24.9	75	57	101	87.5	28.9	78.1	0	101	75.2
42	22.95	64	0	101	52.17	27.8	80.6	0	91.7	43.7
43	22.5	63	0	73.6	51.83	27.1	82.3	10	71.7	42.5
44	20.05	63	0	45.1	34.5	19.8	82.3	0	42.4	31.8
45	19.1	55	0	30.6	21	22	78.4	0	29	28.5
46	18.6	59	0	34.8	12.5	20.9	75.5	0	32.2	25.5
47	19	71	0	45	12.33	20.1	58.4	0	44.3	15.8
48	18.65	65	0	42.7	13.33	20.6	66.3	0	40.8	11.7
49	17.35	60	0	17.8	11	21.2	67.9	0	19.7	9
50	16.75	67	0	16.1	8.333	18.8	59.6	0	17.6	8.17
51	14.9	83	0	15.4	7.5	23.1	71.7	0	16	12
52	12.65	77	0	8.33	3.833	14.8	77.4	0	8.55	7

Table 2: Correlation coefficients (r) between trap catches of fruit flies (*Bactocera* spp.) in mango crop and abiotic factors at Lucknow

Meteorological Parameters	Traps		
	Year	Bottle trap	Wooden block trap
Average temperature	2004	0.741***	0.680***
	2005	0.262*	0.296*
Average RH	2004	0.155^{NS}	0.212^{NS}
	2005	-0.126^{NS}	-0.208^{NS}
Total rainfall	2004	0.452**	0.362**
	2005	0.316**	0.387**

*, ** and *** denote correlation coefficients to be significant at P<0.01, 0.005 and 0.001, respectively. NS is for non-significant.

Fruit fly population buildup in the years 2004 and 2005 showed statistically significantly positively correlated to the population of fruit flies in both bottle (r= 0.741; P<0.001; r=0.262; P<0.01) and wooden block (r=0.680; P<0.001; r=0.296; P<0.01) traps. No statistically significant correlation was found between average relative humidity and fruit fly population in both the years 2004 and 2005. However, the total rainfall was positively correlated with the fruit fly populations trapped in both bottle and wooden block traps in the years 2004 (r= 0.452; P<0.005 and r=0.362; P<0.005, respectively) and 2005 (r= 0.316; P<0.005 and r=0.387; P<0.005, respectively).

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Sustainable end use of black soldier fly for successful entrepreneurial venture

Atun Roy Choudhury[1] and Neha Singh[2]

[1]*Scientific Officer, Ramky Enviro Engineers Ltd., Gachibowli, Hyderabad, India-500 032*
[2]*Assistant Manager, Ramky Enviro Engineers Ltd., Gachibowli, Hyderabad, India-500 032*
**E-mail: atunroy.choudhury@ramky.com*

ABSTRACT

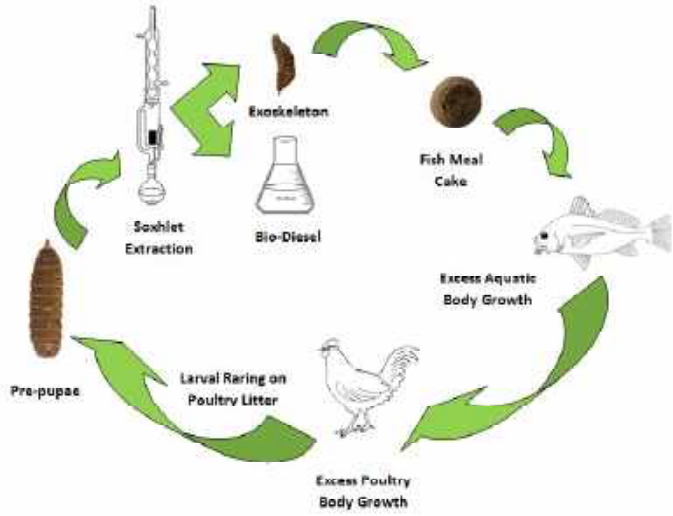
The larvae of *Hermetia illucens*, colloquially known as black soldier fly (BSF) pose an enormous potential for small-scale entrepreneurship, especially for economically backward nations. Engaging these avid eaters in frugal application towards the societal benefit can open a new dimension to explore feasible business opportunities and mitigate unemployment issues. The present study was tried to emphasize the various possible end applications of the BSF larvae in a holistic and wholesome way. The prime advantage of dealing with these larvae incorporates the minimization of the threat associated with the mortality rates, due to the ancillary applications of the dead larvae towards the nutri-culture industry and production of alternative fuel. Furthermore, the nutrient-rich compost formation due to the larval digestion activity on the municipal organic waste (MOW) fraction creates a new entrepreneurial niche for lower and middle-income nations. The research yields synthesis of primarily three major end products in terms of compost, bio-diesel, and fish meal cake. Initially, the larvae were employed for the degradation and stabilization of MOW and the product of stabilization was further analyzed and identified as compost as per the Fertilizer Control Order (FCO) 1985. The departed counts have further compressed by means of compaction machine with capacity 3000 kN and body fluid was segregated. The crude liquid was purified using centrifugation and successively followed by Soxhlet extraction. Ultimately, the separated bottom sludge has been blended with the crushed body skeleton of the larvae and turned into protein-rich fish meal cake. Thus, it's evident to state that besides substantial societal benefits BSF poses magnificent potential to be explored by the entrepreneurial venture.

Key words: Bio-diesel, black soldier fly, compost, fish meal cake, struvite

Highlights:

- Conversion of dead pre-pupae into cost-effective bio-fuel through the Soxhlet extraction.
- Homogenization and solidification of the exoskeleton to convert it into protein-rich cake.

Graphical Abstract:



- Fish meal cake is readily consumable in all type of varieties and helps to gain excess body weight due to higher fat and protein content.
- Direct feeding as poultry meal may enhance the body mass index up to 30% in mature product.
- Poultry litter was feed to the juvenile larvae and the same has been further stabilized in the form of compost.

In a middle-income nation like India presently a wholesome solution for the overall good in terms of mitigation of unemployment issue is of utmost concern. In this scenario an approach associated with BSFL composting attributed with other ancillary facts could be the answer to the existing giant issue pertaining in various lower and middle income countries (Gabler, 2014). Rather than the waste treatment and minimization, the above process is also capable of addressing multidimensional issues such as rising demand of implementing renewable fuel, increment of protein content in farm and aquatic diet, yielding compost with high nutrient content, etc. The larvae of black soldier fly consume the organic fraction of the waste ravenously and build a body composition with the higher amount of protein and fat contents. The protein content of the larvae generally used as a crude source of protein which replaces

the expensive conventional protein source in pet food, poultry feedstock, fish meal, etc. and the body fat has been successfully converted into value-added co-products such as biodiesel. Other major advantages comprise higher consumption rates and faster rate of degradation and bio-conversion (Richard 2015; Alvarez, 2012). Hang *et al.* (2013) stated it is utmost feasible in capturing the nutrients from the waste stream which can be further utilized as agro-based plant manure and the bioconversion technique stabilizes the primary pollutants and minimizes the production of obnoxious gases and odour formation by 94.5 percent. The larval composting has also proven to be effective against the removal of *Escherichia coli* with an index range of 92.0 percent and successive reductions were observed by the same researcher in total weight, total Kjeldahl nitrogen and moisture content in stabilized waste around 67.2, 76.0 and 80.0 percent, respectively. The economic proficiency of the above technique even makes it more feasible with the yearly profit rages from US$33.4-46.1 per m^3, observed during the operational period. In order to interpret the above scenario an experimental study conducted by Tschirner and Simon (2015) may be considered as a benchmark. They have investigated the influence of different growing substrates on the crude nutrient and they observed the impact of different fodder consumption on the larval body composition. They reported the yield of different nutrients for the experimental period of 15 days, where protein and fibre value ranges around 0.93 and 0.43 kg of wet mass, respectively. They also reported the changes in protein content due to different substrate consumption, which showed the crude protein content values of 37.2, 44.6 and 52.3 percent of dry matter, respectively. In this context a baseline by Li *et al.* (2011a) reported that synthesis of value-added co-products such as grease, biodiesel, etc, is technically feasible, utilizing dairy manure as substrate. The extraction of grease from BSFL was performed with the help of petroleum ether, and thereafter biodiesel could be extracted in a similar manner with a two-step method. At last the remaining fraction of the manure could be anaerobically hydrolyzed to produce sugar. In their study, roughly 1248 g raw dairy manure was converted by 1200 larvae into 273.4 g compost material in 21 days. Once the stabilization got over approximately 15.8 g of biodiesel was obtained from 70.8 g dry BSFL, while 96.2 g sugar was produced from the anaerobic digestion of treated dairy manure. After completion of grease extraction, the residual dry fraction of the larvae was used as a potential source of protein-rich food stuff for the animals. In support of the above hypothesis Surendra *et al.* (2016) carried out the chemical analysis of the bio-oil secreted from BSF larvae and reported that body fluid comprises higher concentration (i.e. approx. 67 percent) of medium chain saturated fatty acids whereas, the concentration of polyunsaturated fatty acids found to be significantly lower, ranging from 13-15 percent of total fatty acids (Nguyen *et al.*, 2015; Canavoso *et al.*, 2001; Ramos *et al.*, 2009; Sanchez-Muros *et al.*, 2014; Meher *et al.*, 2006; Marchetti *et al.*, 2007). The above phenomenon confirms the bio-oil to be potentially acceptable as superior quality biodiesel. A study conducted by Nguyen *et al.* (2018) reported optimum recovery of bio-diesel from the live count by means of performing transesterification with zero requirement of any pre-treatment facility. The study was executed using a 1:2 blend of n-Hexane and methanol which further enhanced the bio-fuel yield up to 94 percent. Ultimately, the optimal recovery of the bio-fuel was reported by Zheng *et al.* (2012) in which the larvae of *Hermetia illucens* were cultured on restaurant waste and production of bio-diesel was doubled performing raring activity prior to the segregation. The larvae also showed potential against pathogen removal, a study conducted by Qiaolin *et al.* (2008), reported the ability of BSFL for *E. coli* reduction from dairy manure and they introduced the larvae into 50, 75, 100, or 125 g sterilized dairy manure homogenized and inoculated with *E. coli* and stored for 72 h at 27^0C. They concluded that the larvae composting potentially decreased the *E. coli* count in all the respective conditions. Not only this, pronto the black soldier fly larvae have been acclaimed as the most pertinent alternative to the costlier commercial animal protein sources. Nyakeri *et al.* (2016) has reported a complete nutrition profile; the researchers have performed experiments such as proximate analysis for vitamins and minerals and concluded that wild *Hermetia illucens* larvae consist approximately 40 percent protein, 33 percent crude fat, 12 percent crude fibre, 15 percent ash and remaining all sort of trace elements such as manganese, sodium, iron, potassium etc. It also includes the different variety of proteins namely, thiamine, riboflavin and vitamin E etc. The similar body composition was reported in another successive study conducted by Sara *et al.* (2016), who worked on the protein synthesis aspect and concluded that the protein extractability of larval flour fraction segregated was around 36 percent crude protein and 60 percent crude fat respectively. The further improvement in the protein quantity recovered was done by defatting operation and it yields increment in crude protein content by 47 percent, while depleting the crude fat content by 8.8 percent. The above nutrition profile of the black soldier fly larvae designated its ability, hence it should be considered as a potential and cheap alternative protein source. Consistently, Thomas *et al.* (2016) also stated that due to the greater amount of protein content in the body mass composition in prepupae stage BSFL can be considered as high-quality protein source for animal diet, though the substrate composition plays a vital role from the point of

view of the variation in EE and ash content level.

Eventually, the entire research community has been agreed to validate black soldier fly larvae as the most unique and profitable conversion and stabilization agent of the new era with minimal hindrance. The technique is rampant and further research in this domain may help the lower middle-income nations to get rid of the unsightly and unscientific dumping yards. Hence, composting utilizing BSFL should be recommended in India for sustainable waste management (Ali, 2002; Ahmed, 2002; Ghughuskar, 2012; Gayatri and Madhuri, 2013; Ritika *et al.*, 2015).

The primary objective of this research work was to emphasize the superiority of BSFL composting over the conventional, time consuming and primitive methods and also to substantiate the miscellaneous utilization of the larvae towards the frugal end application for societal good.

MATERIALS AND METHODS

The entire operation comprises three major operations such as compost recovery, bio-diesel preparation, and synthesis of by-products for the Nutri-culture industry. The details have been delineated below

Compost preparation

The trail was substantiated with the help of stabilizing and composting agents namely, BSFL. A maturation period of 14 days was allocated for individual trails and after 11 days addition of excessive moisture was restricted in order to drop down the moisture content. Once the treatment period was over the residue has been recovered from the bio-reactor and sent to the tipping floor for 48h to reduce the moisture level to 15-20 percent. Thereafter, the semi-fermented material was screened with the help of 20 mm trammel and plastics, inters, wooden materials etc. were separated as trammel reject. The permeate was further cured with the help of sunbath to reduce the stickiness for a period of 4 days and finally, fed to the 4 mm trammel. The final permeate passed through the 4 mm trammel was considered as compost.

Struvite extraction

Nutrients from the cattle farm waste streams were recovered by aerobic treatment mechanism, utilizing fluidized bed reactor with dairy and goat manures as feed influents. In order to optimize the recovery, an effective pH value was determined and upheld by using a buffer solution of $MgCl_2.6H_2O$ and NaOH.

Larval preparation

The larvae utilized for bioconversion and stabilization purpose was further separated into two fractions. One part of it was reverted back to the raring system for successive culture generation. Whereas, the other fraction was utilized for the derivation of value-added coproducts. In order to minimize the chances of possible contamination, the larval count was kept under the open sunlight in a closed container for 12h and then washed with alcohol. The live counts were further made operation ready by heating them at 105^0C for 2.5 h and the volatile water content in the body has been reduced by 20% of the entire body mass. Ultimately the oven-dried mass was used for bio-diesel extraction.

Segregation of body fluid

The body fluid of the larvae was extracted using compaction testing machine with a capacity of 3000 KN. The sample was kept between the pressure plate of the apparatus and the observations were made (table 1). The body fluid found to be separated easily and was collected at the extreme end by means of sample collection bottle.

Table 1: Compaction details

Parameters	*Unit*	*Value*
Modulus of Elasticity	N/mm^2	121.47
Strain at Max Stress	%	35.44
Displacement at Peak Load	mm	8.86
Max Load	kN	2429.9

Centrifuge separation

The crude body fluid of BSF larvae comprises colloidal particles and other impurities and thus, the same has been centrifuged. A rotation speed of 4000 RPM was maintained over a period of 20 min and the supernatant liquid was separated.

Organic extraction

The supernatant fraction was further purified by organic solvent extraction using n-Hexane as a solvent. The sample was placed inside the thimble the apparatus was operated for 1 h to ensure optimal recovery. Once the extraction was over both the liquids formed an immiscible layer and further separated by funnel separator. The Bio-oil found to have higher viscosity and density when compared to the solvent and came to the bottom of the funnel once shaken properly.

Homogenisation

The bottom sludge of the centrifuge tube was separated from the supernatant fluid using Whatman Filter Paper 40 micron pore size. The reject of the filter paper was further fused with the crushed body skeleton of the larvae and homogenized in the mixer grinder with the addition of a suitable quantity of water.

Cake preparation

Post-homogenisation the successful conversion of the semi slurry into the nutrient-rich cake was the other challenging issue. The consortium was transferred into the grinder was operated for a period of 5 min at different RPM and finally, the paste was transferred to the mould. The mould was further placed in the oven and dried at a uniform temperature of 105^0C for 5 h. The final yield of the process was utilized as fish meal.

Nutri-feeding

Utilization of the dead counts in an eco-friendly was undoubtedly one of the most delicate issues, it has been further valorized by adopting them as poultry meal. Primarily, the hens were fed on the house fly larvae and the same resulted as a nutritious substrate for accelerated body growth and hence the BSF larvae were fed to hens kept in captivity over a week's period of time and the factor of body growth was observed keenly.

RESULTS AND DISCUSSION

The present study aimed to emphasize the economic feasibility of BSF larvae in terms to be used as a potential agent for small-scale entrepreneurship. An elaborative study has been conducted to explore the possible end use of BSF larvae towards the proclamation of waste derived value-added co-products and the results have been summarized as follows.

Compost recovery

The mature larvae were allowed to feed on the organic fraction of the municipal solid waste and once the readily biodegradable matter got consumed the remaining fraction has been recovered from the reactor. Furthermore, the leftover fraction was cured over a period of 48h and the dried matter has been further sieved by using BIS standard 4 mm sieve.

Table 2: Grub compost analysis report

Parameters	*Units*	*Compost Test Values*	*FCO standards*
Particle size	%	96.28	Minimum 90 percent material should pass through 4.00 mm sieve
C:N ratio	-	11.81	20.0 Max
Bulk density	gm/cm^3	0.81	<1.0
Moisture	%	24.19	15.0-25.0
Total organic carbon	%	11.24	12.0 min
Total nitrogen as N	%	0.72	0.8 min
Total phosphate as P_2O_5	%	0.29	0.4 min
Total potash as K_2O	%	0.32	0.4 min
Pathogen	-	Not detected	Absent

The recovery fraction recorded as 62.10 percent by weight (Richard, 2015; Hang *et al.*, 2013, Gayatri and Madhuri, 2013; Ritika *et al.*, 2015). But, due to minimal maturation period, the quality of the compost found to be slightly inferior in some of the trails (Barry, 2014; Green and Popa, 2012). The different parameter values instructed by FCO (1985) have been analyzed and the report has been tabulated in Table 2.

As the recovered fraction was claimed from Indian municipal organic waste thus, a possibility of heavy metal contamination always sustains due to the absence of source segregation. Therefore, it was mandatory to undertake a complete analysis of the compost to ensure the nullification of possible contamination from persistent pollutants and the report has been tabulated in Table 3.

Table 3: Analysis report of persistent pollutants

Parameters	*Units*	*Compost Test Values*	*FCO standards*
Arsenic as AS_2O_3	mg/kg^{-1}	1.86	10.0 maximum
Cadmium as Cd	mg/kg^{-1}	1.03	5.00 maximum
Chromium as Cr	mg/kg^{-1}	23.59	50.00 maximum
Copper as Cu	mg/kg^{-1}	85.44	300.00 maximum
Mercury as Hg	mg/kg^{-1}	0.0059	0.15 maximum
Nickel Ni	mg/kg^{-1}	3.65	50.0 maximum
Lead as Pb	mg/kg^{-1}	3.19	100.0 maximum
Zinc as Zn	mg/kg^{-1}	354	1000.0 maximum

Quality enhancement

Starch-Iodine test has been performed on the final end products in the form of compost which yielded an appearance of brownish-green colour, signified semi-fermented nature of the material (Jimenez and Garcia, 1989; Hill *et al.*, 2013). The interpretation of Table 2 also explicitly reveals that the quality of the compost is moderately lower when compared to the prescribed limits mentioned in FCO (1985) and therefore three different quality improvement drives have been carried out and delineated as follows (Nyakeri *et al.*, 2017).

Phosphate rich organic manure (PROM) preparation

The deficiency in phosphate content of the matured compost has been nominalized by the addition of rock phosphate powder. The powder was mixed with the grub compost in 30:70 ratio and a bottled culture of phosphate solubilising bacteria namely, *Enterobacter cancerogenus* was introduced with the consortium for the fixation of phosphate into ordinary compost (Narayanan, 2012; OFNL, 2012). Post mixing resulted in a tremendous improvement in the compost quality (Sekhar and Aery, 2005; Aery *et al.*, 2006; Narayanan, 2006) and the same has been tabulated in Table 4.

Table 4: Detailed analysis report of PROM

Parameter	*Unit*	*Compost Test Values*	*FCO standards*
Particle size	%	98.35	Minimum 90 percent material should pass through 4.00 mm sieve
C:N ratio	-	12.24:1.26	<20.0:1.0
pH @25^{0}C	-	6.69	6.70 max
Bulk density	gm/cm^3	1.09	<1.60
Moisture	%	26.58	25.0 min
Total organic carbon	%	11.61	7.90 min
Total nitrogen as N	%	0.98	0.4 min
Total phosphate as P_2O_5	%	11.25	10.4 min
Pathogen	-	Not detected	Absent

Bio-enriched organic manure preparation

A liquid solution of Bio N, P, K was added to normal grub compost in order to prepare bio enriched manure. An optimum dosing of 2 percent by the weight of compost was practiced, attributed with the addition of a suitable quantity of water (Kanwal *et al.*, 2011; Yadav *et al.*, 2013; Louisa and Taguiling, 2013). The process yield manure was further tested to ensure the quality component and the values are portrayed in Table 5.

Struvite rich organic manure preparation

Magnesium ammonium phosphate recovered from the waste stream of cattle farm proved to be a vital source of nutrient for grub compost (Fattah *et al.*, 2008; Hutnik *et al.*, 2013; Altinbas *et al.*, 2002). The aerobic method of struvite crystallization by means of fluidized bed reactor proven to be an economically feasible source of nutrient for ordinary compost. At the same time, the deficiency in organic carbon has been compensated by the addition of coir pith powder and tobacco crush (Pan *et al.*, 2002). The factor of quality enhancement has been emphasized in Table 6.

Pathogen reduction

Multiple studies reported the larvae of *Hermetia illucens* to be an efficient pathogen reducer from different substrate consortium. Numerous researchers concluded that BSF larvae efficiently reduce *Escherichia coli* and *Salmonella* spp. from pig, swine and diary manure respectively (Erickson *et al.*, 2004; Zheng *et al.*, 2013; Liu *et al.*, 2008; Nordentoft *et al.*, 2017). Thus, this study has undertaken an approach to cross-examine the quality of manure yielded from BSFL composting in terms of pathogen removal. The compost specimen was analysed as per the standard procedure mentioned in FCO, (1985). The experiment resulted negative in terms of gas

Table 5: Detailed analysis report of bio-enriched organic manure

Parameters	*Units*	*Compost Test Values*	*FCO standards*
Particle size	%	96.74	Minimum 90 percent material should pass through 4.00 mm sieve
C:N ratio	-	12.50	18.0 max
pH @25^{0}C	-	7.71	6.50-8.00
Bulk density	gm/cm^3	0.81	<1.00
Moisture	%	35.15	30.0-40.0
Total organic carbon	%	16.38	14.0 min
Total nitrogen as N	%	1.31	0.8 min
Total phosphate as P_2O_5	%	0.79	0.5 min
NPK nutrients- Total of $N_2P_2O_5$ and K_2O	%	3.60	Not less than 3 percent
Total viable count (N, P, K, and Zn bacteria) or (N and K bacteria)	cfu/g^{-1}	35x10^{-4}	5.0x10^{-6} (Within the date of manufacture)

Table 6: Detailed analysis report of struvite riched organic manure

Parameters	*Units*	*Compost Test Values*	*FCO standards*
Particle size	%	93.23	Minimum 90 percent material should pass through 4.00 mm sieve
C:N ratio	-	12.38	20.0 max
pH @25^{0}C	-	7.09	6.50-7.50
Bulk density	gm/cm^3	0.82	<1.00
Moisture	%	26.97	25 min
Total organic carbon	%	17.59	14.0 min
Total nitrogen as N	%	1.42	0.5 min
Total phosphate as P_2O_5	%	0.88	0.5 min
Pathogens	cfu/g	Not Detected	Absent

production and established the potential of BSFL against effective pathogen removal.

Characteristics of the bio-fuel

The crude body fluid of *Hermetia illucens* larvae has enormous potential to yield supreme quality bio-fuel (Li *et al.*, 2011a; Surendra *et al.*, 2016; Ramos *et al.*, 2009; Meher *et al.*, 2006, Marchetti *et al.*, 2007; Nguyen *et al.*, 2018; Zheng *et al.*, 2012). The solvent extraction (APHA, 2005) yielded the purest form of bio-fuel and that was further analysed as per the standard procedure mentioned in IS 1448 [P: 2]: 2007. Table 7 portrays the analysis report and the ASTM standards prescribed for each parameter.

Table 7: Detailed analysis report of biodiesel extracted from BSFL

Parameters	Bio-diesel	Diesel	ASTM Standard	Unit
Density	0.864	0.838	0.84-0.9	Kg/L^{-1}
Viscosity	5.2	1.9-4.1	3.5-5.0	mm^2/s^{-1}
Flash point	155	60	Min 100	^0C
Solidifying point	-12	-50-10	-15	^0C
Total base value	3.41	10-15	2-5	mg KOH/ gm^{-1}
Heating value	41	40-45	-	Mj/Kg^{-1}

Characteristics of the fish meal cake

The homogenised body paste of BSFL was further heated at the required temperature and successfully converted into nutri-rich fodder for aquatic life (Katya *et al.*, 2017; Widjastuti *et al.*, 2014; Tschirner and Simon, 2015; Rumpold *et al.*, 2018). The cakes were further analysed and the report is listed in Table 8. A research conducted by Katya *et al.* (2017) has reported the utmost acceptability of BSF meal for juvenile barramundi (*Lates calcarifer)* reared in freshwater. Whereas, the present study has undertaken substrate compatibility check with Oscar carp which was found to be readily consumable attributed to major body growth (Fig. 1).

Figure 1: Oscar carp (aquarium grade) feeding on BSFL cake

Table 8: Nutritional characteristics of the fish meal cake

Parameters	Unit	Parameter values
Physical state	-	Solid
Loss on drying (LOD @ 105^0)	%	13.89
Crude protein	%	38.6
Crude fat	%	21.9

Acceleration of growth rate

The experiment explicitly revealed that the chicks fed on normal diet gained limited body growth. Whereas, the same chicks raised under captivity and supplied maggot meal showed higher growth rate factor (Tschirner and Simon, 2015; Liland *et al.*, 2017; Barragan-Fonseca *et al.*, 2017). Schiavone *et al.* (2017) have reported that partially defatted BSF larvae resulted in better digestibility when compared to highly defatted larvae. Though, the present study does not claim conduction of any defeating operation but, still the consumption of raw pre-pupae resulted in better body mass index. Fourteen chicks were raised under captivity from the day of emergence. The initial average weight of the chicks recorded as 40g. The anticipated body growth with ordinary meal observed to be varying with the ambient temperature. The optimal weight gain associated with a pertinent temperature of 23-28^0C found to be approx 160g over a period of 1 week in the case of ordinary fodder practice (Lara and Rostagno, 2013; Khawaja *et al.*, 2012). The influence of temperature varied inversely proportional to the body growth over 28^0C and impacts were severe over the range of 35^0C which drastically reduced the factor of mass gain up to 100g per week (Applegate and Lilburn, 1998). Although, a certain drop in temperature up to 15^0C observed as ineffective over the feeding rate and body mass index of the chicks (Persia *et al.*, 2003; Loyau *et al.*, 2016). Furthermore, the minimization of the initiation period of 40 days (associated with minimum body weight of 1.8 to 2 kg) as per the commercial practice of dispatching the full grown hens provoked the idea of

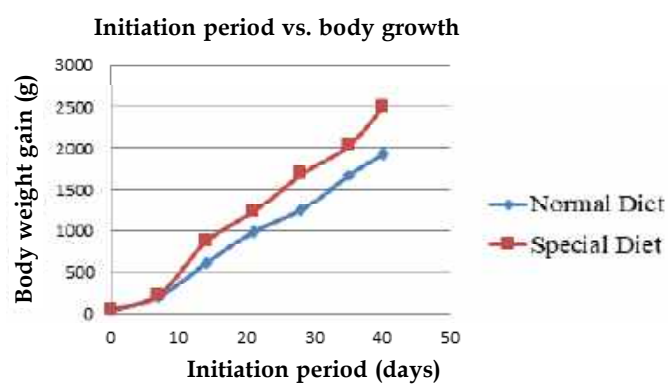


Figure 2: Graphical representation of the body growth of chick fed over different ration

utilizing BSF larvae as alternative food resource. Three trails were conducted using different replacement ratios between ordinary diet and maggot diet such as, 75: 25, 50:50, and 25:75. Amid 75 percent replacement yielded optimal achievement of body growth with minimal initiation period of 32 days and a magical growth rate of gain of 185g/ week was recorded. The variation in weight gain for the chicks fed on normal diet and special diet portrayed in Figure 2 whereas, Figure 3 tried to represent the correlation of the temperature with anticipated body growth.

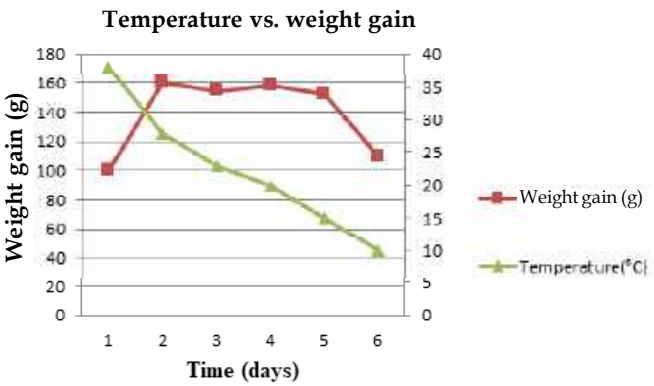


Figure 3: Graphical representation of the variation in body growth with temperature

The prime aspect of this study was to explore the techno-economic feasibility of BSF larvae towards societal welfare. The research work yielded three major end products in the form of compost, biodiesel, and animal fodder. Synthesized products were individually analysed to ensure the bio-safety and minimal environmental interference. The Analysis yielded positive output and each item found to be satisfactory as per the prescribed limits. Since the maturation period was minimized the compost quality in terms of the presence of vital soil conditioning nutrient recorded as slightly sub-standard. Furthermore, the same has been compensated by means of introducing inexpensive and readily available nutrients, either extracted from waste stream or natural resources. Whereas, other two by-products readily met the quality bench mark and showed significant potential to be utilized as promising alternatives. Numerous frugal end applications and applicability with minimal environmental intervention interpolate a thought of using this holistic creature as a proficient agent for bioconversion and stabilization which can be further remoulded into a profitable entrepreneurial element.

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Management of major insect pests of rice through organic manures with special emphasis on use of neem and karanj cakes

Rabindra Prasad

Department of Agricultural Entomology, Birsa Agricultural University, Kanke, Ranchi – 834 006 (Jharkhand)
Email : rabindraento@yahoo.co.in

ABSTRACT

The field experiment conducted at Birsa Agricultural University farm during 2010 and 2011 revealed that silver shoots (SS), caused by *Orseolia oryzae* (gall midge) was minimum (1.05, 1.26 and 1.21, 1.96%, respectively) in plots treated with neem and karnaje cake @ 2.5 t ha^{-1} against the highest with plants treated with the sole use of N @ 100 kg ha^{-1} through urea (20.15 and 24.45%) during 2010 and 2011, respectively. The neem cake application also recorded minimum incidence of *Scirpohaga incertulas* Wlk. (YSB) (1.92 and 2.65%DH) and was at par with karange cake (2.75 and 3.88% DH) but significantly lower than that of sole use of nitrogen @ 100 kg ha^{-1} through urea (28.34 and 31.75% DH) and full dose (100%) of recommended chemical fertilizers N,P,K @ 80:40:40 kg ha^{-1} (19.89 and 22.63% DH) during 2010 and 2011, respectively. However, full dose of RDF remained significantly superior over sole use of N @ 100 kg ha^{-1} (in the form of urea) in suppressing the incidence of gall midge and YSB during both the years of experimentation. Full dose of green manure (GM) applied through dhaincha, *Sesbania rostrata* L. (@ 10 t ha^{-1}) supplemented with 50 per cent RDF (N,P,K @ 40:20:10 kg ha^{-1}) was also found significantly effective than that of RDF (100%) of in reducing the pest incidence. Almost similar trends were found in case of incidence of *Nephotettix* spp. (GLH), *Cnaphalocrosis medinalis* Gn. (leaf folder) and rice hispa, *Dicladispa armigera* Ol. As regards the yield of paddy grains (41.37 and 43.80 q ha^{-1}) the maximum was recorded with 100 per cent RDF followed by GM @ 10 t ha^{-1} 50 per cent RDF (37.63 and 40.68 q ha^{-1}) during the respective years. Among the organic treatments, cake (NC) application proved little superior (33.00 and 36.88 q ha^{-1}) but almost at par with karanj cake (32.33 and 35.68 q ha^{-1}) in realizing yields of paddy grains during 2010 and 2011, respectively. It was noticed that fertilizer nutrients supplied through organic sources showed remarkable reduction in the prevailing major insect pest's infestation levels and in turn produced higher yields ie, 25.38 and 28.50 q ha^{-1} with FYM, 32.33 and 35.68 q ha^{-1} with KC and 32.00 and 36.88 q ha^{-1} with neem cake against the significantly lower yields of 20.14 and 24.68 q ha^{-1} with N through urea @ 100 kg ha^{-1} and lowest 9.75 and 14.68 q ha^{-1} from untreated control (No, Po, Ko) during 2010 and 2011, respectively. The findings suggests that balanced dose of N,P,K is effective both in terms of suppression of pest incidence and realization of higher grain yield. Moreover, neem cake and karange cake that contains considerable amount of azadirachtin and karanjin, respectively proved their superiorty and higher effectiveness in pest reduction and yield enhancement in the organic mode of rice production.

Key words: Rice, pests, balanced dose of N,P,K, organic manures, neem and karanj cakes, yield.

Rice is (*Orzya sativa* L.) is one of the most important crop in India including Jharkhad state. Among the various factors responsible for causing loss in grains yield, the insect pests occupy major place (Prasad and Prasad 2006, Prasad *et al*., 2018). Nonjudicious and imbalanced use of inorganic fertilizers (especially, N) is also responsible in enabling the crop to be highly prone to vagaries of insect pests and diseases. Judicious use of plants nutrients supplied to the plants especially through organic sources with special emphasis on neem or karanj cakes can be one of the effective tools for reducing the pest incidence and enhancing the rice grains yield (Prasad *et al.*, 2004, Prasad *et al*. 2018). However, information in this regard in India in general and Jharkhand in particular is almost lacking.

In order to fulfill these objectives, the present study on comparative efficacy of certain organic manures in reducing the incidence of insect pest species and their ultimate impact on yields of grains of rice in Jharkhand was undertaken.

MATERIALS AND METHODS

The experiment was conducted at the Rice Research Farms of Birsa Agricultural University, Ranchi during the *Kharif* season for the two consecutive years, 2010 and 2011 in RBD with rice, var. Pusa Basmati – 1 in plot size of 5 x 4 m^2 comprising of nine treatments and four replications. The treatments were : T_1- untreated control, no use of manures and fertilizers (i.e. No, Po, Ko); T_2 Use of 100 per cent RDF (N,P, K @ 80:40:40 kg ha^{-1} through chemical fertilizers) N in 3 splits; T_3 – use of farm yard manur FYM @ 10 t ha^{-1}; T_4 – use of green manure (GM) i.e. *Sesbania rostratra* @ 10 t ha^{-1}; T_5- GM (as T_4) + 50 per cent RDF through chemical fertilizers, N as top dressing in 3 splits ; T_6- vermicompst (VC) @ 2.5 t

ha^{-1}; T_7- Karanj cake (KC) @2.5 t ha^{-1}; T_8- Neem cake (NC) @ 2.5 t ha^{-1} and T_9-N @ 100 kg ha^{-1} through urea (i.e. N 100 Kg ha^{-1}, Po, Ko) applied in 3 splits. Karanj and neem cake, green manure and vermi compost and FYM were applied in the soil at the time of field preparation and pudling just two week before transplanting (WBT) of rice seedlings. The field was again puddled a day before transplanting and prepared for rice seedlings to be put into the soil conveniently. The recommended dose of chemical fertilizers, RDF (N,P,K 280:40:40 kg ha^{-1}) – T_2 as well as T_9- sole use of nitrogen, N @ 100 kg ha^{-1} (through urea in 3 splits) in addition to the untreated check ($N_oP_oK_o$) were kept as two separate treatments for the relative comparison. Transplanting of rice seedlings was made on 20th and 26th July, 2010 and 2011, respectively. No pesticide treatment was applied. Observations on the incidence of major insect pests were registered periodically for comparison. Yields of rice grains were recorded at harvest. Proper statistical analyses of the experimental data after suitable transformation ware done to arrive at proper conclusions.

RESULTS AND DISCUSSION

Results presented in the table showed relatively lesser incidence of major insect pests *viz.* gall midge (*Oraseolia oryzae* Wood Mason), yellow stem borer YSB (*Scirpophaga incertulas* Wlk.) rice hispa (*Dicladispa armigera* Oliv.) and green leaf hoppers (*Nephotettx nigropictus* Stal. and *N. virescens* Distants) during 2010 compared to 2011. However, incidence of leaf folder (*Cnaphalocrosis medinalis* Guenee) remained some what more during 2010 as compared to that of 2011. It was interesting to note that the rice plants receiving no plant nutrients (No. Po Ko) from out side harboured substantially lesser incidence of almost all the major insect pests, probably because of poor vigour and health of the plants. Almost similar results were reported by Prasad *et al*., (2004) in the direct seeded rice in the upland ecologies of Jharkhand.

It is worth while to note that rice plants receiving neem cake @ 2.5 t ha^{-1} as organic manure harboured the lowest incidence of almost all the major insect pests viz., gall midge, silver shoot (SS) 1.05 and 1.26 per cent; yellow stem borer dead heart 1.92 and 2.65 per cent and white ear head (WE) 0.73 and 1.52 per cent; leaf folder damaged leaves 10 hills^{-1} 11.0 and 9.63 folder (LFDL); rice hispa damaged leaves (HDL) per 10 hills^{-1} (3.50 and 4.79) and green leaf hopper, GLH 10 hills^{-1} 5.50 and 6.50, during 2010 and 2011, respectively. Karanj cake (2.5 t ha^{-1}) treated plants remained at par in this regard. Vermi-compost, applied as organic manure @2.5 t ha^{-1} occupied next position to neem and karanj cake in terms of lowering down the incidence of major insect pests of rice followed by green manure, *dhaincha* (*Sesbania rostrata* L.) applied @ 10 t ha^{-1}. It was noted that rice plants receiving recommended dose of chemical fertilizers, N, P, K @ 80,40,40 kg ha^{-1} recorded significantly higher incidence of all the major rice insect pests compared to other treatments excepting those receiving nitrogen alone (@ N100 kg ha^{-1} in form of urea). As such, rice plants treated with N alone (@ 100 kg per hectare, through urea), registered 20.15 and 24.45 per cent SS incidence of 28.34 and 31.75 per cent DH; 19.64 and 21.38 per cent WE, 53.48 and 56.566 no. of HDL 10 plants^{-1} (hills); 96.33 and 89.96 no. of LFDL 10 hills^{-1} and 119.60 and 130.60 no. of GLH 10 hills^{-1} of gall midge, yellow stem borer, rice hispa, leaf folder and green leaf hopper during 2010 and 2011, respectively probably because the excessive use of nitrogen (N @ 100 kg ha^{-1} through urea) made the plant more succulent, luxuriant and succumbed to attack of the pest species.

The rice plants receiving balanced dose of N,P,K @ 80,40,40 kg ha^{-1} even through chemical fertilizers recorded significantly lower incidence of the respective pest species to the level of 9.94 and 16.66 per cent SS; 19.89 and 22.63 per cent DH, 12.25 and 14.66 per cent WE, 28.75 and 33.60 HDL 10 hills^{-1} (plants); 76.75 and 69.55 LFDL 10 hills^{-1} as well as 86.5 and 90.38 no. of GLH 10 hills^{-1} during, 2010 and 2011 in respective orders. Prasad *et al*. (2004) also reported that the balanced dose of N,P,K @ 60, 60 and 60 kg ha^{-1} through chemical fertilizers induced relatively higher level of resistance in rice plants against stem borer, GLH and ear bugs in case of direct sown rice (var. Birsa Dhan 101) in upland conditions. They also found that the higher dose of N applied alone (N60 P60 Ko kg ha^{-1} ie. without K) in upland rice resulted in higher incidence of the prevailing major insect pest species. These findings as well as the results obtained by Vaithilingam *et al*., (1979), Sudhakar *et. al.,* (1993) and Pathak and Ram (1999) are almost in consonance with that of the present results.

It is interesting to note that the rice plants getting N,P,K through organic sources (FYM, green manure, vermi compost, neem cake or karanj cake) recorded significantly lesser level of incidence of almost all the major insect pests during both of the experimental years. It is also worth noting that rice plants receiving NPK from the green manure (@ 10 t ha^{-1}) coupled with half doze of RDF (ie. N:P:K @ 40:20:20 kg ha^{-1}) also showed significantly lesser attack of prevailing insect pest species, resulting thereby higher grains yield of 37.63 and 40.68 q ha^{-1} during, 2010 and 2011 respectively. The present finding suggests that combination of balanced doses of organic manures (preferably neem or karanj cakes) and the inorganic fertilizers could play an important role in minimizing the incidence of insect pests and maximizing the yield of grains of rice.

The rice grain yield data obtained under different treatments however, reveal significantly lowest yields (20.14 and 24.68 q ha^{-1}) from plots receiving N alone through urea (@ 100 kg ha^{-1}) as compared to that receiving full recommended dose of fertilizer i.e. N,P,K @ 80:40:40 kg ha^{-1} (41.37 and 43.80 q ha^{-1}). Tondon (1973) and Prasad *et al.*, (2007) and Prasad *et al.,* (2018) reported more or less similar findings. Green manure (GM) @ 10 t ha^{-1} supplemented with 50 per cent of recommended dose of fertiliser, the N,P,K @ 40:20:20 kg ha^{-1} recorded the next best grain yield than in the plant getting N,P,K through full dose of RDF.

Table 1. Effect of organic manuring on incidence of rice insect pests and its yield during 2010 and 2011

Treatment			Insect pest incidence						Yield (q ha^{-1})
			Gall-midge	Stem borer		Leaf folder	Hispa No. HDL	GLH no. 10	
Tr. No.	Particulars	Year of experimentation	SS(%) at 50 DAT	DH (%) at 50 DAT	WE (%) at preharvest	LFDL 10 hills^{-1} at 70 DAT	10 hills^{-1} at 30 DAT	hills^{-1} at 55 DAT	
T_1	Untreated control ($N_0P_0K_0$)	2010	1.89 (7.76)*	5.48 (13.49)*	0.29 (3.12)*	6.25 (2.59)**	2.50 (1.73)**	39.25 (6.30)**	9.75
		2011	3.22 (10.31)*	7..36 (15.72)*	2.68 (9.38)*	7.68 (2.86)**	3.80 (2.07)**	44.68 (6.73)**	14.68
T_2	RDF (NPK : 80:40:40 (kg ha^{-1})	2010	9.94 (18.40)	19.89 (26.45)	12.25 (20.54)	76.75 (8.79)	28.75 (5.41)	86.50 (9.33)	41.37
		2011	16.66 (24.08)	22.63 (28.39)	14.66 (22.51)	69.55 (8.37)	33.60 (5.84)	90.38 (9.54)	43.80
T_3	FYM @ 10 t ha^{-1}	2010	5.76 (13.85)	13.74 (21.73)	5.48 (13.47)	38.50 (6.24)	20.75 (4.16)	45.75 (6.80)	25.38
		2011	7.85 (16.22)	14.24 (22.15)	8.88 (17.31)	32.68 (5.76)	22.68 (4.81)	52.66 (7.29)	28.50
T_4	Green manure*** (Dhaincha) GM @ 10 t ha^{-1}	2010	5.81 (13.96)	5.95 (14.08)	4.22 (11.84)	36.75 (6.10)	21.00 (4.64)	43.00 (6.59)	25.44
		2011	8.96 (17.39)	7.68 (16.06)	7.44 (15.79)	28.58 (5.39)	24.65 (25.15)	47.31 (6.92)	29.60
T_5	GM (as T4) + ½ RDF; N as top dressing in 2 splits	2010	4.42 (12.12)	15.51 (23.19)	6.03 (14.18)	57.00 (7.58)	32.75 (5.77)	62.25 (7.92)	37.63
		2011	5.85 (13.96)	17.53 (24.74)	9.63 (18.06)	49.46 (7.07)	37.58 (38.09)	67.38 (8.24)	40.68
T_6	Vermi compost (VC) @2.5 t ha^{-1}	2010	4.33 (11.98)	7.85 (16.24)	2.82 (9.65)	27.50 (2.59)	19.75 (4.50)	26.50 (5.19)	26.09
		2011	5.38 (13.37)	9.72 (18.16)	4.77 (12.53)	26.55 (5.21)	21.38 (4.78)	28.30 (5.37)	28.58
T_7	Karanj cake (KC) @ 2.5 t ha^{-1}	2010	1.21 (6.32)	2.75 (9.47)	1.48 (6.82)	13.00 (3.67)	9.25 (3.12)	3.50 (2.00)	32.33
		2011	1.96 (7.94)	3.88 (11.26)	2.16 (8.36)	12.13 (3.55)	12.22 (3.57)	4.60 (2.26)	35.68
T_8	Neem cake (NC) @ 2.5 t ha^{-1}	2010	1.05 (6.32)	1.92 (7.94)	0.73 (4.92)	11.00 (3.92)	3.50 (2.00)	5.50 (2.45)	33.00
		2011	1.26 (6.35)	2.65 (9.29)	1.52 (7.06)	9.63 (3.18)	4.79 (2.30)	6.50 (2.65)	36.88
T_9	N alone @ 100 kg ha^{-1} (through urea) applied in 3 splits	2010	20.15 (26.92)	28.34 (32.18)	19.46 (26.51)	96.33 (9.84)	53.48 (7.35)	119.60 (10.96)	20.14
		2011	24.45 (29.62)	31.75 (34.29)	21.38 (27.51)	89.96 (9.51)	56.56 (7.55)	130.60 (11.45)	24.68
CD (P = 0.05)		2010	(0.57)	(0.89)	(0.57)	(0.76)	(0.59)	(0.85)	(3.72)
		2011	(0.69)	(0.88)	(0.62)	(0.79)	(0.62)	(0.91)	4.12
C.V. (%)		2010	(12.44)	(10.98)	(13.69)	(9.76)	(10.66)	(12.63)	(13.22)
		2011	(13.88)	(10.46)	(12.72)	(9.88)	(11.76)	(14.22)	10.82

* Figures in parentheses are angular transformed values; ** Figures in parentheses are square root ("n+0.05) transformed values; *** Green manure with dhaincha (*Sesbania rostrata* L). SS-Silvers shoot ; DH – dead heart; WE – white ear head; LFDL - Leaf folder's damaged leaves; HDL – Hispa damaged leaves; GLH- Green leaf hopper.

Ghose and Saikia (1999) also reported that the balanced dose of NPK in conjunction with organic manure (i.e. FYM) resulted in higher yield of rice as compared with that without application of FYM. The organic sources of plants nutrients proved highly effective in reducing the incidence levels of major insect pests prevailing in the area and in turn helpful in producing higher grains yields ranging from 25.38 and 28.50 q ha^{-1} with FYM @ 10 t ha^{-1}, 33.00 and 36.88 q ha^{-1} with neem cake @ 2.5 t ha^{-1} and 32.68 and 35.68 q ha^{-1} with karanj cake @ 2.5 t ha^{-1} during 2010 and 2011, respectively as against untreated (control) and those having sole use of N (@ 100 kg ha^{-1}). Findings of Prasad *et al.,* (2007) and Prasad *et al.,* (2018) are more or less in agreement with the present results.

Among the organic treatments neem and karanj cake proved to be most effective in terms of pest suppression and yield enhancement during both of the years of experimentation. Both oil cakes (NC and KC) applied @ 2.5 t ha^{-1} in the soil just two week before final field preparation for transplanting of rice seedlings proved more effective and instrumental in effective management of major prevailing insect pest species. These treatments although recorded comparatively lower grain yield than with full dose of RDF (41.37 and 43.80 q ha^{-1} during 2010 and 2011) the reduction in the level of insect pests infestation in the organically manured crop compared to that of in-organic mode of production system and the higher price of organically produced farm produce in general with particular and aromatic rice in the domestic as well as foreign markets is quite encouraging. It is already known that azadirachtin in neem cake and karanajin in karnaj cake have significant insecticidal value and considerable proportion of plants nutrients as well. Neem and karanj cake contain NPK to the tune of 5.4, 1.1 and 1.5 and 4.0, 0.9 and 1.3 per cent of N, P and K, respectively. (Prasad *et al*., 2007 and Prasd *et al.* 2018). Therefore, both the oil-cakes (as organic manures) can be used as production as well as protection inputs for sustainable production of rice just by altering their doses as per requirements of the soil in the region and locality.

CONCLUSION

It is concluded that neem/karanj cake, applied @ 2.5 t ha^{-1} are effective in reducing the incidence of major rice insect pests to its lowest level and subsequently resulting in realizing substantial increase in the grain yield.

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Effect of different dates of rice transplanting on incidence and abundance of major insect pests and the crop yield

Rabindra Prasad

Department of Entomology, Birsa Agricultural University, Kanke, Ranchi-834006 (Jharkhand)
Email: rabindraento@yahoo.co.in

ABSTRACT

The field experiment conducted with seedlings of rice (var. IR-64) transplanted on four different dates at two weeks intervals starting from 1st of July till 14th August during wet season of 2015 and 2016 in 10 replications in RBD revealed that earlier were the date of transplanting, significantly lesser were the intensities of attack of yellow stem borer, rice hispa, leaf folder, case worm and green leaf hopper (GLH) and vice versa during 2015 and 2016. However, in case of ear bug, earlier was the date of planting, higher was the attack of earbug and vice-versa. Early transplanted crop realized higher grain yield compared to those planted latter. The crop transplanted early (1st July), normal date of planting (15th July), delayed planting (30th July) and very delayed planting crop (14th August), yielded 44.46, 39.85, 34.64 and 29.20 q ha^{-1} during, 2015 and 46.90, 40.90, 35.75 and 30.80 q ha^{-1} during 2016, respectively.

Key words: Rice, insect pests, dates of planting, shifting, yield

Rice (*Oryza sativa* L.), the most important food crop of Jharkhand, is grown in 18 lakh hectares of area during *Kharif* season. It is damaged by more than half a dozen insect pest species causing loss in grain's yield from 25 to 35 per cent in general in the state (Prasad and Prasad, 2006). Keeping in view the scope of growing organic rice in the state, non-chemical methods of pest management is quite imperative. Proper shifting and adjustment in dates of transplanting could play an important role in this regards. As information on this aspect is almost lacking, the present field study was undertaken.

MATERIALS AND METHODS

The experiment was conducted at the Rice Research Farm of Birsa Agricultural University, Kanke, Ranchi with rice (var. IR-64) with four dates of sowing and transplanting and 10 replications in RBD in plot size of 15x2.50 square meter during wet season of 2015 and 2016. The four different dates of transplanting were kept at an intervals of two weeks as –D_1-early planting (1st July), D_2-normal or timely planting (15th July), D_3 – delayed planting (30th July) and D_4 – very delayed planting (14th August). Three weeks old seedlings were used for transplanting. The crop was raised under normal agronomical package of practices without applying any control operation against insect-pests. Blanket application of a combination product of fungicide, Saaf (carbendazim + mancozeb) @ 3 g l^{-1} water was done thrice at 30, 80 and 100 days after transplanting (DAT) to protect the crop from foliar diseases like leaf blast, neck blast, brown spot and false smut.

Observations on the incidence and abundance of prevailing insect-pests in crops raised from each dates of transplanting were regularly recorded. Data on total number of tillers (TT) and dead hearts (DH) at 50 DAT (days after transplanting), total of number tillers and white ears (WE) from ten randomly selected plants at maturity stage of the crop were recorded for calculating the percentage of DH and WE. Total number leaves and number of damaged leaves due to rice hispa (LDH), case worm (CW) and leaf folder (LF) at 30, 40 and 80 DAT were recorded to calculate percentage leaf damage caused by the respective leaf feeding insect pest species. Observations on the incidence of green leaf hopper (GLH) and ear bug (EB) were recorded through net sweep method on 10 plant basis at 90 DAT and milking stage of the crop, respectively. Yield of grains were recorded after harvesting of crop at attainment of crop maturity. The experimental data after transformation were subjected to the statistical analysis for proper interpretation, documentation and deriving the conclusion.

RESULTS AND DISCUSSION

The data table 1 revealed that the crop during 2015 recorded relatively lower incidence of major insect pests than in 2016. The crop transplanted early (1st July, 2016) registered minimum incidence of yellow stem borer *(S. excorptalis)* dead heart (4.8%) and white ear (4.2%) as compared to those transplanted two weeks later (15 July, 2016) on the normal date of transplanting (7.85% and 6.68%, respectively). Delayed transplanting (30th July) during 2016 and very delayed transplanting (14th August) during 2015 recorded

significantly higher 11.46, 9.38 per cent and 14.58 and 13.46 per cent yellow stem borer dead hearts and white ears, respectively (Table 1). Although, the extent of incidence of DH and WE, caused by yellow stem borer during, 2016 remained relatively higher as compared to 2015, the impact of different planting dates on the pest incidence observed during, 2016 followed almost similar trends to that of 2015 remaining in the order of: early planting < normal planting <delayed <planting <very delayed planting (1st July, 15th July, 30th July and 14th August), registering 4.80, 7.85, 11.46 and 14.58 per cent DH and 4.22, 6.68, 9.38 and 13.46 per cent WE in the present studies. Prasad (2015) and Prasad *et al.* (2017) also expressed similar views.

Incidence of hispa (Dicladispa armigera. Ol.) was significantly impacted with the dates of planting. Earlier was the dates of planting of rice, lesser was the incidence of rice hispa. Accordingly, in the case of earliest planting the lowest leaf damaged due to hispa (LDH) to the tune of 3.56 and 4.77 per cent while the highest leaf damage of 12.60 and 14.66 per cent was registered in case of the very delayed planting (14th August) of rice during 2015 and 2016, respectively.

Significant effect of dates of planning was registered on the incidence of green leaf hopper, (*Nephotetix nigropictus* Stal.) (GLH) during wet season of 2015 and 2016, respectively. The lowest number of GLH 10 hills^{-1} (plants) of 6.60 and 8.40 was recorded during, 2015 and 2016, respectively in case of the earliest planting done on 1st July as against the highest incidence of 19.38 and 23.86 GLH 10 hills^{-1} in the respective years.

The occurrence of leaf folder, (*Caphalocrosis medinalis* Guenee) showing the lowest leaf damage of 4.72 and 5.85 per cent was recorded in the earliest transplanting done at on 1st July during both the year of experimentation. Whereas, the highest percent leaf damage (18.60 and 20.68%) due to leaf folder was found with the very delayed planting done on 14th August 2015 and 2016. An intermediate level of leaf damage to the tune of 8.73 and 9.78 per cent in case of normal time of planting (15th July) and 13.84 and 15.25 per cent leaf damage in case of delayed planting (30th July) of the crop was registered during, 2015 and 2016, respectively.

The results obtained in terms of leaf damage caused by larvae of case worm, (*Nymphula depunctalis* Guenee) (LDW) recorded in case of early, timely (normal), delayed and very delayed planting conditions differed significantly. The percentage of damaged leaves due to these insect pests was

Table 1: Effect of different dates of rice transplanting on the incidence and abundance of major insect pests and rice yield during 2015 and 2016

Treatment(s) Date of transplanting	Year of experimentation	Incidence of major rice insect pests							
		YSB DH(%) at 50 DAT	WE at maturity stage of crop (%)	LDH at 30 DAT (%)	LDCW at 40 DAT (%)	LDLF at 80 DAT (%)	GLH 10 hills^{-1} at 90 DAT	EB 10 hills^{-1} at milking stage of crop	Grain yield (q ha^{-1})
D1- 1st July	2015	3.60	3.75	3.56	2.96	4.72	6.60	22.72	44.46
(Early planting)		(13.72)*	(11.09)*	(10.80) *	(9.84) *	(12.54) *	(2.66) **	(4.82) **	
	2016	4.80	4.22	4.77	5.60	5.85	8.40	24.60	46.90
		(12.66)*	(11.85) *	(12.58) *	(13.72) *	(13.96) *	(2.98)**	(5.01)**	
D2- 15th July	2015	6.40	5.87	6.75	6.40	8.73	10.48	16.80	39.85
(Normal planting)		(14.67)	(13.95)	(15.10)	(14.66)	(17.18)	(3.31)	(4.16)	
	2016	7.85	6.68	7.93	8.87	9.78	12.60	18.50	40.90
		(16.28)	(14.89)	(16.35)	(17.28)	(18.18)	(3.62)	(4.85)	
D3- 30th July	2015	10.30	8.97	8.78	12.46	13.84	14.76	13.70	34.64
(Delayed planting)		(18.74)	(17.38)	(17.17)	(20.65)	(21.82)	(3.91)	(3.77)	
	2016	11.48	9.38	9.89	14.88	15.25	17.68	14.78	35.75
		(19.78)	(17.76)	(18.26)	(22.66)	(22.98)	(4.12)	(3.91)	
D4 - 14th August	2015	13.88	11.86	12.60	21.78	18.60	19.38	10.70	29.20
(Very delayed planting)		(21.83)	(20.09)	(20.79)	(27.78)	(25.56)	(4.46)	(3.35)	
	2016	14.58	13.46	14.66	26.82	20.68	23.86	9.69	30.80
		(22.42)	(21.49)	(22.49)	(31.20)	(26.99)	(4.93)	(3.19/)	
CD (P=0.05)	2015	(0.93)	(2.49)	(2.04)	(4.38)	(3.82)	(0.54)	(0.39)	4.23
	2016	(2.66)	(2.97)	(1.66)	(3.34)	(3.79)	(0.73)	(0.45)	4.65

Figures under the parentheses marked with * and ** are angular transformed values and $\sqrt{n+0.5}$ (square root transformed values, respectively, DH- Dead heart caused by yellow steam borer (YSB), WE- white ear due to YSB; LDH- Leaf damage due to hispa; LDCW – Leaf damage caused by case worm; LDLF- Leaf damage caused by leaf folder; GLH- green leaf hopper.

2.96, 6.40, 12.46 and 21.78 per cent in 2015 and 5.60, 8.76, 14.88 and 26.82 per cent during 2016, respectively.

Significant impact of dates of planting on the occurrance of ear bug, (*Leptocorisa acuta Thunberg)* was registered during both the years. Accordingly, the highest of 22.72 and 24.6 ear bug (EB) 10 hills^{-1} (plants) were recorded in early planted crop (1st July) of 2015 and 2016, respectively as against the lowest of 10.70 and 9.69 EB 10 hills^{-1} in the very delayed (14th August) transplanting during 2015 and 2016, respectively.

The foregoing results reflected that the incidence of YSB, hispa, leaf folder, case worm and GLH remained in the descending order of early planting (1st July) <normal planting (15th July)< delayed planting (30th July)< very delayed planting (14th August) in terms of degree of the incidence of these insect pest species. However, the impact of dates of planting on the degree of incidence of ear bug remained in the reverse order to that of other insect pests infesting rice.

The yield data obtained from the crop transplanted on four different dates of planting differed significantly. The grains yield obtained from varying dates of planting were found to be in ascending order of early planting (1st July) > normal planting (15th July) > delayed planting (30th July) > very delayed planting (14th August) being 44.46, 46.90; 39.85, 40.90; 34.64, 35.75 and 29.23, 30.80 q ha^{-1} during 2015 and 2016, respectively. Early planted (1st July) crop gave significantly highest yield of 44.46 and 46.90 q ha^{-1} as against the lowest of 29.20 and 30.80 q ha^{-1} from the very delayed planting (14th August) during 2015 and 2016, respectively. The experimental findings of Prasad and Prasad, (2015) and that of Anonmymous (2016) are almost in the conformity with the results of the present study in terms of incidence of major insect pests and rice yield.

CONCLUSION

It is concluded that early or timely transplanting of rice seedling that minimizes the incidence of major insect pests prevalant in the area *viz.,* YSB, hispa, leaf folder, case worm and GLH etc. except gundhi bug and provide maximum crop production may be preferred by the farming communities in general and the resource poor farmers in particular for sustainable cultivation of rice in Jharkhand.

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Status of coconut insect pests in managed and unmanaged garden

S.M. Wankhede[1], V.V. Shinde[2] and S.L. Ghavale[3]

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
[1]Jr. Entomologist, Regional Coconut Research Station, Bhatye, Dist. Ratnagiri.
[2]Agronomist, Regional Coconut Research Station, Bhatye, Dist. Ratnagiri.
[3]Research Officer, Regional Coconut Research Station, Bhatye, Dist. Ratnagiri.
[4]Project Coordinator, ICAR-AICRP (Palms), ICAR-CPCRI, Kasaragod, Kerala
[5]Director of Research, Dr. BSKKV, Dapoli.

ABSTRACT

In a fixed plot survey carried out at bimonthly interval from April 2018 to February 2019 at Regional Research Station, Bhatye, Ratnagiri, the incidence and intensity of major pests on coconut was recorded. Two plots were selected for observations, one was well managed (good sanitation, use of fertilizer etc.) and another unmanaged (with poor sanitation and no fertilizers). The infestation of major pest's in managed plot was minimum for rhinoceros beetle (25.73%), eriophyid mite (41.74%) and mite grade index 0.71. Whereas, maximum infestation of rhinoceros beetle, red palm weevil and eriophyide mite of 30.31, 0.37, 71.70 per cent, respectively and mite grade index (1.57) was recorded in unmanaged plot. The average data of two fixed plots revealed that the incidence of rhinoceros beetle was in the range of 7.64 to 48.00 per cent, the maximum was in and minimum was February 2019. The infestation of red palm weevil and black headed caterpillar were 1.11 and 0.64 per cent in February 2019. The infestation of eriophyid mite was in the range of 41.65 to 64.98 per cent, the maximum noticed in the month of April, 2018 and the least in October, 2018. The mite damage grade index 1.39 (moderate) was recorded in February 19. However, lowest MGI (0.67) was observed in October, 2018.

Key wards: Coconut, rhinoceros beetle, red palm weevil, eriophyid mite, black headed caterpillar

Coconut (*Cocos nucifera* Linn) is the most important versatile tree crop cultivated in the tropics providing livelihood and employment securities to the rural agrarian mass in the region. It is an important plantation crop which is being mainly cultivated by farmers of southern state and states like Goa, Maharashtra, Gujarat, West Bengal, Odisha, Asam, Andaman and Nicobar Islands. Lakshdweep and Minicoy islands are also having considerable area under coconut. Coconut is essentially a crop of marginal and small farmers in India. The low size of the land holding by coconut growers is a serious challenge to both profitability and sustainability of the crop. The crop is attacked by a variety of insect pests. The majority attack the leaves, while others attack the trunks (stems), inflorescences, young nuts and the roots. Some are major pests, which cause considerable damage and yield loss, while some are less damaging. Most of these insects remain as minor pests, either because the environmental conditions are not favorable for their rapid multiplication or because they are adequately controlled by natural enemies. The coconut eriophyid mite *Aceria guerreronis* Keifer was first reported as a serious pest in Kerala during 1997-98. Subsequently, the devastating effects of these mites were noticed in Coimbatore and Theni districts of Tamil Nadu and Bangalore in Karnataka (Sathiamma et al., 1998 and Mohanasundaram et al., 1999). Since extensive damage has been caused to coconut palms in the southern states of India (Nair et al., 2000), Mathen, 1962 reported that the red palm weevil, *Rhynchophorus ferrugineus* Oliv, (RPW) (curculionidae, Coleoptera) is a serious pest attacking different species of palm trees (e.g. date palm, Coconut palm, and royal palm). Chalapathi Rao et al., 2018 found that per cent of leaf damage due to rhinoceros beetles ranged from 12.5 to 35.5 and spindle damage ranged from 33.3 per cent to 45 per cent. Considering the economic importance of pests and yield loss that they cause, the present investigation on assessment of major pests in fixed plot survey was carried out.

MATERIALS AND METHODS

The field survey was carried out as Entomological Experiment under 'Pest surveillance of coconut at (AICRP (Palms), RCRS, Bhatye Dist. Ratnagiri (M.S.) during 2018-19. Two different plots at different locations with well managed (good sanitation and use of fertilizers etc) and unmanaged (poor sanitation, no use of fertilizers) were selected. One plot received all the need based management

treatments for major pests while the other plot was with kept management (natural control). Six observations per year at 2 months interval *viz.*, April, June, Aug, Oct, Dec and February were recorded. Major pests like rhinoceros beetle, red palm weevil, black headed caterpillar and eriophyid mite were recorded by using following methods 1. Rhinoceros beetle: Per cent of palm infested (out of 100 palms garden^{-1})- The top 10 fronds in each palm with single/ multiple cuts was observed. Per cent leaf damage (25 palms at random garden^{-1}) (infested/total number of leaves x 100), 2. Eriophyid mite: Per cent nut infested (mite infested nuts total nuts^{-1}) (25 palms at random garden^{-1}). Damage grade (mature bunch) (intensity 0-4 scale) (out of 100 nuts garden^{-1}) using CPCRI scales were followed. 3. Red palm weevil: Per cent of palms infested (out of total palm (>100) garden^{-1} with typical symptom of RPW. 4. Black headed caterpillar: Per cent leaf damage (infested leaf total leaf^{-1}) (50 palms garden^{-1}) were used.

CPCRI Scale			
Per cent damage on nut surface	**Scale**	**Grade Index**	**Intensity**
Nuts with no mite damage	0	0	Nil
< 25%	1	0.1-1.0	Mild
25-50%	2	1.1-2.0	Moderate
50-75%	3	2.1-3.0	High
>75%	4	3.1-4.0	Severe

RESULTS AND DISCUSSION

The data depicted in table 1 indicated that minimum per cent incidence of major pest status viz., rhinoceros beetle (25.73%), eriophyid mite (41.74%) and mite grade index (0.71) was noticed in managed garden. Whereas, maximum infestation of 30.31, 0.37, 71.70 per cent, respectively of rhinoceros beetle, red palm weevil and eriophyid mite and mite grade index of 1.57 (moderate) in unmanaged garden was recorded (Table 2).

The average data of two fixed plots are presented in Table 3. The data revealed that the incidence of rhinoceros beetle was in the range of 20.00 to 48.00 per cent. The maximum infestation was observed in the month of June 2018 (48.00%) while the minimum incidence was observed in December, 2018 (20.00%). Chalapathi Rao et al., 2018 found that the per cent of leaf damage due to rhinoceros beetles ranged from 12.5 to 35.5 and spindle damage ranged from 33.3 per cent to 45 per cent.. The infestation of red palm weevil and black headed caterpillar were not recorded during these surveys. The infestation of eriophyid mite was in the range of 41.65 to 64.98 per cent. Similar results on eriophyid mite infestation was also noticed by Alagar et al., 2019. Maximum infestation (64.98%) was noticed in the month of April, 2018 and least incidence was observed in October, 2018 (41.65%). The mite damage grade index 1.37 (Moderate) was recorded in April, 18. However, lowest MGI (0.67) was observed in October, 2018. Present data correlated with Levin and Mammooty, 2003 indicated that most of the infested nuts were in the damage category of two and three and the percentage of mite damage was 25.4 per cent. Desai et at., 2009 indicated that the eriophyid mite infestation was higher in Thane district followed by Sindhudurg district. Gurav et at., 2018 observed that pest incidence and pest intensity trend

Table 1: Extent of infestation by different pests in fixed plot (managed) during survey in Maharashtra (Plot No. 1)

Month	Rhinoceros beetle			Red palm weevil incidence (%)	Black headed caterpillar incidence (%)	Eriophyid mite	
	Incidence (%)	Leaf damage	Spindle damage			Infestation (%)	MGI
April,18	24.00	2.80	0.00	0.00	0.00	56.58	1.22
June,18	52.00	7.03	0.00	0.00	0.00	53.11	0.92
Aug.,18	36.00	4.00	8.00	0.00	0.00	37.82	0.50
Oct., 18	28.00	3.60	0.00	0.00	0.00	35.82	0.61
Dec., 18	08.00	1.60	0.00	0.00	0.00	30.88	0.54
Feb., 19	06.41	2.00	1.28	0.00	0.00	36.25	0.51
Mean ± SE	**25.73 ± 7.72**	**3.50 ± 0.87**	**1.54 ± 1.43**	**0.00 ±0.00**	**0.00 ±0.00**	**41.74 ± 4.68**	**0.71 ±0.13**

Table 2: Extent of infestation by different pests in fixed plot (unmanaged) during survey in Maharashtra (Plot No. 2)

Month	Rhinoceros beetle			Red palm weevil incidence (%)	Black headed caterpillar incidence (%)	Eriophyid mite	
	Incidence (%)	Leaf damage	Spindle damage			Infestation (%)	MGI
April,18	25.00	6.00	0.00	0.00	0.00	73.39	1.53
June,18	44.00	7.20	0.00	0.00	0.00	76.09	1.78
Aug.,18	48.00	6.00	4.00	0.00	0.00	72.01	1.39
Oct., 18	24.00	4.40	4.00	0.00	0.00	47.49	0.74
Dec., 18	32.00	5.20	0.00	0.00	0.00	78.80	1.76
Feb., 19	8.88	3.20	3.33	2.22	0.00	82.42	2.27
Mean ± SE	**30.31 ± 6.42**	**5.33 ± 0.62**	**1.88 ± 0.93**	**0.37 ± 0.40**	**0.00 ± 0.00**	**71.70 ± 5.56**	**1.57 ± 0.22**

Table 3: Average per cent infestation by different pests in fixed plot survey in Maharashtra

Month	Rhinoceros beetle			Red palm weevil incidence (%)	Black headed caterpillar incidence (%)	Eriophyid mite	
	Incidence (%)	Leaf damage	Spindle damage			Infestation (%)	MGI
April,18	24.50	4.40	0.00	0.00	0.00	64.98	1.37
June,18	48.00	7.11	0.00	0.00	0.00	64.60	1.35
Aug.,18	42.00	5.00	6.00	0.00	0.00	54.91	0.94
Oct.,18	26.00	4.00	2.00	0.00	0.00	41.65	0.67
Dec., 18	20.00	3.40	0.00	0.00	0.00	54.84	1.15
Feb., 19	7.64	2.60	2.30	1.11	0.64	59.33	1.39
Mean ± SE	**28.02 ± 5.44**	**4.41 ± 0.63**	**1.71 ± 1.16**	**0.18 ± 0.00**	**0.10 ± 0.00**	**56.71 ± 4.25**	**1.14 ± 0.13**

showed that it was at peak during summer months (April to May), started declining from September onwards and reached to minimum during winter (November and December). Muyengi at el., 2015 showed that about 46.7 per cent of the farmers experienced the problem of *rhinoceros* beetle (*Oryctes monoceros*) and about 4.7 per cent with coconut mites (*Aceria guerreronis*). Vanderplank (1959a), Bedford (1975), Paul (1985) and Seguni (2010) also indicated the same results.

CONCLUSION

The fixed plot survey concluded preponderance of four major insect pests namely, the rhinoceras beetle (*Oryctes rhinoceros*), black head caterpillar (*Opisina arenosella*), eriophid mite (*Aceria guerreronis*) and the red palm weevil (*Rhynchophorus terrugineus*) infesting cocconut trees in Ratnagiri district of Maharastra. The well managed plots receiving good sanitation and fertilizers recorded minimum incidence of rhinoceros beetle (25.73%) and eriophyid mite (41.74%) against the unmanaged plots, where no sanitation and fertilizer was added, with maximum of 30.31 and 71.70 per cent, respectively.

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Management of bruchid beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae) in stored cowpea through plant extracts and carbaryl

Daniel Brhane, Tufail Ahmad*, Birkti Mehari, Danait Netsereab, Henok Shimendi and Saron Berihu

Department of Plant Protection, Hamelmalo Agricultural College, Keren, Eritrea, Africa
**Author for correspondence, Email: tufailrm@gmail.com*

ABSTRACT

Cowpea bruchid, *Callosobruchus maculatus* is a major pest of stored cowpea in Eritrea. A comparative study on the effectiveness of plant extracts (5 percent of neem and lantana leaf), wood ash and 2 per cent carbaryl as grain protectants against *C. maculatus* conducted at Hamelmalo Agricultural College, Eritrea in three replications revealed that the plant extracts significantly reduced the population of *C. maculatus* at different days of intervals. At 14 DAT, the mortality by carbaryl was high (8.21%) against wood ash and control with low mortality at 7.67 and 7.34 per cent, respectively. The mean weight loss in control with wood ash, lantana leaf extract, neem leaf extract and carbaryl treatments was 44.9, 41.8, 38.4, 34.2 and 19.5 per cent, respectively. The treated seeds recorded higher germination percentage while the control recorded least (40%). Among the botanical protectants, neem extract was found most effective against the storage pests.

Key words: Cowpea, *Callosobruchus maculatus*, neem, lantana, ash, carbaryl

Cowpea (*Vigna unguiculata* L. Walp), member of the family Fabaceae, is a warm season, annual, herbaceous, widely cultivated and economically important legume crop in Eritrea. Its fresh or dried seeds, pods and leaves are commonly used as food for human and livestock. Like other crops, cowpea is also attacked by a wide range of diseases and pests which in turn reduces the grain longevity and the annual yields. The yield reductions due to insects can reach as high as 95%, depending on location, year and the cultivar. The damage causes loss of weight, nutritional value and viability of stored grains.

Bruchids (*Callosobruchus* spp.) are the main problem pests of cowpea in Eritrea. The two most widespread species of bruchid beetle are *Callosobruchus maculatus* and *Callosobruchus chinensis*. On-farm storage studies in Eritrea showed that pulses under storage are attacked by different storage pests causing germination losses from 4 to 88 per cent (Adugna, 2007). According to Adugna (2006) one of the main problems of storage in Eritrea is management of infestation in the stored areas. Farmers in most of the areas keep old and new harvested grains in the same vicinity, which causes an easy migration or infestation of the new grains from the old grains. They also use different pest control methods; some are using chemicals and traditional methods like mixing of grain with ash, sand, chilly pepper, smoke and plant materials. The renewed interest in plant materials as stored product protectants can be attributed to various factors including the development of resistance to synthetic insecticides, fears over their misuse and overuse (during application) and fears about the potential effect of insecticide residues on consumers, wildlife and the environment.

The present work has been undertaken to observe the efficacy of selected botanical powders on cowpea (*Vigna unguiculata* L. Walp) against *Callasobruchus maculatus* (Fab.) and also to investigate their potential as source of sustainable alternative protectants to synthetic insecticides.

MATERIALS AND METHODS

The experiment was carried out in the laboratory of the Department of Plant Protection of Hamelmalo Agricultural College (HAC) between February and May 2018. HAC is located 13 Km north of Keren at an altitude of about 1330 m above sea level. The average rainfall and annual temperature of the area are 436 mm and 24°C, respectively.

The infested cowpea seeds were brought to the laboratory and were reared to reach sufficient population for inoculation of the treatments. Each treatment of 500 g of clean cowpea seeds were inoculated with 10 ten adults (1:1 sex ratio) of *C. maculatus* in 1.5 L volume plastic vials. Observations on the number of adult bruchids that survived in each container was recorded of two weeks intervals. The survival of the adult beetles was later calculated. The number of exit holes seed^{-1} (weevil perforation index) was taken randomly from 100 seeds per container after two months (57 days) of treatment.

Fresh leaves of neem and lantana having insecticidal value against *C. maculatus* were collected from Hamelmalo

Agricultural College and dried under shade for a week. Five per cent of the botanicals, wood ash and 2 per cent of carbaryl used as treatments, were mixed thoroughly and uniformly with the cowpea seeds.

Data on bruchid mortality and natality, grain damage, weight loss and seed germination were collected. Adult mortality was recorded at 14 days interval after application of the treatments. Insects that failed to respond to three probing using blunt dissecting probe were assumed dead and were included in the counts (Onu and Baba, 2003).

$$(\%)\ \text{mortality} = \frac{\text{No of dead insects}}{\text{Total no of insects}} \times 100$$

Grain damage (%) was assessed after a month of bruchid inoculation and was calculated as:

$$(\%)\ \text{mortality} = \frac{\text{No of perforated grains}}{\text{Total no of insects Total no of grains counted}} \times 100$$

Germination in treated and untreated seeds was recorded after three months from each treatments. For this five seeds selected randomly from the experimentally treated grains and control groups from each plastic vial were considered.

$$(\%)\ \text{germination} = \frac{\text{Number of seeds that germinated}}{\text{Total number of seeds planted}} \times 100$$

The statistical software, Genstat 4th edition was used for the analysis of variance (ANOVA) under the experimental design CRD – complete randomized design with three replication in each treatment. The analysis was performed at @5% level of significance.

RESULT AND DISCUSSION

Effect of treatments on the mortality of *C. maculatus* adults

The study showed that the percentage of adult mortality was significantly higher at second two weeks of application of the botanicals than that of first two weeks after treatment. Percentage mortality progressively increased with the time of exposure. The treatments were highly significant in the mortality of *C. maculatus* adult. At 14 DAT, there was significant difference in mortality in all the treatments and control but carbaryl recorded high mortality (8.21%), while ash and control showed low mortality of 7.67 and 7.34 per cent, respectively. At 28 DAT, the mortality of *C. maculatus* was significantly reduced. The control showed significant mortality (9.6%). At 42 DAT, the treatments and control were significantly different from each other. However, the least *C. maculatus* adult mortality occurred in the control treatments for the 28 DAT, 42 DAT and 56 DAT. The present finding was supported by Ahmad *et al.,* (2015) that storage of faba bean and cowpea treatment with different physical, neem seed powder and sesame oil were found significantly managing the bruchid beetle in laboratory condition. The insecticidal potential of *A. indica* could be attributed to the presence of azadirachtins, which is toxic to stored product insect pests. Onu and Baba. 2003 showed that cowpea seeds treated with plant powders, ash and carbaryl caused significant mortality within 28 DAT and the effectiveness increased up to 60DAT. *A. indica*, and carbaryl powders caused more than 50 per cent mortality of adult bruchid beetle at different concentrations in laboratory (Ileke, 2012).

Effect of treatments on quality of cowpea

Plant extracts significantly affected the bruchid beetle and reduced its damage potentiality on stored seeds in laboratory. At 14 DAT, percentage damage of treated seed was not significantly different from the control (13.33%) (Fig 2). At 28 DAT, percent damage in all the treated seed and control was significantly different from each other. Moreover, the percentage damage in all the treated seed and control was highly significant to each other at 42 and 56 DAT. The damage caused to control was due to low mortality and high progeny emergence implying that the insect numbers were increasing thereby causing more damage on grain. There was a significant reduction in damage by the bruchid to the treated cowpea seeds compared with the control and that is why the weight loss of treated samples was low compared with the control. There was a corresponding reduction in the number of exit holes in treated cowpea seeds as a result of limited contact of the bruchids with the treated seeds especially those treatments such as carbaryl, neem, lantana and ash, sequentially.

Assessment of weight loss and germination test

The result of germination of the cowpea seeds is presented in Figure 3. Germination percentage in the pre-treatment was not significantly different in all the treatments and control. However, the germination percentage in the treated seeds (post-treatment) was highly significant. The treated seeds recorded higher germination percentage while the control had the least germination percentage (40%). This result showed that the bruchid attack altered the germination of the control treatments. It also showed that plant materials tested against *C. maculatus* did not show any adverse effect on germination capacity of the cowpea seeds. Weight loss of stored cowpea seeds was not significantly affected by the treatments. The result for weight loss of the cowpea seeds revealed that at 56 DAT, mean weight losses in the different treatments were significantly different from each other. The

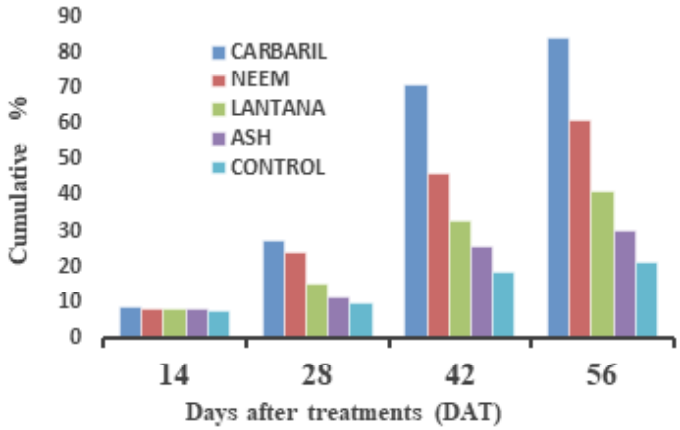

Figure 1: Effect of treatments on *C. maculatus*

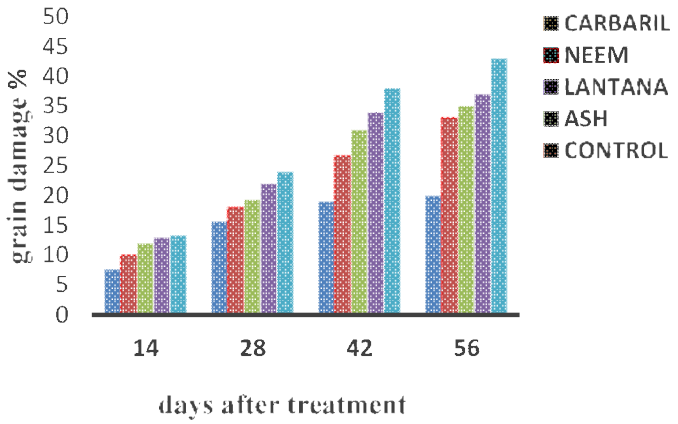

Figure 2: Per cent grain damage by cowpea beetle

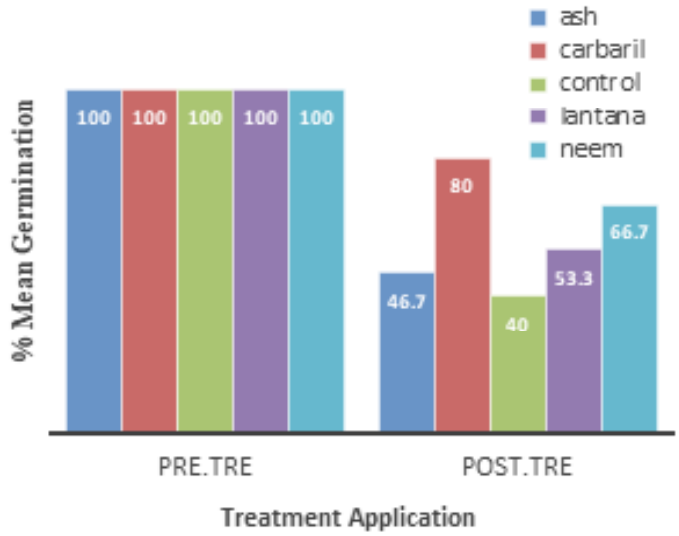

Figure 3: Per cent damage and germination test

mean weight loss in control, wood ash, lantana, neem and carbaryl was 44.9, 41.8, 38.4, 34.2 and 19.5 per cent, respectively.

CONCLUSION

The results revealed that most of the botanical powders were effective and had insecticidal activity similar to synthetic chemicals for the control of *C. maculatus*. The treatments significantly achieved high mortality of *C. maculatus* adults and significantly reduced weight loss due to its ability to inhibit oviposition by adult *C. maculatus* and hatching ability of the eggs. Most botanicals have anti-feedant and repellent capability to control the insect pests in cowpea and reduce the seed damage and weight loss of the seed. Moreover, the local availability of these botanicals makes it easy for small farmers and reduces the cost of cowpea seed production.

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Bio-efficacy of novel insecticides and combination formulations on major insect pests of Sugarcane Early shoot borer and Top shoot borer

Shrirang Donawade, R.S. Meena and P.S. Singh

Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh, India
Email: radheento@gmail.com

ABSTRACT

The field experiment was conducted with a view to study the bio-efficacy of some novel insecticides and combination formulations on major insect pests of sugarcane early shoot borer and top shoot borer at the Agricultural Research Farm of Institute of Agricultural Sciences, BHU, Varanasi. In the present study Chlorantroniliprole 18.5 SC was also found to be effective against *C. infuscatellus* and significantly superior over other insecticidal treatments. Among the other treatments fipronil 5 SC 75 g a i ha^{-1} treatments stood second and next best treatment is Fipronil 40 WG + Imidacloprid 40 WG combination treatment stood third followed by Indoxicarb 14.5 SC, Cartap hydrochloride 50 SP, Spinosad 45 SC. The results obtained during the evaluation of test insecticides against Top shoot borer (*S. excerptalis*) revealed that Chlorantroniliprole 18.5 SC treatment was significantly superior over other insecticidal treatments. The second best chemical was Fipronil 5 SC, which were followed by Fipronil 40 WG + Imidacloprid 40 WG, Indoxicarb 14.5 SC, Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos that have nearly same per cent field bio- efficacy. Fipronil in combination with Imidacloprid as it was observed in case *S. excerptalis* was also proved effective.

Key words: Bio-efficacy, insecticides, *C.infuscatellus, S. excerptalis*

Sugarcane (*Saccharum officinarum* L.) one of the most important cash crops grown in all tropical and subtropical countries of the world, is world's most efficient harvester of solar energy, storing this energy as huge quantity of biomass in the form of fiber and fermentable sugar. Insect pests like termites, borers, *Pyrilla*, whiteflies, bugs, mites, etc. attack this crop and cause heavy loss in terms of yield and sugar recovery. Sugarcane borers make holes, tunnels in internodes due to which food supply to aerial parts of stem and leaves stops and also pave ways for certain diseases. The shoot borer is widely distributed in all sugarcane growing areas in India. *Chilo infuscatellus* is the most notorious and destructive one.

The shoot borer damages crop mainly at cane formative phase. A number of researchers have estimated the loss due to the infestation of this pest in terms of yield at harvest. In sugarcane among the 15 pests which are reported to cause considerable loss in yield, the shoot borer, *Chilo infuscatellus* causes great economic losses (Gupta and Sharma, 2007). The caterpillars after hatching from eggs get scattered and enter into the young shoots by making holes just above ground level and tunnel downwards, and as a result shoot dries up causing "dead hearts". It is a characteristic sign of the presence of the pest within the plants. The dead heart emits an offensive smell and is easily pulled out of the control shoot. David (1979) reported that 9 species of borers regularly damage sugarcane. Of these, the shoot borer, *Chilo infuscatellus* is posing serious threat to sugarcane production all over India. It has cosmopolitan distribution and infests the crop at the shoot stage both in tropical as well as subtropical India.

S. excerptalis a major devastator pest of sugarcane, infests the top portion of sugarcane plant as stated by Deka and Sharma (2005) resulting in the reduction of cane production about 36-56 per cent. The life history of *S. excerptalis* showed complete metamorphosis with four developmental stages viz., egg, larva, pupa and adult (Kumar and Rana, 2013). Young larvae feed and bore into young leaves of sugarcane plant through its midrib (Singh *et al.*, 1984). The serious damage was occurred from third week of May to first week of July (Rana *et al.*, 1992). The mean incidence of top borer was 15.86, 12.31 and 3.22 per cent and the mean natural parasitization on the larvae of the top borer was 27.72, 21.56 and 8.72 per cent, during 1999-2000, 2000-01 and 2001-02, respectively (Rajendran and Giridharan, 2003). Bhatti *et al.*, (2008) observed that the top borer appeared in the month of March and caused maximum damage of 14.46 per cent in July.

MATERIAL AND METHOD

Field trial was laid out in Randomized Block Design (RBD) with 3 replications and 8 treatments including untreated control during *kharif* 2016-17 to evaluate the bio-efficacy of certain insecticides against shoot borer and top shoot borer in sugarcane crop. Experiment was conducted in an area of 450 m^2, which was divided into three blocks each of 6m wide and 31m long. These blocks were further divided into 8 plots, each of 6m long and 3m wide with a gap of 1m between the two plots. Two main irrigation channels of 1m were made along the width of the plots and two sub irrigation channels of 1.5 m were made between the blocks. A field border of 1.5 m was made along the length of the field. Pests were monitored at regular intervals and when pest population/damage reached the economic threshold level, insecticides were sprayed as per the schedule laid out in two sprays:

RESULT AND DISCUSSIONS

The dead hearts percentage was significantly low in all the insecticidal treatments as compare to untreated control when observations were recorded 15 DAS. Chlorantroniliprole 18.5 SC was found superior over all the remaining treatments recording lowest dead heart (4.5%), Fipronil 5 SC stood second in effectiveness which recorded 4.9 per cent dead hearts. The significant difference did not exist among the treatments with Fipronil 40 WG+ Imidacloprid 40 WG and Indoxacarb 14.5 SC. The next best treatments in order of their efficacy were Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos 20 EC were 6.44, 7.03 and 7.7 per cent dead hearts were observed (Table 1). The data on per cent dead hearts recorded 21DAS showed that Chlorantroniliprole 18.5 SC was found consistently to be the most promising treatment where lowest (3.57%) dead hearts were recorded. The treatment with Fipronil 5 SC continued to be best treatment next in order of effectiveness with 4.24 per cent dead hearts. The significant difference did not exist Fipronil 40 WG + Imidacloprid 40 WG and Indoxacarb 14.5 SC. The next best treatments in order of their efficacy were Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos 20 EC were 5.96, 6.38 and 7.17 per cent dead hearts were observed. The data on per cent dead hearts recorded 15 DAS showed that Chlorantroniliprole 18.5 SC was found consistently to be the most promising treatment where lowest (3.95 per cent) dead hearts were recorded. The treatment with Fipronil 5 SC continued to be best treatment next in order of effectiveness with .4.27 per cent dead hearts. The significant difference did not exist Spinosad 45 SC and Chloropyriphos 20 EC.The next best treatments in order of their efficacy was Fipronil 40 WG+ Imidacloprid 40 WG were 4.79 per cent dead hearts were recorded. The next best treatments in order of their efficacy were Indoxacarb 14.5 SP and Cartap hydrochloride 50 SP, were 5.19and 6.1 per cent dead hearts were recorded. The observations on dead hearts 21 DAS day after spray in different insecticidal treatments. Among the treatments, Chlorantroniliprole 18.5 SC was found to be significantly superior over all other treatments and recorded 3.54% dead hearts. The treatment with Fipronil 5 SC was next in order of efficacy (3.95 % dead hearts). The next best treatment in order

Table 1. Effect of insecticidal treatments against *C. infuscatellus* after 1st insecticidal sprays

S.No.	Treatments	Dose/ha	Per cent dead hearts					Mean
			DBS	1 DAS	7 DAS	15 DAS	21 DAS	
1.	Cartap hydrochloride 50 SP	25 g a.i.	9.2*	8.6	6.8	6.44	5.96	6.95
			(17.65)**	(17.0)	(15.10)	(14.69)	(14.12)	(15.23)
2.	Indoxacarb 14.5 SC	125 g a.i.	9.4	8.1	6.4	5.7	5.06	6.31
			(17.84)	(16.52)	(14.64)	(13.80)	(13.0)	(14.19)
3.	Spinosad 45 SC	45 g a.i.	10.23	9.3	7.76	7.03	6.38	7.61
			(18.64)	(17.44)	(16.17)	(15.36)	(14.62)	(15.89)
4.	Chlorantroniliprole 18.5 SC	100 g a.i.	8.3	6.9	5.2	4.5	3.57	5.04
			(16.73)	(15.22)	(13.17)	(12.24)	(10.89)	(12.88)
5.	Fipronil 5 SC	75 g a.i.	7.8	7.5	5.6	4.9	4.24	5.56
			(16.21)	(15.88)	(13.68)	(12.78)	(11.88)	(13.55)
6.	Chloropyriphos 20EC	75 g a.i.	10.4	10.1	8.5	7.7	7.17	8.36
			(18.80)	(18.52)	(16.94)	(16.10)	(15.52)	(16.77)
7.	Fipronil 40 WG + Imidacloprid 40 WG	175+175 g a.i.	8.5	7.9	6.01	5.83	5.2	6.23
			(16.94)	(16.31)	(14.18)	(13.94	(13.17)	(14.4)
8.	Untreated control	_	10.2	10.6	11.6	12.7	13.2	12.02
			(18.61)	(18.99)	(19.81)	(20.86)	(21.29)	(20.23)
	S.Em.±		N.S	0.10	0.09	0.11	0.20	0.12
	C.D. @ 5%		N.S	0.31	0.28	0.36	0.45	0.35

of efficacy was Fipronil 40 WG + Imidacloprid 40WG recorded 4.51 per cent dead hearts and found on par with Indoxacarb 14.5 SC recording 5.07 per cent dead hearts, followed by Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos 20 EC where 5.42, 6.1 and 6.49 per cent dead heart recorded, respectively

In the present study Chlorantroniliprole 18.5 SC was also found to be effective against *C. infuscatellus* and significantly superior over the other insecticidal treatments. Among the other treatments fipronil 5 SC treatments stood second and next best treatment is Fipronil 40 WG + Imidacloprid 40 WG combination treatment stood third followed by Indoxacarb 14.5 SC, Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos 20 EC. But in the present study it is clear that Chlorantroniliprole 18.5 SC is effective against early shoot borer and this is in close concurrence with results obtained by Bhawar *et al.*, (2014) who confirmed the superiority of Chlorantroniliprole 18.5

Table 2. Effect of insecticidal treatments against *C. infuscatellus* after 2nd insecticidal sprays

S.No.	Treatments	Dose/ha	Per cent dead hearts					Mean
			DBS	1 DAS	7 DAS	15 DAS	21 DAS	
1.	Cartap hydrochloride 50 SP	25 g a.i.	7.6* (15.99)**	7.1 (15.44)	6.6 (14.87)	6.1 (14.29)	5.42 (13.46)	6.30 (14.51)
2.	Indoxacarb 14.5 SC	125 g a.i.	7.4 (15.71)	6.6 (14.88)	6.0 (14.17)	5.19 (13.16)	5.07 (12.97)	5.71 (13.79)
3.	Spinosad 45 SC	45 g a.i.	8.4 (16.73)	7.5 (15.88)	7.2 (15.36)	6.82 (15.08)	6.1 (14.29)	6.95 (15.20)
4.	Chlorantroniliprole 18.5 SC	100 g a.i.	6.74 (15.03)	5.07 (13.00)	4.2 (11.81)	3.95 (11.47)	3.54 (10.84)	4.19 (11.78)
5.	Fipronil 5 SC	75 g a.i.	5.78 (13.91)	5.6 (13.68)	4.8 (12.64)	4.27 (11.91)	3.95 (11.47)	4.65 (12.42)
6.	Chloropyriphos 20EC	75 g a.i.	8.0 (16.42)	7.7 (16.10)	7.23 (15.54)	7.01 (15.36)	6.49 (14.76)	7.05 (15.38)
7.	Fipronil 40 WG+ Imidacloprid 40 WG	175+175 g a.i.	8.2 (16.63)	6.06 (14.25)	5.4 (13.43)	4.79 (12.64)	4.51 (12.27)	5.19 (13.14)
8.	Untreated control	_	8.3 (16.70)	8.5 (16.94)	8.96 (17.41)	9.23 (17.69)	9.88 (18.32)	9.14 (17.59)
	S. Em.±		N.S	0.07	0.10	0.12	0.12	0.10
	C.D. @ 5%		N.S	0.21	0.30	0.35	0.36	0.30

Table 3. Effect of insecticidal treatments against *S. excerptalis* after 1st insecticidal sprays

S.No.	Treatments	Dose/ha	Per cent dead hearts					Mean
			DBS	1 DAS	7 DAS	15 DAS	21 DAS	
1.	Cartap hydrochloride 50 SP	25 g a.i.	9.6* (18.04)**	9.42 (17.87)	8.67 (17.12)	8.41 (16.86)	7.43 (15.80)	8.48 (16.91)
2.	Indoxacarb 14.5 SC	125 g a.i.	9.1 (17.47)	9.03 (17.48)	8.22 (16.65)	8.00 (16.42)	6.88 (15.20)	8.03 ((16.43)
3.	Spinosad 45 SC	45 g a.i.	9.89 (18.32)	9.78 (18.21)	9.38 (17.83)	8.82 (17.27)	7.95 (16.37)	8.98 (17.34)
4.	Chlorantroniliprole 18.5 SC	100 g a.i.	8.2 (16.63)	7.73 (16.13)	6.07 (14.26)	5.58 (13.65)	4.92 (12.81)	6.05 (14.21)
5.	Fipronil 5 SC	75 g a.i.	8.63 (17.06)	8.19 (16.62)	6.81 (15.12)	6.19 (14.40)	5.73 (13.84)	6.73 (14.99)
6.	Chloropyriphos 20EC	75 g a.i.	10.18 (18.60)	10.03 (18.44)	9.81 (18.24)	9.03 (17.48)	8.43 (16.87)	9.32 (17.57)
7.	Fipronil 40 WG + Imidacloprid 40 WG	175+175 g a.i.	8.4 (16.87)	8.33 (16.77)	7.43 (15.81)	6.85 (15.17)	6.40 (14.65)	7.25 (15.6)
8.	Untreated control	_	10.12 (18.54)	10.61 (19.00)	11.34 (19.67)	11.41 (19.73)	12.02 (20.28)	11.34 (19.67)
	S. Em.±		N.S	0.11	0.10	0.12	0.13	0.11
	C.D. @ 5%		N.S	0.32	0.31	0.36	0.33	0.33

Table 4. Effect of insecticidal treatments against *S. excerptalis* after 2nd insecticidal sprays

S.No.	Treatments	Dose/ha	Per cent dead hearts					Mean
			DBS	1 DAS	7 DAS	15 DAS	21 DAS	
1.	Cartap hydrochloride 50 SP	25 g a.i.	7.83*	7.73	6.47	6.12	5.22	6.38
			(16.24)**	(16.14))	(14.73)	(14.31)	(13.21)	(14.59)
2.	Indoxacarb 14.5 SC	125 g a.i.	7.93	7.62	6.07	5.7	4.82	6.05
			(16.24)	(16.01)	(14.25)	(13.80)	(12.68)	(14.18)
3.	Spinosad 45 SC	45 g a.i.	8.1	7.93	6.85	6.50	5.66	6.73
			(16.52)	(16.35)	(15.16)	(14.76)	(13.75)	(15.00)
4.	Chlorantroniliprole 18.5 SC	100 g a.i.	7.26	6.33	4.84	4.03	3.62	4.70
			(15.63)	(14.56)	(12.70)	(11.57)	(10.97)	(12.45)
5.	Fipronil 5 SC	75 g a.i.	7.21	6.82	5.32	4.92	4.06	5.28
			(15.57)	(15.13)	(13.33)	(12.81)	(11.62)	(13.22)
6.	Chloropyriphos 20 EC	75 g a.i.	8.31	8.28	7.24	6.81	5.64	6.99
			(16.74)	(16.69)	(15.61)	(15.12)	(13.74)	(15.29)
7.	Fipronil 40 WG +	175+175 g a.i.	7.41	7.22	5.69	5.32	4.46	5.67
	Imidacloprid 40 WG		(15.79)	(15.58)	(13.79)	(13.33)	(12.18)	(13.72)
8.	Untreated control	_	8.43	8.65	9.08	9.46	9.94	9.28
			(16.87)	(17.10)	(17.53)	(17.90)	(18.37)	(17.72)
	S. Em.±		N.S	0.11	0.12	0.13	0.11	0.11
	C.D. @ 5%		N.S	0.33	0.36	0.38	0.32	0.34

SC over the Fipronil 5 SC, Indoxacarb 14.5 SC, Cartap hydrochloride 50 SP, and Imidacloprid 17.8 S. However, Singh *et al.,* (2009) also recorded that was Chlorantroniliprole 18.5 SC most effective treatment recording the lowest incidence of sugarcane early shoot borer (15.4%) treatment with Fipronil 5 SC proved next effective treatment and found at par with Indoxcarb14.5 SC.

The results obtained during the evaluation of test insecticides against top shoot borer revealed that Chlorantroniliprole 18.5 SC treatment was significantly superior over other insecticidal treatments. The second best chemical was Fipronil 5 SC, which were followed by Fipronil 40 WG + Imidacloprid 40 WG, Indoxacarb 14.5 SC, Cartap hydrochloride 50 SP, Spinosad 45 SC and Chloropyriphos that have nearly same per cent field bio- efficacy. Fipronil in combination with Imidacloprid as it was observed in case *S. excerptalis* was also proved effective. Among the sole insecticidal treatments Indoxacarb was found to be more effective against Cartap hydrochloride. Similar results were obtained by Jaipal *et al.,* (2000) who reported that Chlorantroniliprole treatments applied as root drench and sand mix soil application were assessed for the control of early shoot borer (*Chilo infuscatellus* Snellen) and the top borer (*Scirpophaga excerptalis* Walker) in sugarcane crop, all treatments of (8) were Chlorantroniliprole significantly superior over untreated check as well as Carbofuran 3G @ 1.0 kg a.i. ha-1 or Phorate 10G @ 2.0 kg a.i. ha-1 standard in controlling top borer. A comparison of Chlorantroniliprole treatments made against second and third brood indicated that the chemical applied as root drench against second brood offered superior control of the borer. The mean cumulative incidences of the third, the fourth and the fifth broods of the top borer were the lowest when Chlorantroniliprole was applied as root drench than as sand mix treatment (Table 2, 3, 4). These recommended insecticides can be considered for the IPM strategy to control the two borers.

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Role and utility of well-protected area (sick plot) for the study of plant diseases in Hamelmalo agricultural fields, Eritrea

[1]Syed Danish Yaseen Naqvi* and [2]Sethumadhava Rao, G.

[1, 2]*Department of Plant Protection, Hamelmalo Agricultural College Farm, Eritrea*
**Corresponding Author E-mail ID: syeddanishnaqvi@gmail.com*
[2]*Coauthor Email ID: sethumadhava.g@gmail.com*

ABSTRACT

A well protected area (WPA) called 'sick plot' designed for the study of pathogens and their activity on crops was established at the farm of Hamelmalo Agricultural College, Eritrea with the aims of finding out the soil mycoflora and identify the diseases on various crops grown in the plot. The sick plot, spread in 1032.5 square meter area, having 48 plots each of 3 x 3.5 m with a bio-fencing was planted with some vegetable and field crops for the study of pathogen reactions in the form of symptoms. Dry root rot caused by *Rhizoctonia bataticola* in Lentils; blights on mustard and cabbage; rusts on chickpea and early blights, fusarial wilts and root-knot nematodal infections on tomato were recorded. This preliminary investigation, Phase-I, was done only to find out the pathogen reactions on the crop plants. It will be continued in various seasons to evaluate colony forming units per gram of soil and to calculate the disease occurrences in Phase-II, and the role of antagosnists and arbuscular micorhhiza on the habitation of variuos field mycoflora in Phase-III.

Key words: Agricultural crops; insect pests; mycoflora; plant diseases; well-protected area.

A well protected area (WPA) called 'Sick Plot' is not only useful in studying the activity of pathogens crops as a research methodology but also acts as a teaching learning tool. This plot can be one of the investigation areas for execution of trial experiments on breeding programmes, testing the development of diseases and their reactions on newly bred varieties of cultivated crops as also as the introduced lines of crops such as legumes, vegetables before they are released for commercial use. It is established in an isolated area, far away from the fields of agricultural farms, where the wind flow is less. Different soil samples brought from the farmers' field along with infected plant parts are deposited in this and is maintained with proper moisture and required substrates for the growth of the spores of fungi, bacteria and other resting spores of various microorganisms.

Eritrea is a country of North Eastern Africa, where cereal cultivation is estimated as 463,926 hectares (Grando et al., 2010). Eritrean farmers use to grow wide range of crops under rainfed production system (AATF, 2011). Since the farmers are using fertilizers indiscriminately to get more produce, the soil profile and texture are changing day by day. According to (Bahadur and Singh, 2003) usage of organic manures along with bio-fertilizers is not only helpful in improving soil health, growth, yield and quality but also avoid chemical based farming. A recent research (Martin and Brathwaite, 2012) indicates that compost tea, a product of compost, has also been shown to suppress soil-borne diseases including damping-off and root rots caused by *Pythium ultimum*, *Rhizoctonia solani*, *Phytophthora* spp. and wilts caused by *Fusarium oxysporum* and *Verticillium dahliae*. By fetching the samples from different fields, research projects are usually carried out to screen and assess the soil-borne diseases.

Fusarial wilts; *Rhizoctonia* infections; *Alternaria* blights; *Sclerospora* diseases; rusts and smuts of field crops; bacterial and fungal rots on vegetable crops; leaf spots on ground nut; anthracnoses and die-back on fruit crops; mildews on fruit and horticultural crops and nematodes such as *Meloidogyne spp* on tomato, okra etc. are the most important diseases to cause losses in Eritrea as evidenced by the observation and results of the senior research projects. Fungi such as *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Colletotrichum graminicola*, *Fusarium moniliforme, Helminthosporium sorghicola, Mucor* spp., *Penicillium oxalicum* and *Rhizopus* spp. were isolated from the sorghum variety HACNL (Syed Danish et al., 2015). In tomato and chillies the percentage of disease incidence showed more than 77 per cent in some villages during *Hagay* season but the severity was observed between 20 and 60% (Sethumadhama Rao et al., 2016). Inoculation of the soil with these pathogens renders many areas in the field unsuitable for commercial production.

Because of the importance of these deleterious diseases which has already been stated in many vegetable crops in

Eritrea, a real need for devoloping a well protected area (WPA) called Sick Plot, which helps in determining the genetic resistance of different varieties of the vegetable and legume crops as well as the effectiveness of environmentally safe control measures on disease incidence and severity, was felt. In this country, most of the farmers are not aware of the diseases and the symptoms caused by fungal and bacteria, hence this project was developed at HAC campus in November, 2013 by the Department of Plant Protection in three phases with the general and specific objectives to find out soil mycoflora in/upon plant rhizosphere, observe seedling diseases, evaluate the seed germination of crops, observe the colony forming units of a gram ($cfu^{-1}g$) of soil, assess the Vesicular Arbuscular Mycorrhiza (VAM), calculate the disease occurrences eventually which can be an epidemic to execute research projects and to evaluate the appropriate management practices.

This project proposal was planned to be executed in three phases: Phase-I: identification of the symptomatology of crops cultivated in the sick plot after the spore inoculation; Phase-II: analysis of inoculums density and their percentage occurrence in each plot; Phase-III: identify and evaluate the populations and percentage of antagonists, for example, VAM fungi, and how they participate in the sustainable management of the diseases.

MATERIALS AND METHODS

The experiment was conducted at Hamelmalo Agricultural College located on the bank of the river Hamelmalo at 15p 53' N latitude and 38p 66' E longitude and at on elevation of 1292m above sea level with the average annual temperature varying from 16° to 38°C. Climate is fluctuating in the whole year; it is cold from November to March while it is hot from April to June and the remaining months are with moderate temperature. The total annual average rainfall is about 497.2 mm and the major amount of rainfall occurs between June and August. The soil of the sub-zoba is predominantly sandy loam with 5.5 up to 7.5 pH values [Anonymous, 1997].

An area of 1032.5 sqm was used for the establishment of sick plot. The total area was fenced by using elephant grass to avoid the dissemination of pathogen and their spores to other neighbouring farms. The bio fencing, the cuttings of *Duranta repens* were planted around the sick plot between fencing and trench. A protection trench of 0.5m was also dug around sick plot to be not connected the soil with adjacent farms. The land was prepared by removal of weeds and shrubs and then by ploughing, disc harrowing and leveling. The field was moistened before inoculation of propagules of pathogens and the infected plant parts.

The proposed area of sick plot was 59 x 17.5 m four replication plots within and was separated with three passages in between. One and half meter breadth of wide passage in between second and third rows, 0.5 m space between first, second, third and fourth row was left for observation and study of the soil ecology of each plot. It was divided into a total of 48 plots (Fig. 1). Each replication plot had an area of 3 x 3.5 m. It was planned to cultivate vegetable crops such as solanacious, cucurbits and pulse crops easy to maintain within the available resources in HAC and affordable crop husbandry practices.

Phase-I: Soil samples and diseased plant material showing typical symptoms of blights caused by *Alternaria* sps; wilt (*Fusarium)*, root rot and damping-off (*Fusarium*, *Rhizoctonia*

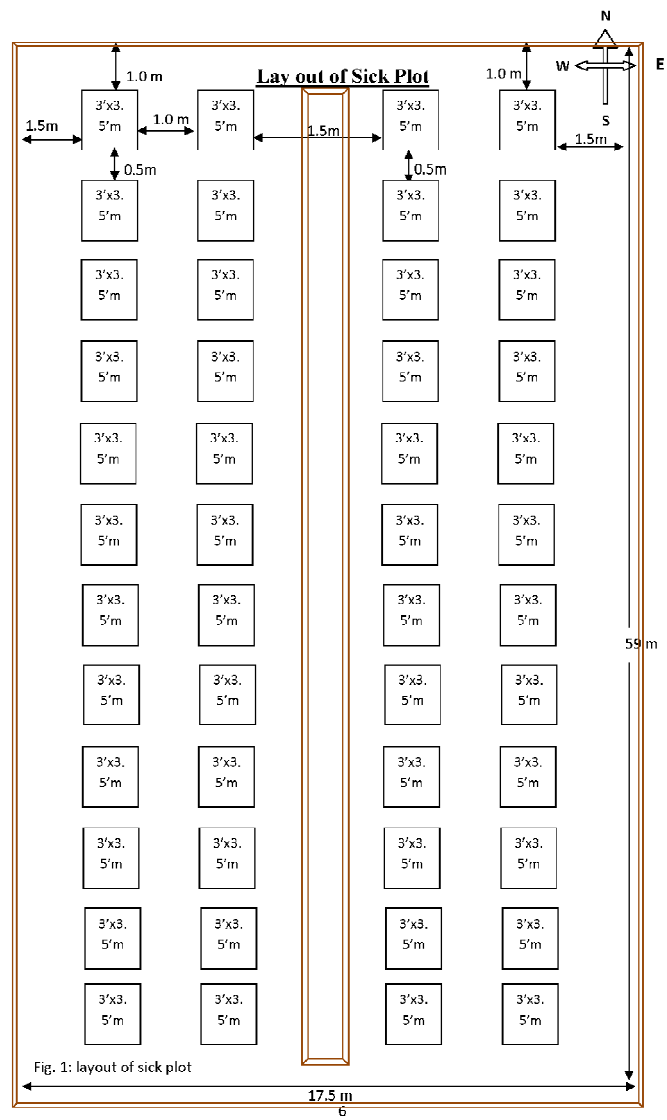

Fig. 1: Layout of sick plot

and *Pythium*) and also infected plants showing galled roots typical to root-knot infection were collected from farmers fields of different regions, chopped into small pieces and then incorporated into the soil of WPA. After addition of diseased material, the land was thoroughly irrigated for establishment of different pathogens in the soil. Addition of diseased plant material will continue every season after harvest of the crops, so as to raise the inoculum density of the pathogen.

The field after removing weeds and leveling was kept ready before the rainy season to be inoculated with the infected plant material and soil samples brought from various fields of farmers of zoba Anseba. Field crops such as lentils, chickpea; horticultural crops i.e. tomato, cabbage, cauliflower, garden peas and mustard were cultivated in the sick plot. During the various growth stages of the crops, different infections were noticed and recorded (Fig. 2).

Pathogens were isolated after 5 to 7 days of inoculation and were identified based on their morphological characteristics (the shape of the spores, mycelium or hyphae and different stages of root knot nematode -*Meloidogyne* spp.).

Precautions were taken, strictly, to avoid dissemination of propagules of pathogens from the sick plot to nearby farms. For this separate sterilized tools and ceased the irrigation channels were used. Insect 'vertical trap nets' were also used around the plot and trapped insect pests were removed manually.

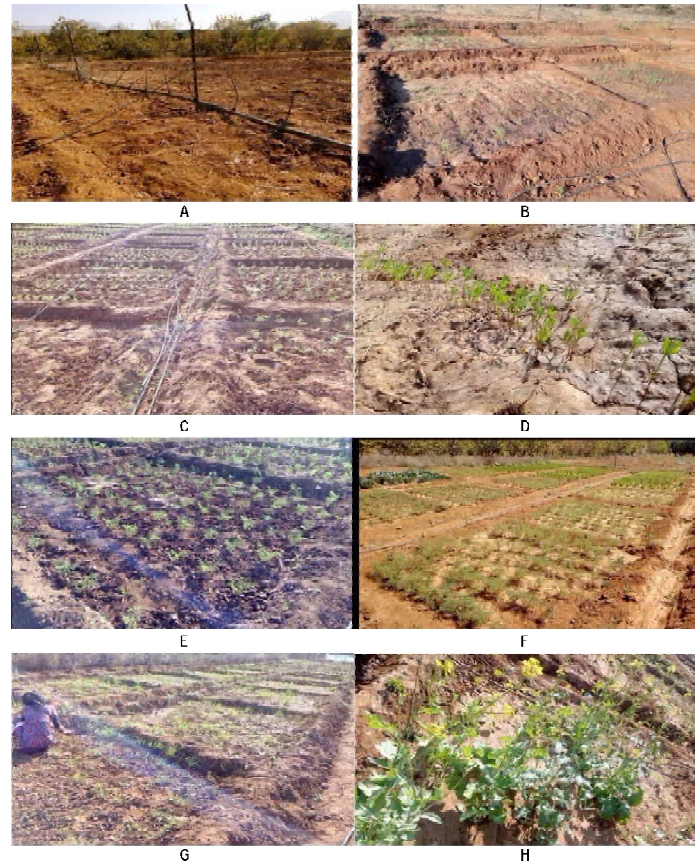

Fig. 2: Prepared plots for the inoculation of infected plant parts (A and B); Irrigation (C); Cultivation of lentils (D); Chickpea (E and F); (F); Weeding the plots (G); Mustard (H).

RESULTS AND DISCUSSION

In lentils (*Lens culinaris* Medik), severe dry root rot caused by species of *Rhizoctonia bataticola* (Daub) Butler; (*Macrophomina phaseolina* (Tassi. Goid) was observed. It also called as seedling blight which was also reported from Australia, Ethiopia, Iran, Pakistan Sudan and the USA (Haware and Nene, 1980). The infected plants showed sudden drying under dry and hot conditions and affected plants could be pulled out easily due to rot of lateral and finer roots. The tap root became dark and brittle towards its tip. The mycelium of *Rhizoctonia bataticola* is hyaline when young and turns olive brown. The minute, dark brown sclerotia developed on and inside the bark. Sclerotia are 80-174 mm, black, round to irregular and develop abundantly in the bark and pith. The pathogen perpetuates on diseased debris and persists in soil as facultative parasite. The fungus has a wide host range. Low soil moisture and temperature 26-35°C are conducive for the disease development. This dry root-rot associate at the post-flowering stage increased with crop age and showed a highly negative correlation will soil moisture.

Dry root rot is seemingly widespread in Eritrea as it is encountered in the field of the college on crops such as chickpea, okra, tomato and eggplants. The same disease was also observed in most of the farmers' fields ranging in incidence from 15 to 45 per cent. This disease was also observed the in sick plot in chickpeas. Drying of the plants appears suddenly in the field at flowering and podding stages. The roots are usually dry, unless the soil is wet. The tap root is quite brittle and shows shredding of the bark and can be broken easily (Figs. 3A-3F).

Mustard (*Brassica juncea* (L.) Czerniak) leaves showed dark brown coloured blight symptoms due to the infections of fungi. Though it may not affect the crop but it reduces the yield. In this field the blights are not severe compared to the fields of farmers in other regions of this country (Figs. 3G and 3H).

Cabbage (*Brassica oleracea* var. *capitata*) family Brassicaceae (formerly Cruciferae) is one of the most important vegetables in Eritrea. This is a biennial herb, widely

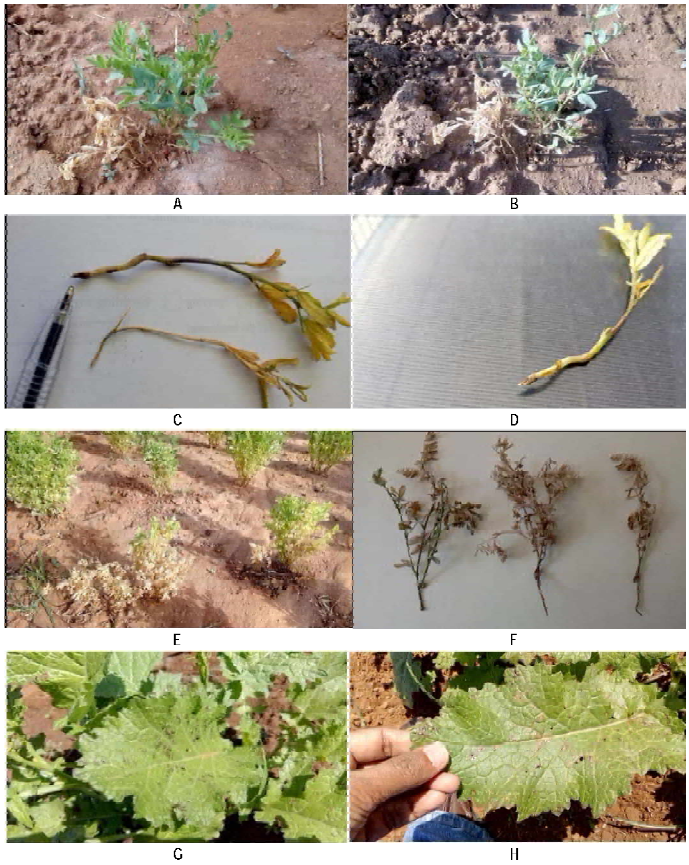

Fig. 3: Infected lentil plants with fungi (A and B); Dry Rot symptoms on the the base of the stem at seedling stage (C and D); Total plants and stems became dry (E and F); Blights on the leaves of mustard (G and H).

cultivated in temperate regions for food. The head is the main edible portion made up of numerous thick overlapping smooth leaves covering terminal bud which is a rich source of vitamins A and C and major minerals including phosphorus, potassium, calciam and Iron. This cole vegetable crop is not well-known in lowland, *Hagaz* and Hamelmalo (Anseba Zoba); so it has been cultivated in the Sick Plot (WPA) during the season i.e. November to February for execution of trials on soil borne, rhizosphere and phylloplane pathogens and insect pests. Due to the infections caused by *Sclerotium* sps, the base of stem become weak and turned brown in colour and unable to hold the shoot system; as a result the entire plant falls down (Figs. 4A and 4B). There were whiteflies and aphids observed on the leaves which can transmit the viruses (Figs. 4C and 4D).

Chickpea (*Cicer arietinum* L.) is another most important pulse crop in Eritrea with an estimated cultivated area of 18,590 ha during the 2005–2006 growing season (FAO, 2008). (FAOSTAT, 2008). In Eritrea, viral diseases of chickpea have

Fig. 4: Infected cabbage stems above soil line (A and B); White flies on the leaves of cauliflower (C and D); chickpea leaves are highly infected with rusts (E and F); Early blight on the leaves of tomato (G and H).

not been extensively studied and no information is available on their incidence but the rusts are found infecting the leaves of chickpea. The diseased leaves are covered with small, round or oval, light dark to dark brown rust pustules due to the infection of uredinales fungi. These obligate parasites

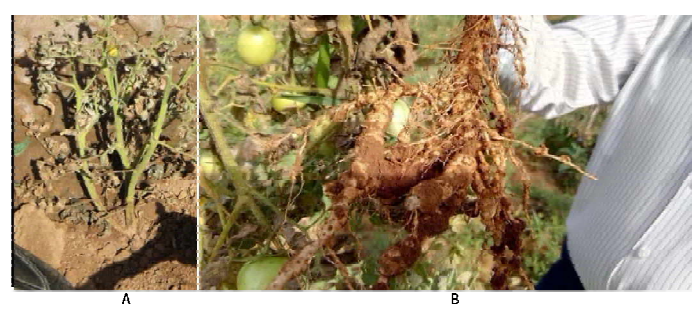

Fig. 5: Wilts caused by *Fusarium* sps in tomato (A); Nematode root-knots on root system of tomato (B).

gave a rusty appearance to a plant (Figs. 4E and 4F).

Alternaria early blight symptoms are visible right from the beginning of flowering stage on tomato plants. These concentrate circle symptoms cause severe damage to the crop by reducing the metabolic activities in the plant which leads to low yield (Figs. 4G and 4H).

Wilt infections were noticed in some plants grown in the Sick Plot. *Fusarium* wilt is a serious problem of pulses, vegetables and fruits in Eritrea and other parts the world. When *Fusarium* fungi attacked on the root system, they penetrate to the xylem and block water transportation as a result plant unable to get adequate water supply (Fig.5).

Root-knots recorded in the tomato root, caused by Root-knot nematodes (*Meloidogyne* spp.), is a widespread disease problem in this country, particularly in tomato as well as in other vegetable and fruit crops as evidenced by the results of research projects conducted by researchers in this college (Haddish, 1997). According to the same author the number of root-knot nematodes per gram fresh weight of banana roots in *Akurdet* and *Gadelli* were respectively 36 and 51 per cent. It has been mentioned by (Agrios, 1997) that root-knot nematodes attack more than 2000 species of cultivated plants. They cause considerable damage either alone or in association with wilt and root rot causal fungi (Singh, 1978). Losses of 38 to 42.2 per cent in tomato yield have been reported (Sikora and Fernandez, 1990) and (Reddy et al., 2001). More than the average root-knot infections were identified in tomato of this sick plot (Fig. 5B).

Future line of work

The preliminary investigations carried out to find out the pathogen reactions on the crop plants in Phase-I is very important for quantitative estimation of pathogens, inoculum density (Phase-II), identification of arbuscular mycorhhizal fungi in condusive soils and their activity on soil inhabitants and soil transients' (Phase-III) in the sick plot.

CONCLUSION

The information derived above will be useful to the farmers to get awareness of soil mycoflora. The diseases of various crops grown in their areas can be recognized based on the visibility of symptoms. This communication therefore, might be useful to the groweres to reduce the yield loss by employing appropriate management practices.

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Management of leaf crinkle disease in blackgram

Hemachandra Haller and A.S. Byadagi

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

ABSTRACT

Leaf crinkle disease of blackgram was effectively managed employing combined treatments of heat therapy of seeds, seed treatment with imidacloprid 600 FS, spraying the crop with imidacloprid 17.8 SL and growing borders sorghum along. During *Kharif* 2011 and 2012, sorghum bordered experiment with treatment of heat therapy of seeds, seed treatment with imidacloprid 600 FS and spray with imidacloprid 17.8 SL at 25 days after sowing (DAS) (T_6) recorded the least PDI and aphid population. In without border experiment during *Kharif* 2011, the least PDI recorded was 18.00 with 44.9 per cent reduction in disease over control and 0.8 aphids three leaves^{-1} plant^{-1} at 60 DAS. The least PDI recorded was 16.67 with 40.00 per cent reduction in disease control and 0.6 aphids three leaves^{-1} plant^{-1} at 60 DAS was recorded in blackgram border crop experiment and during *Kharif* 2012 The least PDI recorded was 20.33 with 42.45 per cent reduction in disease incidence over control and 0.6 aphids three leaves^{-1} plant^{-1} at 60 DAS in blackgram without border experiment, while in border crop experiment of blackgram, PDI recorded was 18.33 with 38.21 per cent reduction in disease incidence over control and 0.8 aphids three leaves^{-1} plant^{-1}.

Key words: Blackgram, leaf crinkle, heat therapy, imidacloprid, border crop

Blackgram is an important pulse crop widely cultivated in Indian subcontinent. In India, it is popularly known as "Urad dal" and it is highly prized pulse among all the pulses. Blackgram has medical properties which help to heal Rheumatic pains, stiff shoulder and contracted knees. The seeds are used for treating rheumatism, a kind of nervous system ailments and liver afflictions, while the roots are narcotic used for relieving bone pains. High amount of magnesium and folate of blackgram support blood circulation. It is consumed in many forms including the grains (whole or split). The whole grains are eaten after germination parched, salted with sugar or boiled with condiments. It is also consumed as a boiled dal, bean cakes, noodles and pudding (Anon., 2018).

Many viruses are known to infect the blackgram. Among them, the leaf crinkle that infects and reduces yield and quality of the seed is vital. If has now-a-days become one of the major production constraint in both *kharif* and *rabi* seasons. Williams *et al*. (1968) first reported the occurrence of the leaf crinkle on blackgram and greengram from the states of Delhi and Uttar Pradesh in India. The symptoms of disease appear in the form of extreme crinkling, curling, puckering and rugosity of leaves, stunting of plants, malformation of floral organs and pollen fertility and pod formation is also reduced severely in infected plants (Nene, 1972).

Management strategy involves management of insect vectors with cultural practices and discriminate usage of insecticides. Effective seed treatment with hot water also provide protection against virus, since *Urdbean leaf crinkle virus* is reported to be seed borne. A good cultural practice like border crop with combination of insecticides play an important role in managing vector populations by reducing the number of individuals that can acquire and transmit a virus and some insecticides act like antifeedant that interfere with virus transmission. Best combination of all management strategies increases the crop yield with good cost benefit ratio.

MATERIALS AND METHODS

Field experiments were conducted at MARS, UAS, Dharwad during *kharif* 2011 and 2012 in a randomized block design (RBD) with three replications and seven treatments to test the efficacy of different management practices against leaf crinkle disease of blackgram. The trial was laid with different treatments and their combinations in the field under natural epiphytotic condition. The plot size of each treatment was 3.5 x 3.75 m. The blackgram variety TAU-1 was used for sowing with a spacing of 30 x 10 cm. The treatments consisted of (T_1) heat therapy of seeds at 60° C for 10 min, (T_2) seed treatment with imidacloprid 600 FS (10 ml kg^{-1} seeds), (T_3) spray with imidacloprid 17.8 SL @ 0.25 ml l^{-1} at 25 DAS, (T_4) $T_1 + T_3$, (T_5) $T_1 + T_2$, (T_6) $T_1 + T_2 + T_3$ and (T_7) untreated check. These seven treatments were taken up with boarder crop of sorghum and without boarder crop. Recommended agronomic practices were followed.

The per cent disease inhibition over control was calculated by using the formula given by Vincent (1947).

$$\text{Per cent disease inhibition} = \frac{C - T}{C} \times 100$$

Where,

C = Per cent disease in control

T = Per cent disease in treatment.

The cost and benefit ratio was calculated based on the present market value of test crops, insecticides and labours engaged.

RESULTS AND DISCUSSION

Integrated disease management (IDM) of leaf crinkle disease in blackgram during first season

The results of IDM strategies employed against leaf crinkle disease in blackgram without border crop during 2011 *kharif* are presented in Table 1. Observations recorded after 15 DAS showed lowest disease incidence of 5.00 per cent in T_1 (heat treated seeds), which was on par with T_6 (heat therapy of seeds, seed treatment with imidacloprid 600 FS and spray with imidacloprid 17.8 SL at 25 DAS) and T_4 (heat therapy of seeds and spray with imidacloprid 17.8 SL at 25 DAS) and all treatments were superior over check (8.33%). T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) was the best treatment recording the least PDI of 14.67, 16.33 and 18.00 at 30, 45 and 60 DAS respectively, which was significantly superior over control with 44.90 per cent reduction over control at 60 DAS. The PDI of 16.33, 18.67 and 19.33 at 30, 45 and 60 DAS, respectively was recorded T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS), which was second best treatment. It was also significantly superior over the control.

The highest aphid population of 0.6 three leaf^{-1} plant^{-1} was recorded in T_4 (heat therapy of seeds and spray with imidacloprid 17.8 SL at 25 DAS) followed by 0.4 per three leaves^{-1} plant^{-1} in T_3 (spray with imidacloprid 17.8 SL at 25 DAS) and T_1 (heat therapy of seeds), while no aphids were recorded in other treatments at 15 DAS. The lowest aphid population in subsequent observations at 30, 45 and 60 DAS recorded in T_3 (spray with imidacloprid 17.8 SL at 25 DAS), T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) and T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) and these were superior over control.

In sorghum bordered blackgram, the per cent disease incidence recorded (Table 2) at 15 DAS showed lowest PDI of 3.67 in heat treated seeds (T_1) followed by PDI of 4.33 in T_6 (heat therapy of seeds, seed treatment with imidacloprid 600 FS and spray with imidacloprid 17.8 SL at 25 DAS) and T_2 (seed treatment with imidacloprid 600 FS). The highest PDI of 7.67 was recorded in T_7 (untreated check). However, T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) recorded the least PDI of 12.00, 15.67 and 16.67 at 30, 45 and 60 DAS respectively, which was significantly superior over control with 36.70 per cent reduction over control at 60 DAS. The next best treatment was T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) with PDI of 14.33,

Table 1. Integrated management of leaf crinkle disease of blackgram without border rows of sorghum during during first season

Tr. No.	Treatment	15 DAS		30 DAS		45 DAS		60 DAS		Decrease in PDI at 60 DAS over control
		PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	
T_1	Heat therapy of seeds	5.00 (12.87)	0.4	19.67 (26.26)	12.2	23.66 (29.07)	7.8	25.00 (29.96)	2.6	23.5
T_2	Seed treatment with imidacloprid 600 FS (10 ml kg^{-1} seeds)	6.33 (14.53)	0	19.00 (25.68)	5.4	22.66 (28.39)	3	23.67 (29.06)	1	27.6
T_3	Spray with imidacloprid 17.8 SL @ 0.25 ml l^{-1} at 25 DAS	6.00 (14.14)	0.4	21.33 (27.47)	0	23.00 (28.60)	0.8	24.00 (29.29)	0.6	26.5
T_4	$T_1 + T_3$	5.66 (13.72)	0.6	16.33 (23.75)	0	18.67 (25.55)	0.6	19.33 (25.98)	0.6	40.8
T_5	$T_1 + T_2$	6.00 (14.14)	0	16.00 (23.54)	5.2	23.00 (28.63)	2.8	24.33 (29.51)	1.8	25.5
T_6	$T_1 + T_2 + T_3$	5.33 (13.33)	0	14.67 (22.41)	0	16.33 (23.79)	0.6	18.00 (25.05)	0.8	44.9
T_7	Untreated check	8.33 (16.77)	0.4	28.67 (32.30)	12.8	31.33 (34.00)	8.4	32.67 (34.82)	3.8	--
	S.Em.±	**0.72**	**0.02**	**1.39**	**0.39**	**1.21**	**0.25**	**1.30**	**0.11**	--
	C.D. (P=0.05)	**2.22**	**0.06**	**4.28**	**1.21**	**3.74**	**0.78**	**4.01**	**0.33**	--

PDI – Per cent disease incidence, DAS – Days after sowing, * - Figures in parentheses are arc sin transformed values

Table 2. Integrated management of leaf crinkle disease of blackgram with border rows of sorghum during first season

Tr. No.	Treatment	15 DAS		30 DAS		45 DAS		60 DAS		Decrease in PDI at 60 DAS over control
		PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	
T_1	Heat therapy of seeds	3.67 (11.01)	0.2	16.33 (23.80)	7.4	21.00 (27.20)	3.8	22.33 (28.17)	1	15.18
T_2	Seed treatment with imidacloprid 600 FS (10 ml/kg seeds)	4.33 (11.99)	0	17.67 (24.81)	2.2	21.33 (27.46)	1.6	22.67 (28.40)	0.6	13.91
T_3	Spray with imidacloprid 17.8 SL @ 0.25 ml/l at 25 DAS	6.67 (14.89)	0.2	16.67 (24.07)	0	19.33 (26.06)	0.6	20.33 (26.77)	0.6	22.78
T_4	$T_1 + T_3$	5.33 (13.26)	0	14.33 (22.22)	0	18.67 (25.57)	0.2	19.67 (26.27)	0.8	25.31
T_5	$T_1 + T_2$	5.67 (13.68)	0	13.67 (21.63)	2.2	20.33 (26.78)	1.4	22.33 (28.17)	1	15.18
T_6	$T_1 + T_2 + T_3$	4.33 (11.89)	0	12.00 (20.22)	0	15.67 (23.29)	0.4	16.67 (24.03)	0.6	36.70
T_7	Untreated check	7.67 (16.02)	0.4	20.67 (27.00)	7.2	25.33 (30.18)	4.6	26.33 (30.84)	2.2	--
	S.Em.±	**1.02**	**0.01**	**0.98**	**0.22**	**0.95**	**0.13**	**1.11**	**0.06**	--
	C.D. (P=0.05)	**3.13**	**0.03**	**3.03**	**0.69**	**2.92**	**0.41**	**3.41**	**0.19**	--

PDI – Per cent disease incidence, DAS – Days after sowing, * - Figures in parentheses are arc sin transformed values

18.67 and 19.67 at 30, 45 and 60 DAS respectively, which was also significantly superior over the control.

The highest aphid population of 0.4 three leaves^{-1} plant^{-1} were observed in untreated check (T_7) followed by 0.2 in T_1 (heat therapy of seeds) and T_3 (spray with imidacloprid 17.8 SL at 25 DAS), while no aphids were observed in other treatments at 15 DAS. In subsequent observations at 30, 45 and 60 DAS, T_3 (spray with imidacloprid 17.8 SL at 25 DAS), T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) and T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) recorded the lowest aphid population and these treatments were superior over control.

IDM of leaf crinkle disease in blackgram during second season

The results of the without border crop experiment recorded in Table 3 revealed that at 15 DAS, lowest disease incidence of 4.33 per cent was recorded in T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS), followed by PDI of 4.67 in T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) and 5.00 in T_1 (heat therapy of seeds) as compared to PDI of 8.33 in the untreated check (T_7). However, T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) recorded the least PDI of 15.33, 19.33 and 20.33 at 30, 45 and 60 DAS respectively, this was significantly superior over control with 41.50 per cent reduction over control at 60 DAS and it was also on par with T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) with PDI of 17.67, 20.00 and 20.67 at 30, 45 and 60 DAS respectively. Both treatments were significantly superior over the control.

Aphid population of 0.4 three leaf^{-1} plant^{-1} was recorded in untreated check (T_7), while T_3 (spray with imidacloprid 17.8 SL at 25 DAS) and T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) recorded 0.2 aphids and other treatments were free from aphids at 15 DAS. T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) and T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) recorded the lowest aphid population in subsequent observations at 30, 45 and 60 DAS and they were on par to each other and superior over control.

Sorghum bordered blackgram recorded the lowest disease incidence of 3.33 per cent in T_1 (heat treated seeds) followed by T_6 (heat therapy of seeds, seed treatment with imidacloprid 600 FS and spray with imidacloprid 17.8 SL at 25 DAS) and T_4 (heat therapy of seeds and spray with imidacloprid 17.8 SL at 25 DAS) with PDI of 4.00 and 4.67 respectively and all treatments were superior over control (T_7) with PDI of 7.67 at 15 DAS. Further, in subsequent observations at 30, 45 and 60 DAS, T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) recorded the least PDI of 12.67, 17.33 and 18.33, respectively which was significantly

Table 3. Integrated management of leaf crinkle disease of blackgram without border rows of sorghum during second season

Tr. No.	Treatment	15 DAS		30 DAS		45 DAS		60 DAS		Decrease in PDI at 60 DAS over control
		PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	PDI	Aphids 3 leaves^{-1} plant^{-1}	
T_1	Heat therapy of seeds	5.00 (12.87)	0	18.67 (25.52)	13.2	25.67 (30.40)	8.4	26.67 (31.06)	3	24.52
T_2	Seed treatment with imidacloprid 600 FS (10 ml/kg seeds)	6.33 (14.50)	0	21.67 (27.63)	5.8	24.67 (29.74)	4.4	25.33 (30.18)	1.2	28.30
T_3	Spray with imidacloprid 17.8 SL @ 0.25 ml/l at 25 DAS	7.00 (15.31)	0.2	22.33 (28.17)	0	24.33 (29.52)	0.6	25.00 (29.96)	1	29.24
T_4	$T_1 + T_3$	4.67 (12.45)	0.2	17.67 (24.76)	0	20.00 (26.51)	0.6	20.67 (26.99)	0.8	41.50
T_5	$T_1 + T_2$	6.00 (14.14)	0	16.33 (23.79)	5	24.00 (29.31)	3.2	25.33 (30.17)	1.4	28.30
T_6	$T_1 + T_2 + T_3$	4.33 (11.99)	0	15.33 (22.96)	0	19.33 (26.04)	0.4	20.33 (26.70)	0.6	42.45
T_7	Untreated check	8.33 (16.75)	0.4	27.67 (31.66)	13.4	34.33 (35.83)	9	35.33 (36.44)	3.4	--
	S.Em.±	**0.75**	**0.01**	**1.42**	**0.42**	**1.14**	**0.27**	**1.22**	**0.10**	--
	C.D. (P=0.05)	**2.32**	**0.03**	**4.37**	**1.28**	**3.51**	**0.85**	**3.76**	**0.32**	--

PDI – Per cent disease incidence, DAS – Days after sowing, * - Figures in parentheses are arc sin transformed values

superior over control with 38.21 per cent reduction over control at 60 DAS. This was followed by T_4 (heat therapy of seeds + spray with imidacloprid 17.8 SL at 25 DAS) with PDI of 15.00, 20.33 and 21.00 at 30, 45 and 60 DAS respectively, which was also significantly superior over the control.

Aphid population of 0.2 three leaf^{-1} plant^{-1} was recorded in untreated check (T_7), and T_3 (spray with imidacloprid 17.8 SL at 25 DAS), while other treatments were free from aphids at 15DAS. T_6 (heat therapy of seeds + seed treatment with imidacloprid 600 FS + spray with imidacloprid 17.8 SL at 25 DAS) and T_4 (heat therapy of

Table 4. Integrated management of leaf crinkle disease of blackgram with border rows of sorghum during second season

Tr. No.	Treatment	15 DAS		30 DAS		45 DAS		60 DAS		Decrease in PDI at 60 DAS over control
		PDI	Aphids three leaves^{-1} plant^{-1}	PDI	Aphids three leaves^{-1} plant^{-1}	PDI	Aphids three leaves^{-1} plant^{-1}	PDI	Aphids three leaves^{-1} plant^{-1}	
T_1	Heat therapy of seeds	3.33 (10.34)	0	16.00 (23.54)	7.2	23.67 (29.07)	4.6	24.33 (29.53)	1.4	17.99
T_2	Seed treatment with imidacloprid 600 FS (10 ml/kg seeds)	5.00 (12.87)	0	20.33 (26.72)	3	22.33 (28.16)	2.4	23.33 (28.85)	0.8	21.36
T_3	Spray with imidacloprid 17.8 SL @ 0.25 ml/l at 25 DAS	6.33 (14.50)	0.2	18.00 (25.07)	0	21.00 (27.25)	0.8	22.00 (27.93)	0.8	25.85
T_4	$T_1 + T_3$	4.67 (12.45)	0	15.00 (22.75)	0	20.33 (26.77)	0.4	21.00 (27.21)	1	29.22
T_5	$T_1 + T_2$	5.67 (13.75)	0	14.00 (21.89)	2.6	22.00 (27.93)	1.4	23.67 (29.07)	1	20.23
T_6	$T_1 + T_2 + T_3$	4.00 (11.47)	0	12.67 (20.78)	0	17.33 (24.56)	0.4	18.33 (25.28)	0.8	38.21
T_7	Untreated check	7.67 (16.02)	0.2	22.67 (28.40)	7.8	28.00 (31.90)	4.4	29.67 (32.96)	2.4	--
	S.Em.±	**0.81**	**0.006**	**1.17**	**0.23**	**1.05**	**0.14**	**1.20**	**0.07**	--
	C.D. (P=0.05)	**2.51**	**0.019**	**3.59**	**0.72**	**3.23**	**0.44**	**3.70**	**0.21**	--

PDI – Per cent disease incidence, DAS – Days after sowing, * - Figures in parentheses are arc sin transformed values

seeds + spray with imidacloprid 17.8 SL at 25 DAS) recorded the lowest aphid population in subsequent observations at 30, 45 and 60 DAS and they were on par to each other and superior over control (Table 4).

Seed treatment with chemicals mainly aimed for managing aphid vectors was practiced in experiment by Dubey (1981) and Bhardwaj *et al.* (1982), while imidacloprid in particular was used by Mote *et al*. (1993), Jarande and Dethe (1994) and Dandale *et al*. (2001).

Heat therapy of seeds to deactivate virus in seeds was followed by Kadian (1980), who followed dry heat therapy, wet heat therapy and solar heat therapy. Water bath at 55°C for 30 minutes (Sharma and Dubey, 1984), thermotherapy of infected seeds at 70°C for 10 minutes was effective (Chetan Joshi, 1998). Nageswara Rao (2002) reported that wet heat at 55°C for 30 minutes of blackgram seeds reduced the disease incidence and this with combination of systemic insecticide gave good result over single wet heat therapy.

Vector control through spraying of insecticides is one of the methods in integrated management to reduce the disease spread. Many workers (Kadian, 1980, Nageswara Rao, 2002, Ganapathy and Karuppiah, 2004, Rathore, 2009 and Punith Kumar, 2012) demonstrated the insect vector control by using insecticides. In present investigations combination of cultural practices (border row of sorghum), physical (heat therapy of seeds) and chemical treatments (seed treatment and spray with imidacloprid) gave good control of disease both in greengram and blackgram.

CONCLUSION

Effective management of leaf crinkle disease of blackgram crop can be achieved through combined use of sowing heat therapied insecticide treated seeds spraying the crop with systemic insecticide and bordering the field with tall crop. These treatments are helpful in reducing the initial inoculum, vector population, spread of the virus and blocking of vector movement, respectively.

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8. Significant Achievements of the Nominee
9. Awards & Honors, including Scientific Leaderships
   (i) International Awards
   (ii) National Honor/Awards
   (iii) Other Honors/Awards
   (iv) Scientific Leadership
10. Publications

List below 20 best research publications in the descending order of Journals of impact and high standing (as identified by the NAAS): indicating (i) name of author(s), (ii) year, (iii) title, (iv) name of journal, volume no. and page nos.			
S.No.	List of Publications*	NAAS Journal ID	NAAS Rating

*Note: *List of Journals identified by the Academy and their assigned weightage is available on Academy web site http://www.naasindia.org*

11. Please attach additional list of publication
12. Papers published in Journal of Eco-friendly Agriculture

I certify that the information given in the form is correct.

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