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(Doctor's Agricultural and Horticultural Development Society)
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www.ecoagrijournal.com
E-mail : ecofriendlyagriculture@gmail.com
ecofiriendlyapproaches@gmail.com

Summary Proceedings and Recommendations of the 'International Conference on Sustainable Organic Agri-Horti Systems

A three day International Conference on Sustainable Organic Agri-Horti Systems was organized by Doctor's Krishi Evam Bagwani Vikas Sanstha, Lucknow from 28 to 30 November, 2018 in the Auditorium of Chatrapati Shahuji Maharaj Shodh Evam Prashikshan Sansthan, Bhagidari Bhawan, Near Taj Hotel, Gomti Nagar, Lucknow (U.P.)

Inauguration Session

The inauguration function of the international conference was organized on 28th November, 2018. The function was inaugurated by Smt. Swati Singh, Hon'ble Minister of State (Independent Charge) for NRI, Food Control, Agriculture Export, Agricultural Marketing, Agricultural Foreign Trade, Women and Child Welfare Government of U.P. The dignitaries present on the dias were Dr. R.K. Pathak, Ex Director, CISH, Lucknow, Dr. R. P. Srivastava, Organizing Secretary, Dr. Rajiv Dutta, Vice-president of the Society and Dr. A. K. Misra Chief Editor of the Journal of Eco-friendly Agriculture. At the very outset, the chief guest and others on the dias were welcomed by presenting bouquet and honoured by presenting shawl, thereafter lighting of lamp was done by all the guest at the dias.

Miss Aavya Saxena of the K. K. Academy School, Indira Nagar, Lucknow recited the Saraswati Vandana.

Dr. R.P. Srivastava, Organizing Secretary of the conference & Ex Director, CISH, Lucknow presented his welcome address. He, on behalf of the organizing committee and steering committee, welcomed the dignitaries on the dias, delegates and all the guests attending the conference. He also welcomed the Chief Collaborator of the conference National Centre of Organic Farming, Ghaziabad for support. He also welcomed ICAR-CISH Lucknow, CSIR-CIMAP Lucknow, Dept. of Horticulture and Food Processing U.P. and Directorate of Plant Protection, Faridabad. He also welcomed all the executive committee members of the society viz. Dr. M.D. Pathak, Dr. Rajiv Dutta, Dr. Rajesh Kumar, Dr. A.K. Misra and Dr. Jagdish Chandra. He appreciated Dr. A. K. Misra for his untiring efforts in organizing the conference and compiling the souvenir with the cooperation of Dr. Ajay Verma, Dr. Gundappa and Dr. P.K. Shukla.

He also welcomed Dr. D.K. Tandon, in-charge of the Transport and Accommodation Committee. He also welcomed Dr. Om Prakash, Dr. B. K. Pandey, Mr. Yash Bajpai, Mr. Prasson Kumar Mahwani, Mr. Alok Srivastava, Mr. Abhay Dixit, Dr. L.P. Yadav, Mr. R.P. Shankhwar and Dr. Rajesh Kumar for their untiring support.

Dr. Srivastava informed the house about the history of the society and work conducted during the past two decades. The Society has provided excellent opportunity for exchange of newer ideas on eco-friendly approaches for further research and development work related to organic farming laying special emphasis on using bio-pesticides, bio-agents and bio-fertilizers to manage crop pests, soil health and environment in general. He further appraised the audience that the Society is publishing Journal of Eco-friendly Agriculture since 2006 and thus completed 13 years of its publication.

The steering and organizing committee of our Society has instituted various awards to honour outstanding scientists, professors and researchers who have made significant research contributions in the field of bio-pesticides, bio-fertilizers and as also on organic farming. The Society has also decided to honour farmers engaged in organic farming and producing maximum crop yield per unit area with *Jaivik Krishi Award*. On this occasion, the Organizing Committee has decided to honour eminent scientists for the first time by bestowing fellowship of the Society (Fellow of Doctor's Agriculture and Horticulture Development Society, FDAHDS).

With this brief introduction of the society's activities, I once again welcome you all to this conference with the hope that everyone will be benefitted with the deliberations during these three days. I trust that the research contributions reported herein by scientists involved in eco-friendly crop management and organic farming will pave way to find strategies on sustainable organic Agri-Horti systems.

The chief guest Smt. Swati Singh, released the following publications for the benefits of the participants.

(I) Aam Ke Bagon ki Kahani- by Dr. R. P. Srivastava

(II) Souvenir of the conference

(III) July, 2018 issue of the Journal of Eco-friendly Agriculture.

Life Time Achievement Award

The anchor, Dr. Anju Bajpai, Principal Scientist, CISH, Lucknow then announced Society's decision to honour 5 eminent Scientists for the Life Time Achievement Awards. The award includes a certificate, citation, Memento, Bouquet and Shawl.

The Life Time Achievement Awards were presented by Mrs. Swati Singh, Hon'ble Minister for the following scientists for their meritorious work-

- Dr. (Prof.) R. K. Pathak, Ex Director, CISH, Lucknow
- Dr. S. D. Sawant, Director, ICAR-NRC Grapes, Pune
- Dr. (Ms.) Chandish R. Ballal, Director ICAR-National Bureau of Agriculture Insect Resources, Bangaluru
- Prof. P. K. Seth, Ex Director, Indian Institute of Toxicological Research (IITR), Lucknow
- Dr. A. K. Misra, Ex Project Co-ordinator and Head, Crop Protection, CISH, Lucknow

Fellow of Doctor's Agriculture and Horticulture Development Society (FDAHDS)

Smt. Swati Singh, Hon'ble Minister, conferred the FDAHDS to following 6 scientists. The award is being given for the first time by the society.

- Dr. R. A. Balkai, Head, Dept. of Agriculture, Entomology, University of Agricultural Sciences, Dharwad
- Dr. (Mrs.) Pratibha Sharma, Ex Professor, Plant Pathology, IARI, New Delhi.
- Dr. P. S. Singh, Professor and Head, Dept. of Entomology and Agricultural Zoology, BHU, Varanasi
- Dr. Pankaj Biaswar, Senior Scientist, Plant Pathology, ICAR Research Complex for NEH Region, Umiam, Meghalaya
- Dr. A. P. Dwivedi, Senior Scientist (Agronomy), ICAR-IISR, Lucknow
- Dr. H. B. Singh, Professor, Plant Pathology, BHU, Varanasi

Jaivik Krish Award

Smt. Swati Singh, Hon'ble Minister also gave two *Jaivik Krishi Award* to two progressive farmers.

- Shri Balraj Singh, Village: Pandori, Dasuya, Hoshiyarpur, Punjab
- Shri Pankaj Kumar Verma, Vaishali, Ghaziabad

After the award ceremony, Chief Guest, Smt. Swati Singh, Hon'ble Minister of State (Independent Charge) of NRI, Food Control, Agriculture Export, Agriculture Marketing, Agriculture Foreign Trade and the State Minister in the ministry of Women and Child Welfare in the Govt. of Uttar Pradesh inaugurated the conference on 28th November, 2018.

Welcomed the large gathering, comprising of about 250 scientists, researchers, professors, several extension agencies, development workers, progressive organic Agri-Horti growers and entrepreneurs, in the conference, She congratulated the organizers of the event for holding this conference on Sustainable Organic Agri-Horti Systems solely aimed at a theme of revisiting organic farming in the country. She expressed confidence that the scientists at the end of the event would come forward with organic farming based technologies that could double the income of farming community engaged in producing cereals and horticultural crops.

The chief guest, while speaking on the importance of organic farming said that the organic farming is not a new concept and it was being practiced worldwide in the past till the advent of toxic pesticides leading to quick knock down effect of crop pests. But due to toxic residue in the soil and pollution in the environment having adverse effect on human health and soil health. She requested the scientists to revert back towards the environment friendly techniques of crop management.

Smt. Swati Singh Ji insisted on laying special attention on integrated farming employing bio-pesticides, bio-agents and bio-fertilizers in the cropping systems. Smt. Singh also expressed her concern on the soft pulp near the stone in Dashehari variety of mango. This, in fact, is responsible for its poor storage quality which is hindering the export of mangoes. She expected that the panel of scientists attending the conference will take a note of the problem and try to come out with the solutions so that Dashehari mangoes would be exported from this state. At the end she wished the conference all the success.

While proposing the vote of thanks, Dr. A. K. Misra, Chief Editor of the journal told that a number of organizations are now working on the use of bio-pesticides, bio-agents and bio-fertilizers, water management, IPM, etc. and hence there is an urgent need to consolidate the gains besides coordinating the efforts of different organizations. He thanked Smt. Swati Singh, Hon'ble Minister for accepting the invitation to act as chief guest of the function. He also thanked Dr. Rajiv Dutta, Vice-president of the Society for organizing this function. He congratulated all the awardees, Dr. R. K. Pathak, Ex Director, CISH, Lucknow, Dr. S. D. Sawant, Director ICAR-NRC Grapes, Pune, Dr. Chandish Ballal Director, ICAR-National Bureau of Agricultural Insect Resources, Bangaluru, Prof. P. K. Seth, Ex Director CSIR-IITR, Lucknow and In-charge Biotech Park, Dr. K. K. Kumar Ex Director ICAR-NRC, Litchi, Muzaffarpur, Bihar.

Besides, Dr. A. K. Missra also thanked Dr. R. A. Balkai, Head, Department of Agricultural Entomology, UAS, Dharwad, Dr. P. S. Singh, Professor and Head, Entomology, BHU Varanasi, Dr. Pankaj Baiswar, Scientist, ICAR-Research Complex for NEH Region, Meghalaya, Dr. A. P. Dwivedi, Scientist, ICAR-IISR Lucknow and Dr. H. B. Singh, Professor, Department of Plant Pathology, BHU, Varanasi. The progressive organic farmers Shri Balraj Singh, Punjab and Shri Pankaj Kumar Verma, Ghaziabad were thanked for their participation.

Dr. A. K. Misra also thanked Dr. Om Prakash, Ex PC, CISH, Lucknow, Dr. B. K. Pandey, PS, ICAR HQ, New Delhi, Dr. P. K. Shukla, Dr. Anju Bajpai, Dr. Ajay Verma, Dr. D. K. Tandon, Dr. Gundappa, Dr. Rajesh Kumar, Dr. L. P. Yadav, Mr. Abhay Dixit, Mr. R. P. Shankhwar, Mr. Prem Kumar and Mr. H. Rehman for their valuable support in organizing the conference and make it a success. He specially thanked Dr. S. Rajan, Director ICAR-CISH, for attending the conference and extending valuable help. He also thanked the scientists and students of CIMAP for attending the function and gave valuable support. In the end he thanked the editorial board members of the souvenir for their dedicated service in bringing out this document.

28 November 2018

Session- I : Keynote Lectures

Chairman : Dr. Gadi V. P. Reddy

Co-chairman : Dr. R. K. Pathak

Rapporteurs : Dr. (Mrs.) Anju Bajpai

Keynote Lectures

- Recent trends and future prospects in insect pest control in cereal crops of Montana- *Gadi V.P. Reddy.*
- Challenges to and opportunities for biological control practices in India- *Chandish R. Ballal*
- Innovative Technology- A ray of hope for sustainable agriculture and nutrition - *R.K. Pathak*
- Current scenario of organic fertilizers in Indian agriculture- *Dr. Rashmi Singh*
- Neem coated urea as a source of nitrogen for plants- *Bijay Singh*

Dr. Gadi V. P. Reddy, Head of the Plant Protection Division, Montana State University, Bozeman, Western, Triangle Agricultural Research Centre, Conard, USA, spoke on the recent trends and future prospects in insect pest control in cereal crops of Montana. Wheat is the principal grain produced in Montana. This crop suffers a colossal loss due to insect pests. The entomology/insect ecology programme unit of the University has been developing sustainable organic insect pest management for major pests of cereal crops.

Dr. Chandish R. Ballal, Director of ICAR-National Bureau of Agricultural Insect Resources, Bangaluru spoke on challenges and opportunities for biological control practices in India. She spoke that majority of the studies pointed that insect enemy richness enhances prey suppression. Some of the studies do indicate that natural enemy diversity can even lead to weakened prey suppression due to factors like intraquild predation, behavioural interference and negative selection effects. She narrated the successful example in classical biological control. She gave special emphasis on the bio-agents like *Dipa aphidovora, Micromus igorotus, Encarsia flavoseutellum, Trichogramma chilonis* and *Cryptolaimus montrouzieri* etc.

Dr. Pathak, Ex Director, ICAR-CISH, Lucknow spoke on the innovative technologies: a ray of hope for sustainable agriculture and nutrition. He spoke that in the recent 6-7 decades due to indiscriminate use of agro-chemicals, the water and soil, and nearby environment has been polluted many folds. Hence, the food we consumed, water we drink and air we breathe are polluted. He said that cosmic farming based on systematic and synergistic harnessing of solar energies is the answer to overcome these problems. The use of BD calendar for farm activities, encouraging plantations for greening the area, creation of water bodies for harvesting of rain water using cow products bio-enhancer, organic mulching and homa farming will improve environment health in general.

Dr. Rashmi Singh from National Centre of Organic Farming, Ghaziabad spoke on the current scenario of organic fertilizer in Indian agriculture. She spoke that organic carbon is the backbone of soil health and its fertility. This organic carbon in the soil is declining and can only be recharged with the application of organic fertilizers in the soil. In India, popular organic fertilizers are city compost vermi compost, phosphate rich organic manure (P Rom) and organic manure. Green manuring is also an excellent component to recharge the soil organic carbon.

Dr. Bijay Singh from PAU, Ludhiana spoke on neem coated urea as a source of nitrogen for plants. He said that urea coated with neem cake

(200 kg per ton) (NCU) or neem oil (NOCU) possess nitrification inhibition properties and can increase yield and nitrogen use efficiency in field crops more than untreated urea. He said that in rice and wheat to which more than 50 percent of the urea is consumed in India, is applied, mean increase in grain yield by replacing urea with NCU or NOCU is 5-6 percent in plots managed by researchers. It is pointed out that nitrification inhibitors work better in acidic soils than in neutral or alkaline soils, in course textured soils than in fine textured soils and in irrigated crops than in rainfed crops. Thus, on overall basis replacing all urea being supplied to farmers in the country with NOCU is not likely to show a significant impact on food production levels.

28 November 2018

Session- II : Keynote Lectures

Chairman : Dr. S. Rajan

Co-chairman : Dr. (Mrs.) Chandish R. Ballal

Rapporteur : Dr. P.K. Shukla

Keynote Lectures

- Role of plant growth promoting rhizobacteria (PGPR) in fruit culture - *V.K. Tripathi*
- Sustainable approaches for production of pesticides residue free grapes- *S. D. Sawant*

Dr. V. K. Tripathi, Professor at CSA University, Kanpur, presented his paper on role of plant growth promoting rhizobacteria (PGPR) in fruit culture. He said that the beneficial effect of rhizosphere bacteria have most often been based on increase in plant growth, faster seed germination, better seedling emergence, enhanced nodulation and nitrogen fixation in leguminous crops and suppression of plant diseases. Plant growth promoting rhizobacteria are commonly used as inoculants for improving the growth and yield of agricultural crops. However, screening for the selection of effective PGPR strains is very critical.

Dr. S. D. Sawant, Director, NRC for Grapes, Pune spoke on sustainable approaches for production of pesticides residue free grapes. He told that due to more awareness about food safety compliance to stringent MRL (Maximum Residue Limits) requirements of E.U. countries is not enough and demand for zero residue grapes is increasing worldwide. This is possible by rouging out of primary inoculums of downy mildew and powdery mildew should be done before fruit pruning. Avoid rainy weather during fruit pruning and early growth of new shoots by delaying pruning after 15th October. Drenching root zone with *Trichoderma* or *Bacillus subtalis* to achieve systemically acquired resistance use of bio control agents for the control of powdery mildew is also recommended in alternation with sulphur sprays.

Dr. Shailendra Rajan, Director, ICAR-CISH, Lucknow spoke on mango crop.

Recommendations

- Combination of bio-control agents to enhance suppression of multiple crop pests.
- Research biodiversity of pests and natural enemies.
- Integrated and popularization of organic farming including cosmic farming will help in harassing indigenous knowledge for sustainable agriculture.
- Silt specific nutrient management principal with reference to NCU or NOCU expected to higher crop production and lower fertilizer applicable.

29 November 2018

Session- III: Status and Policy Regulation in Pest Management

Chairman : Dr. Naveen Kumar Arora

Co-chairman : Dr. S. N. Sushil

Rapporteur : Dr. Gundappa and Dr. Deeksha Joshi

Keynote Lecture

- Application of beneficial rhizobacteria for enhancing crop productivity of saline soil along with combating phyto pathogen - *Naveen Kumar Arora*

Lead Lectures

- Plant quarantine regulations in India: emerging issues and way forward- *S. N. Sushil*
- Integrated pest management for sustainable organic agri-horti system - *K. K. Kumar*
- Soil arthropods in sugarcane production system - *Sharmila Roy*
- Impact of climate change on potential distribution of mango insect pests in India- *Gundappa*

Oral Presentations

- Organic farming management under agri-horti system- *Jagat Singh*
- Efficacy of different management practices on the incidence of guava bark eating caterpillar *Indarbela sp. Gundappa*
- Integrated approaches for plant disease management in organic farming: strengths and challenges - *Deeksha Joshi.*
- Newer insights into identification of incitants of mango malformation through 18S amplicon sequencing and metabolite analysis- *Anju Bajpai*

Dr. Naveen Kumar Arora, Chief Scientist, BBA University, Lucknow gave a keynote lecture on the application of beneficial rhizobacteria for enhancing crop productivity of saline soil along with combating phyto-pathogens. He said that plants were isolated and selected. These strains were identified as fluorescent pseudomonads and rhizobia which gives phosphate and zinc solubilisation, production of siderophore, indole acetic acid and exo-polysaccharides even at high salt concentrations. He also observed that selected salt tolerant strains showed strong bio-control activity against *Macrophomina phaseolina* which cause charcoal rot.

Dr. Sushil, ICAR-IISR, Lucknow spoke on the plant quarantine regulations in India: emerging issues and way forward. He said that the liberalized global trade, import/export of plants and plant material are likely to group manifolds thereby warranting fastrack plant quarantine services. Based on pest risk analysis import of various agricultural commodities is either prohibited or restricted for entry. There is also need to regulate seed movement of certain commodities from one region to other to restrict pest movement.

Dr. K. K. Kumar, Ex Director, ICAR-NRC, Litchi, Muzzafarpur, Bihar spoke on integrated pest management for sustainable organic agri-horti systems. He spoke that biological pest suppression, botanicals, semi chemicals and attractants, agronomical manipulations, resistant cultivators etc. are some of the common components of IPM.

Dr. Sharmila Roy, ICAR-IISR, Lucknow spoke on soil arthropods in sugarcane production systems. She spoke that monocropping, tillage burning of trashes and uses of weedicides and pesticides reduce the soil arthropods diversity.

Dr. Jagat Singh, Joint Director in National Centre for Organic Farming in Ghaziabad spoke on the organic farming management under agri-horti systems. He spoke on the overall management in the agricultural and horticultural crops by organic farming by using bio-fertilizers, bio-pesticides etc.

Dr. Gundappa, ICAR-CISH, Lucknow spoke on the impact of climate change on potential distribution of mango insect pests in India. According to him climate factor like temperature and precipitation in particular have a very strong influence on the development, reproduction and survival of insect pest and pathogens.

Dr. Deeksha Joshi, ICAR-IISR, Lucknow spoke on the integrated approaches for plant disease management in organic farming, strengths and challenges. She narrated that at the start of civilization farming was predominantly based on the principal of organic farming and we used to live with nature. Now due to development of chemical fertilizers and chemical pesticides, the fine balance was disturbed and it caused lot of impact on the environment and human health.

Dr. Anju Bajpai, ICAR-CISH, Lucknow spoke on the newer insights into identification of incitants of mango malformation through 18 samplicon sequencing and metabolite analysis. The malformed sample was used for genomic DNA isolation and sequencing of 18 S r DNA on Illumina plate from using 2X250 chemistry which resulted in generation of 755, 054 PE reads.

29 November 2018

Session- IV: Integrated Pest Management

Chairman : Dr. Naveen Kumar Arora

Co-chairman : Dr. S. N. Sushil

Rapporteurs : Dr. Gundappa and Dr. Deeksha Joshi

Lead Lectures

- Development of decision support tools for effective pest management- *Subhash Chander*
- Development of models to predict insect pest populations: An eco-friendly tactic for pest management - *R.A. Balakai.*

Oral Presentations

- Harnessing the potential of smart agriculture, biological for suitable organic agri-horti systems: challenges and opportunities- *Dr. Virendra Arora.*
- Weather based prediction model and forewarning on foliages diseases of tomato- *Adam Kamei*

Dr. Subhash Chander, ICAR-IARI, New Delhi spoke on the development of decision support tools for effective pest management. He said that surveillance is the backbone of the IPM. Remote sensing can be utilized for pest monitoring in large areas. Besides natural enemy based monitoring plants help to reduce dependence on pesticides. He further said that simulation models have been used for several applications in the area of pest management which helped to increase the efficiency of field research greatly.

Dr. R. A. Balikai, UAS Dharwad spoke on development of models to predict insect pest populations- An eco-friendly tactic for pest management. He spoke that the importance of a weather based forewarning models of insect pests can be emphasized only by its ability to forecast their attack well in advance to plan the management schedules. The development prediction/forewarning models of various insect pests in different agro-climate zone on field and horticultural crops have been presented and discussed.

Dr. Virendra Arora of Bio Organic Solutions, New Delhi gave a lecture on urea as biological tool in agriculture.

29 November 2018

Session- V

Biological Control of Pests for Sustainable Agri-Horti Systems

Chairman : Dr. Pradyumn Kumar, New Delhi

Co-chairman : Dr. Sharad Mohan, IARI, New Delhi

Rapporteur : Dr. Shabistana Nisar, NCIPM, New Delhi

Lead Lectures

- Removal of bottlenecks in commercial production of Trichogramma spp. -*Dr. Pradyumn Kumar*
- Potential of entomopathogenic nematodes as promising alternative for insect pest management- *Dr. Sharad Mohan*
- Role of *Coccinella septempunctata* in aphid management vis a vis host plants - *Dr. Shabistana Nisar*
- Efficacy of secondary metabolites of *Trichoderma harzianum* against mango wilt pathogen *Ceratocystys fimbriata - Dr. P. K. Shukla*
- *Trichoderma* spp. its role in organic farming for sustainability and plant disease management - *Dr. Ramji Lal*
- In vitro efficacy of *Trichoderma viridae* and *T. harzianum* against *F. oxysporum* f. spp. cicero collected from different localities - *Dr. Shashi Tiwari*

Dr. Pradyumn Kumar, Emeritus Scientist, ICAR-IARI, New Delhi gave a lecture on removal of bottlenecks in commercial productions of *Trichogramma* spp. He gave an account of rearing of *Corcyra* in the grain which should be ground a day before its use. He also discussed that the smell emanating from *Corcyra* culture attracts *Bracon* adults which parasitized the *Corcyra* larva across the cloth. The embryo of *Corcyra* eggs are killed by exposing them to UV rays. The trichocards should be shipped with adequate cool packs in an insulated box to prevent emergence of paracitoid adults during transit.

Dr. Sharad Mohan, ICAR-IARI, New Delhi spoke on potential of entomopathogenic nematodes as promising alternative insect pest management. He explained that *Steinernema* and *Heterorhabditis* along with their symbiotically associated bacteria *Xenorhabdus* and *Photorhabdus* are useful in IPM technology. EPNs can recycle and persists in soil to keep the insect pest under control. A broadcast application rate of one billion nematodes per acre is generally recommended. For smaller areas the recommended application rate is 250000 per m^2. White grubs damaging sugarcane can be reduced by this technology to 60-75 percent.

Dr. Shabistana Nisar, Aligarh Muslim University, Aligarh gave a lecture on role of *Coccinella septempunctata* in aphid management vis-a-vis host plant. The potential role of *C. septempunctata* on three species of aphids, viz *B. brassicae*, *M. persicae* and *L erysimi* infested cabbage, cauliflower and mustard was assessed. It was found that larval predation was found higher in *M. persicae* over other aphid species.

Dr. P. K. Shukla, Scientist, ICAR-CISH, Lucknow spoke on efficiency of secondary metabolites of *Trichoderma harzianum* against mango wilt pathogen *Ceratocystis fimbriata.* Potential CISH *Tricoderma harzianum* strain 12 (Th-12) was tested against the *C. fimbriata* using dual culture techniques. This gave very emerging results. The culture filtrate of Th-12 were found effective to varying extents and extends up to 20 days. Complete suppression of *C. fimbriata* was observed only at 10 percent concentration.

Dr. Ramji Lal, ICAR-IISR, Lucknow spoke on *Trichoderma* species its role in organic farming for sustainability and plant disease management. In organic farming soil, and water management practices like legume based crop rotations, inter crops residue recycling, use of bio-fertilizer, bio-agents, green manures, compost/vermi compost are employed for sustaining natural resources, agro-ecosystems and management of plant diseases. *Trichoderma* sp. are capable of colonizing/multiplying on farm yard manure (FYM), cowdung, vermi compost, etc. The population of *Trichoderma* in FYM pit can reach upto >10^8 cfu/g in air dried FYM.

Dr. Shashi Tiwari, SHUOATS Prayagraj spoke on the *in vitro* efficacy of *Tricoderma viride* and *Trichodrma harzianum* against *Fusarim oxysporum* collected from different localities. It was observed that *T. virdae* and *T. harzianum* were not able to show any inhibitory effect. *T. viride* had moderate inhibition.

Recommendations

- Validation is most important part for pest modelling. Models can be used to derive location specific EILs.
- Thermal Constant Concept and Mechanistic approach should be given importance for developing universal applicability of IPM programmes.
- To overcome the drawbacks for commercial success of *Trichogramma* it is imperative to plan a year round calendar for production, so that they are readily available at the time of need.
- The over populated ratio of egg in food should be avoided for enhancing the production of *Trichogramma*.
- Because *Trichogramma* are live beneficial organisms, their packaging and shipment should be implemented with great care.
- Efforts should be made to increase awareness within the farmers about the benefits of using entomopathogenic nematode-based products for insect pest management.
- Identification and development of species-specific strains of Cocconelids should be strengthened and given importance.
- For mass multiplication of *Coccinella septempunciata* aphid species *Lipaphis* erysimi reared on cauliflower can be used.
- Farmers should be made aware for identifying mango wilt by distributing information bulletins so that they can timely prevent the trees from wilting by use of *Trichoderma* spp.

29 November 2018

Session- VI : Bio Pesticides for Sustainable Agri-Horti System

Chairman : Dr. M. Y. Zargar

Co-chairman : Dr. (Mrs.) P. D. Kamala Jayanthi

Rapporteurs : Dr. A. P. Dwivedi and Dr. A. K. Bhatacharya

Lead Lectures

- Bio pesticides: A safer and viable approach in pest management- *S. S. Pathania*
- Ecological chemistry of insect-plant interactions- *P. D. Kamala Jayanthi*
- Institutional Intervention for promotion or organic agriculture in mountainous state of Jammu & Kashmir -*M. Y. Zargar*

Oral Presentation

- Chitin (Chitinases-biostimulator) influence the plant microbial interaction, plant defence response against biotic and abiotic stresses and enhancement of crop yield: An overview - A. P. Dwivedi

The first lecture was given by Dr. S. S. Pathania, SKUAJT Srinagar on biopesticides: A safer and viable approach in pest management. He said that to minimize the ill effect of chemical pesticides, bio pesticides have long been rated as alternate to chemical pesticides.

Dr. Kamala Jayanthi, ICAR-IIHR, Bangaluru spoke on the ecological chemistry of insect plant interactions. She said that of several natural processes available for IPM, phytosemiochemcials, *viz* kairomones, pheromones, are not been much exploited inspite of their enormous ability to strengthen IPM programmes. A simple and efficient in silico method for estimating the kairomone efficiency of host cues for chemical ecology studies was standardized.

Dr. M. Y. Zargar informs that a robust microbial consortium known as Shalimar Microbe has been developed for rabbit compositing of solid waste under temperature conditions. A locally isolated cold tolerant *Eisenia foetida* worm species for vermi-compost preparation in Ladakh has also been obtained.

Dr. A.P. Dwivedi, ICAR-IISR, Lucknow spoke on chitin influences the plant microbial interaction, plant defence response against biotic and abiotic stresses and enhancement of crop yield. He told that chitin based treatment augment and amplify the action of beneficial chitinolytic microbes and chitin based products can improve crop yield.

Recommendations

- Bio-pesticides available in the market should not be spurious and need to be checked regularly.
- Instead of trapping male mango fruit flies, female flies can be trapped to reduce the population.
- Organic agriculture must be promoted in hilly areas of Jammu & Kashmir.
- Low molecular weight biostimulator (chitin) can be used for better germination.

30 November 2018

Session- VII : Microbials for Sustainable Agri-Horti System

Chairman : Dr. (Mrs.) Neelima Garg

Co-chairman : Dr. (Mrs.) Indu S. Sawant

Rapporteurs : Dr. Bharti Killadi and Dr. Akanksha Singh

Lead Lectures

- Microbial insecticides for insect pest management in organic farming- *Vinay K. Kalia*
- Role of microorganism in reducing fungicides use and their residues in grapses- *Indu S Sawant*
- Microbial characterization of organic preparations- *Neelima Garg*

Oral Presentations

- Microbial degradation of imidacloprid in mango orchard soil- *A. K. Bhattacherjee*
- Postharvest dip treatment of *Bacilus subtilis* for maintaining quality and shelf life of guava cv. Allahabad Safeda- *Bharti Killadi*

Dr. Vinay Kalia, ICAR-IARI, New Delhi spoke on microbial insecticides for insect pest management in organic farming. She said that about 775 bio-pesticides active ingredients and 700 products have been registered worldwide. In India, only 12 bio-pesticides have been registered, out of these Bt represents the most successful. Besides EPNs are ubiquitous and have wide host range, host location searching/locating capability which make them potential bio-pesticides.

Dr. Indu S. Sawant, ICAR-NRC, Grapes, Pune spoke on the role of microorganisms in reducing fungicides use and their residues in grapes. Among various diseases, powdery mildew disease is caused by the biotrophic, obligate pathogen *Erysiphe necator* and cause substantial qualitative and quantitative losses. Hence, fungicides are being used to control this disease. To control this disease ICAR-NRCG has screened 34-*Trichoderma* and 293 bacterial isolates for biological control programme. The result indicated the *T, afroharzianum* strain. NAIMCC-F-01938 and *Bacillus licheniformes* TL-171 can be used in alteration with sulphur for the control of powdery mildew.

Dr. Neelima Garg, ICAR-CISH, Lucknow spoke on the microbial characterization of organic preparations. She told that organic farming system rely on crop rotation, crop residues, animal manures, legumes, green manure, panchagavya farming, biodynamic farming, etc.

Dr. A. K. Bhattacherjee, ICAR-CISH, Lucknow spoke on the microbial degradation of imidacloprid in mango orchard soil. He isolated 8 bacteria from mango soil, containing imidacloprid residues. Among them the bacterium CISH Bac2 was identified as *Pseudomonas mosseli* strain L-27 which was found most effective in degrading imidacloprid.

Dr. Bharti Killadi, ICAR-CISH Lucknow spoke on postharvest drip treatment of *Bacillus subtilis* for maintaining quality and shelf life of guava. Guava fruits were subjected to postharvest dip treatment for 30 minutes with 4 strains of *B. subtilis* dip solution. The fruits were found glossy, better in quality and taste.

Recommendations

- CIB should revise guidelines for registration of known microorganisms like *Bacillus subtills, B. anylotiquefaciens, B. lichenforms, Trichoderma* species which do not have any safety concerns.
- All tested microbial effective strains should be deposited in a national repository especially at NBAIM, Bangaluru as safe deposits to ensure that they are preserved for future use.

30 November 2018

Session- VIII : Integrated Nutrient Management

Chairman : Dr. Alok Kalra

Rapporteur : Dr. Tarun Adak

Lead Lectures

- Equipping organic farming in MAPs: CIMAPs scientific interventions- *Alok Kalra*
- Bio-enhancer for soil, plant health and insect pest management in organic production of horticultural crops - *R.A. Ram*
- Bio-dynamic agriculture: An advance stage of organic farming- R.A. Ram
- Improvement in yield and quality of mango cv. Mallika trough soil and foliar nutrition of zinc supplements- *S. K. Shukla*

Oral Presentations

- Assessment of different irrigation levels on quality production of headed back guava cv. Lalit under high density plantation- V.K. Singh
- Status of two hundred mango orchards based on some soil indicators- *Tarun Adak*
- Impact of organic manures and moisture conservation practices on root yield, nutrient uptake and economics of Ashwagandha (*Withania somnifera* Dunal.) under water stress conditions- *Kaushal Kumar*
- Medicinal and aromatic plant scenario in India- *Sanjay Kumar*

Dr. Alok Kalra, CSIR-CIMAP, Lucknow spoke on equipping organic farming in MAPs : CIMAP's scientists interventions. The CIMAP has developed a complete recycling package for vermicompost. The major benefits being faster compositing period and nutrient rich vermicopost, a nutrient advantage of about 100-150 percent over the most commonly used FYM. Plant growth promoter like calliterpenones has been tested for induction of rooting in stem cuttings.

Dr. Ram Awadh Ram, ICAR-CISH, Lucknow spoke on bio-enhancers for soil plant health and IPM in organic production of horticultural crops. He informed that in organic systems. There are few effective preparations such as BD-500, BD-501, cow pat pit, BD liquid manure/bio pesticides and Homa organic farming. Studies done on bio-enhancer indicated that there is immense scope of its promotion in organic agriculture.

Dr. R. A. Ram in another paper namely bio-dynamic agriculture: an advance stage of organic farming told that this is a super organic farming system which emerges from cosmos. He also observed that Mother Earth, cow and plants in a synergistic manner are important in various crop productions.

Dr. S. K. Shukla, ICAR-CISH, Lucknow he spoke on improvement in yield and quality of mango cv. Mallika through soil and foliar nutrition of zinc supplements. Zinc deficiency caused decrease in mango quality production which effects in leaf size, plant growth etc. Soil application and foliar spray of Zn is recommended to overcome these problems. Fruit samples from Zn treated fruits were analyzed for various fruit characters with valuable useful results.

Dr. V. K. Singh, ICAR-CISH, Lucknow spoke on assessment of different irrigation levels on quality production of headed back guava cv. Lalit under high density plantation. The experimental plots were irrigated with drip irrigation system having two emitters per plant of 8LPH capacity based on 4 irrigation levels of Pan evaporation (PE). Mulching was done to recover 40 percent area under tree canopy. The results indicated enhancement of flowering and maximum fruit yield.

Dr. P. V. Sindhu, College of Horticulture, Kerala Agriculture University spoke on influence on organic and inorganic manuring on biomass yield, quality and economics of Kalmegh. The experiment was conducted with vermi compost, caster cake and NPK. It was observed that INP (NPK @ 80:40:20 Kg/hac) along with bio-fertilizers and Jivamrut recorded higher biomass yield.

Dr. Sanjay Kumar, CSIR-CIMAP, Lucknow spoke on medicinal and aromatic plant scenario in India. He informed that the major plants that are being cultivated in various parts of the country are menthol, mint, Geranium, Lemongrass, Vetiver and Palmarosa, Kalmegh, Ashwagandha Senna, Sarpgandha, Isabgol and Sataver.

Dr. Kaushal Kumar, CSA Agricultural University & Technology Kanpur spoke on impact of organic manure and moisture conservation practices on root, yield, nutrient uptake and economics of Ashwagandha under water stress conditions. The treatment consists of FYM, vermi compost PSB, RDF and azotobacter. He also discussed some advance methods of composting and observed that vermi compost is the best.

30 November 2018

Session- IX : Crop Production Technologies and Post Harvest Management

Chairman : Dr. S. K. Shukla

Rapporteur : Dr. V. K. Singh

Lead Lectures

- Jackfruit- A new option to organic window for doubling farmers' income- *G. Pandey*
- Recycling of sugar industry wastes and crop residue - *S. K. Shukla*
- Evaluation of jamun (*Syzygium cuminii*) germplasm for growth and yield behaviour- *A. K. Singh*
- Economic feasibility of high value vegetable crops cultivation under polyhouse condition in subtropics -*V. K. Singh*

- Advance in genomics for fruit improvement- *Anju Bajpai*
- Membrane nanopore based biosensor for the prediction of graft success in horticulture plants-*Rajiv Dutta*
- Effect of feed supplement on nutrient utilization and milk production in cattle- *Ramjee Gupta*

Oral Presentations

- Medicinal and aromatic plants: A treasure trove of anti-virulence phytomolecules - *Akansha Singh*
- Applications of ICT for rural development with special reference to mobile apps- *H. C. Verma*

Dr. G. Pandey, ICAR- CISH, Lucknow spoke on jackfruit crop and its prospects in doubling farmers' income. Presently the jackfruit is being grown as completely organic as the farmers are not applying chemicals/insecticides and fungicides. There is a need to sensitize the farmers to follow the organic certification process by making SHGs/FPOs or participating guarantee systems (PGS).

Dr. S. K. Shukla, ICAR-IISR, Lucknow spoke on recycling of sugar industry waste and crop residues. The waste can be used for mushroom cultivation or to bio-fortify these products to organic manure like compost.

Dr. A. K. Singh, ICAR-CISH, Lucknow spoke on the evaluation of jamun germplasm for growth and yield behaviour. He told that he has studied the genetic diversity and anti-oxidant potential of 20 accessions collected from different parts of the country. He notified that CISH J-37 has maximum pulp weight. The maximum TSS was recorded that in Gokak-II and maximum yield was observed in CISH-J37 and CISH- J15.

Dr. V. K. Singh, ICAR-CISH, Lucknow spoke on economic feasibility of high value vegetable crops cultivation under polyhouse conditions in subtropics. Protected cultivation of vegetables like tomato, capsicum and parthenocarpic cucumbers under different protected structures particularly in naturally open ventilated polyhouse has been proved more remunerative than open field cultivation. However cost is the major issue in sustaining this technology.

Dr. Anju Bajpai, ICAR-CISH, Lucknow spoke on advances in genomics for fruit improvement. She described that manipulation of a gene level has emerged as a viable tool to mitigate these boundaries and for enhancing the quality, resistance to the tresses, postharvest and nutritional properties of fruits. Development and advent of genomix using next generation rapid sequencing technologies facilitate whole genome sequencing for major fruit trees species.

Dr. Rajeev Dutta, Director, Sharda University, Greater Noida spoke on membrane nanopore based biosensor for the prediction of graft success in horticulture plants. He said that interfacial electrical resistance across the scion root stock surface may be the marker for measuring the graft success rate in woody plants during grafting process. Bio-sensor is a sensing device consisting of biologically active material.

Dr. Ramjee Gupta, CSAU A&T, Kanpur spoke on effect of feed supplement on nutrient utilization and milk production in cattle. It was observed that the feed supplement (Dugdh Ganga) were found beneficiary for proper milk production and nutrient utilization.

Dr. Akansha Singh, CSIR-CIMAP, Lucknow spoke on medicinal and aromatic plants: a treasure trove of anti virulence phytomolecules. The MAP are reported to adopt multiple mechanism of action targeting critical steps required for pathogenecity.

Dr. H. C. Verma ICAR-CISH Lucknow spoke about rural development. He observed that satellite based weather forecast provides reliable information which helps in proper planning. Internet of things (IOT) is latest technology for providing information on field condition.

Final Recommendations

Recommendations emerged in different sessions are as follows:

1. All tested microbial effective strains should be deposited in a national repository of NBAIM, Bangaluru as safe deposits to ensure that they are preserved for the future.
2. Development and use of bio- fertilizers and bio- pesticides should be promoted in agriculture and horticulture to overcome the problems arise due to continuous use of chemicals.
3. To overcome the drawbacks of the commercial success of Trichogramma, it is imperative to plan a year round calendar for production, so that they are readily available at the time of need. Their packaging and shipment should be implemented with great care.
4. Proper registration and certification of bio-pesticides and bio-fertilizers should be made mandatory before launching it in the market. Marketing of poor quality or sub- standard *Trichoderma* by bio-pesticide companies be given a serious view by Government agencies to obviate set back to this bio- pesticide.
5. Quick and efficient molecular (diagnostic techniques) tools needs to be developed for detection of pathogens.
6. Commercialization of blue green algae (BGA), that has shown its superiority in maintaining ecological balance and organic farming, be encouraged.
7. This is the high time when Indigenous Technological Knowledge (ITK) on organic farming should be documented, validated and promoted and basic strategic applied and anticipatory researches on various aspects of Javik Krishi with bio-pesticides, bio-agents, bio-dynamics and bio-fertilizers should be initiated.
8. Localized production and organized distribution of bio- control agents and bio-pesticides be given due emphasis. Bio-pesticides and pheromones be taken out of the purview of the insecticide act 1968 and a separate bio- pesticides act be enacted.
9. Partnership with ICAR, CSIR, SAU's, and Government agencies NGO's and International partnership is essentially required for organic farming systems.
10. Efforts should be made to increase awareness within the farmers about the benefits of using entomopathogenic nematodes products for insect pest management.
11. Human resource development and awareness programmes must be taken on priority for eco- friendly management of insect pests and diseases.
12. There should be relaxation in Government policies for promotion of eco- friendly bio-pesticides along with incentives to end users.
13. The alternative strategies have to be developed with organic farming for quality food production to feed the ever growing population. This would also lessen the harmful flora and fauna and will also enhance the shelf life of the organically produced fruits and vegetables and will reduce the post-harvest losses. Studies in their lines must be conducted.
14. It is required to build adequate force of skilled human resources to do research, train people and carry out extension activities in area of organic farming. It is essential to demonstrate module Javik farms in potential districts.
15. Neem products and products from other plants such as karanj, tulsi, mahua, etc. should get a place as an alternative to chemical pesticides.
16. Coating of fertilizers with neem, etc. make it more beneficial for the crop and yield, hence needs to be recommended.
17. Microbial pesticides such as *Bacillus thuringiensis, Bacillus creus* (Bacterial), *Beauveria bassiana, Metathizium anisopliae, Verticillum lacanji (fungi).* Baculoviruses

(Virus), *Steinernema carpocapsae and Heterorhabditis* spp (insect parasitic nematodes) have been found effective in controlling number of noxious insect pests and are commercially available. Besides, *Trichoderma* spp. *Aspergillus* spp, bacterium are the commercially manufactured products for disease control. It is, therefore, recommended that researches may be accelerated in this area on priority to identify more potential products by research Institutions for management of insect pests and diseases.

18. *Parasitoids* such as *Trichogramma* spp, predators, *Chrysoperla carnea, Cryptolaemus montouzeri*, *Scymnus* spp. and many other effective coccenellids may be given due importance in pest control strategy. Research may be taken up on top priority to identify more such bioagents and their commercial feasibility.
19. There should be an advance research centre on Javik Krishi in various states of the country. There is need to start graduates and post graduate courses on Javik Krishi in SAU's, ICAR Institutes,' deemed universities, etc.
20. Structural infrastructural support needs to be provided by Government of India/ State Governments far establishment of organic market and bio- villages at different places. The produce should be certified by a competent recognized authority/agency. It is also important to ensure a supply of high quality organic produce to the consumers at a reasonable price and enable the producers to earn increased levels of income from their produce. Thus, Javik farmers may become self-reliant. Awareness programmes conveying the benefit of eco- friendly nature of the Javik produce need to be launched.
21. A separate full fledged institute may be established with its zonal regional sub centre by ICAR, New Delhi.
22. The success stories of different components of bio- pesticides, bio-dynamics and bio-fertilizers may be evaluated further by competent Government/non-Government Institutions to arrive at final conclusions with dosages, time of application and quality of material.
23. Integrated Pest and Nutrient Management rather than Integrated Crop Management (ICM) strategy based on organic resources need to be standardized for sustainable production, maintenance of soil health and eco- friendly environment protection. It is necessary to use adopted varieties, which are more resistance to pest and diseases, and use of healthy seeds. This should be supplemented with appropriate crop rotation and management practices.

Valedictory Function

Dr. R. P. Srivastava, Organizing Secretary, welcomed Dr. R. P. Singh, Director, Directorate of Horticulture, Lucknow for accepting our invitation to attend as chief guest in the valedictory function. Dr. Singh is a well known devoted scientist in the field of horticulture. He also welcomed all the members of the executive committee of the Society. He welcomed Dr. Rajiv Dutta, Vice-president of the Society who took keen interest in the function. He welcomed Dr. A. K. Misra, Chief Editor of journal and Dr. V. K. Singh of CISH, Lucknow. He welcomed all the delegates of the conference who came from all parts of the country and abroad.

There after Dr. Srivastava felicitated Dr. R. P. Singh, Director with shawl and presented him memento and a bouquet.

The function started by presenting various awards to distinguished scientists as below-

1. **Recognition Award**
   Dr. P. K. Shukla, ICAR CISH, Lucknow
2. **Pride of Education Award**
   Dr. Santosh Kumar Bisen, Balaghat M.P.
3. **Innovative Research Award**
   Dr. Shabistana Nisar, AMU, Aligarh

4. Young Scientist Award

(i) **Dr. Brajesh Kumar**, Lovely Professional University, Phagwara, Punjab.

(ii) **Dr. Akansha Singh,** CSIR-CIMAP, Lucknow

(iii) **Dr. Tahseen Fatima,** ICAR-CISH, Lucknow

(iv) **Dr. Deepak Kumar,** Executive Director, Nextnode Bio-science Pvt. Ltd., Kadi, Gujarat

(v) **Dr. Gundappa,** ICAR-CISH, Lucknow

(vi) **Dr. Rajesh Kumar,** Asstt. Development Officer, Lucknow

(vii) **Mrs. Shashi Tiwari,** SHUATS, Allahabad

(viii) **Dr. Kaushal Kumar,** CSAU A&T, Kanpur

5. Poster Presentations & Award

A committee was formed to judge the poster session consisting of Dr. Om Prakash, Ex Project Coordinator, CISH, Lucknow (Chairman), Dr. K. K. Kumar, Ex Director, NRC Litchi, Muzafferpur, Bihar (Member), and Dr. A. K. Misra, Ex Project Coordinator, CISH, Lucknow (Member). In all 15 posters were presented and displayed by different workers from different organizations, i.e. ICAR, CSIR, SAU's, State Departments and NGOs. They were judged based on the material and methods, results & discussion. The results as per the judgement of the committee are as follows-

- **First-** Enzymatic and siderophore production behaviour of fungal isolates from various biodynamic preparations By- Supriya Vaish, Neelima Garg and Iffat Zareen Ahmad
- **Second-** (a) Studies on microbial degradation of chlorpyrifos By- Archit Kumar (b) Eco-friendly management of Pulse Beetle *C. Chinensis* (L) on cowpea in storage. By- Neenu Augustine and R. A. Balikai
- **Third-** (a) *Heterorhabditis indica* infected *Gallaria* codaver technology for controlling white grabs in apple By - Shard Mohan and Akansha Upadhyay (b) Eco-friendly management of anthracnose of chilli caused by *C capsici* (Syd) By- Shashi Tiwari, Rohan D., Lokhandey, Achintya Dubey, Deependra Singh Shekhawat, Umesh Tiwari and Hari Narain.

After award ceremony all the session's rapporteurs presented their report and recommendations. Dr. R. P. Srivastava then presented the final recommendations of the conference which were approved by the house.

Dr. R. P. Singh, Chief Guest in his presidential address gave emphasis on the need for the development of organic farming both in agricultural and horticultural crops, for doubling the farmers' income.

Thereafter, Dr. Rajiv Dutta presented vote of thanks. He thanked all the members of the executive committee and chairmen, co-chairmen and rapporteurs of all sessions for successfully organizing and running the sessions. He thanked Dr. A. K. Misra, Dr. P. K. Shukla, Dr. Gundappa, Dr. Ajay Verma for their keen support. Thanks are also due to Dr. D. K. Tandon and his team Dr. Rajesh Kumar, Dr. L. P. Yadav, Mr. R. P. Shankhwar and Mr. Abhay Dixit for support. Thanks were given to all those who helped in souvenir preparation and certificate preparation, dias arrangement and hall arrangement. Thanks were also due to Dr. Anju Bajpai for helping in anchoring the conference. He also thanks all the delegates, professors and the supporters of Bhagidari Bhawan especially Dr. Jitendra Singh and Shri Saurabh Saxena for making the conference a success.

Special thanks were given to Mr. Yash Bajpai, Mr. Rajeev Srivastava, Mr. P.K. Mahwani, Mr. Alok Srivstava and Mr. Ravi for their valuable support in logistic. Dr. K. K. Kumar Ex Director, NRC Litchi, Muzafferpur, Bihar, Dr. Om Prakash, Ex Project Coordinator (Fruits), CISH, Lucknow and Dr. A. K. Misra, Ex Project Coordinator (Fruit), CISH, Lucknow were given special thanks for their support in judging the research articles in poster session. Special thanks were also given to Dr. Ajay Verma for his untiring support in organizing various sessions including announcement and memento distribution etc.

After the thanks giving ceremony National Anthem was sung by Miss Aavya Saxena, K.K. Academy School, Indira Nagar, Lucknow.

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Review Article

Challenges and opportunities for biological control practices in India - A review

Chandish R Ballal

ICAR-National Bureau of Agricultural Insect Resources, H. A. Farm P. O., Bellary Road, Bangalore – 560 024
**Email: ballalchandish@gmail.com*

ABSTRACT

Intensive agricultural practices employing increased chemical insecticide and fertilizer applications, tillage and irrigation and heavy mechanisation (all leading to decline in the biodiversity of natural enemies) are being followed to cater to the needs of rapidly increasing human population. However, studies have clearly indicated that food can be produced in a sustainable manner by conserving biodiversity. Though majority of the studies point out that natural enemy richness enhances prey suppression, some of the studies do indicate that natural enemy diversity can even lead to weakened prey suppression due to factors like intraguild predation, behavioral interference and negative selection effects. Research conducted at ICAR-NBAIR has pointed out the benefits of conserving the diversity of natural enemies and also the effects of combinations of natural enemies on pest suppression. A classic example of biological control is that of the suppression of the sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner through conservation of the indigenous predators, *Dipha aphidovora* (Meyrick) and *Micromus igorotus* Banks and the parasitoid, *Encarsia flavoscutellum* Zehntner. This was enabled through a recommendation to refrain from applying chemical insecticides. Our studies have also indicated that combinations of biocontrol agents can enhance the overall suppression of multiple crop pests as in the case of *Trichogramma chilonis* Ishii with *Cryptolaemus montrouzieri* Mulsant for the management of brinjal shoot and fruit borer and brinjal mealybug. The compatibility of anthocorid and geocorid predators with *T. chilonis* has also been proved experimentally. Few studies point out the negative impacts of species richness; for eg. the biocontrol of cereal aphids by spiders was disrupted by high densities of large ground beetles. Thus, to ensure conservation and utilization of an array of effective natural enemies, we advocate advanced research on understanding and documenting biodiversity of pests and natural enemies, measuring the role played by specific or combinations of natural enemies on specific target pests and participatory research based on interactions between farmers, researchers and crop advisors.

Key words: Augmentation, biodiversity, biological control, conservation, classical biological control, natural enemies

The services provided by biodiversity to agriculture through pollination and pest control are valued at approx. $ 57 billion per year (Losey and Vaughan 2006). Ecosystem functioning increasingly depends on diversity, especially in the case of natural enemy diversity for pest control. In the 1980s, ecologists viewed the shrinking biodiversity as an alarming situation (Ehlrich and Ehlrich, 1981). Field studies indicated that when number of species and functional diversity of natural enemies increase, there is a significant increase in pest suppression (Evans 2016). There are two key gaps in understanding and utilizing the positive aspects of insect diversity: a general neglect of insects in biodiversity research and an overemphasis on their negative impacts in all other biological research areas. An insect pest or a plant disease or a weed exists in nature along with a pool of natural enemies. The major focus in applied biological control should be to select an appropriate species or combination of species from this pool and to work on a strategy to bring about the desired level of pest or disease suppression with minimal impact on non-target species. Biological control attempts have been either through conservation or augmentation of the potential indigenous biological control agents. Of more than one-and-half million insect species which occur in this world, only about 1.0 per cent have attained the status of pests. Many species which have pestilent potential remain at low levels because of the perpetual regulatory action exerted on them by their natural enemies. Hence, for management of some of our major pests, diseases and weeds it is important to restore the natural balance through purposeful human intervention. For tackling outbreaks of indigenous pests, the management approach could be through augmentation or conservation of indigenous natural enemies. However, when we are targeting invasive species, we may have to resort to importation of exotic agents and the classical biological control approach.

Biological control which focuses on either conserving or utilizing the diversity of natural enemies has proven to be one of the most effective, environmentally sound, and cost-effective pest management approaches as it is expected to drastically cut down the use of broad-spectrum pesticides and is considered to be a cornerstone of organic farming. The fundamental problem in applied biological control is to select an appropriate species or combination of species from the pool that will bring about the desired level of pest suppression with minimal impact on nontarget species.

The advancement in agricultural technology has brought about remarkable changes in the agricultural sector. These changes have been accompanied by excessive use of pesticides. World-wide, there are 500 species of resistant insects, mites and ticks compared with only 25 in 1955 Coupled with this has been the well-publicised environmental effects, such as toxic residues on produce, destruction of beneficial insects and other non-target organisms, and human poisoning. The World Health Organisation (WHO) estimates that world-wide over a million people are poisoned with pesticides each year and up to 2 percent of cases may prove fatal. At this juncture, bio-pesticides offer an alternative method of control that do not seem to provide the rapid development of resistance in the field, leave little or no toxic residues and are generally harmless to beneficial insects and other non-target organisms.

Conservation of bio-control agents

Conservation of natural enemies is probably the most important, readily available, generally simple and cost-effective technology. Natural enemies occur in all production systems, from the backyard garden to the commercial field. They are adapted to the local environment and to the target pest, and their conservation is generally simple and cost-effective. With relatively little effort the activity of these natural enemies can be observed. For example, parasitized aphid mummies are almost always present in aphid colonies. These natural controls are important and need to be conserved and considered when making pest management decisions.

In many instances the importance of natural enemies has not been adequately studied or does not become apparent until insecticide use is stopped or reduced. Often the best we can do is to recognize that these factors are present and minimize negative impacts on them. Natural enemies may be conserved by using insecticides or formulations which are least harmful and by timing applications to reduce the impact on beneficial arthropods. Ballal and Singh (2001) reported that non-intervention and the conservation of natural enemies to be the best strategy for *Helicoverpa armigera* management in the sunflower ecosystem. Studies have indicated that chemical inputs strongly affect beneficial insects and hence compared to conventional farms, organic farms had a higher species richness and abundance of predators and parasitoids (Bengtsson *et al.,* 2005). Effect of insecticide inputs can go beyond farm level. In Midwestern USA, it was reported that crop pest abundance increased with the proportion of harvested cropland treated with insecticides (Meehan *et al.,* 2011).

Besides biodiversity conservation, promoting biodiversity through local and landscape practices is extremely important. Thus focus should be on ecological management of farms through measures like increasing on farm plant diversity, perennial plant cover, etc. Conservation of biological control practices such as refuges for natural bio-agents, conserving weed plants harbouring predators and egg parasitoids, use of safer pesticides, judicious and selective use of non-persistent pesticides, strip treatment, spot treatment, etc. have been found to be effective conservation techniques in several crop ecosystems (Singh, 2002). Local scale intensification (eg. fewer crop species and varieties, increases in chemical pesticide and fertilizers application tillage, irrigation and mechanisation) can lead to distubance of biodiversity. Conservation tillage or no till practices can lead to increase in the populations of predators and parasitoids. However, some carabids and coccinellids prove to be exceptions. Diversity can be increased by planting non-crop vegetation like hedgerows which enhance natural enemy abundance (Nicholls and Altieri, 2013). Use of kairomones, synomones, pheromones, adjuvants, etc. to increase the searching ability and retention of parasitoids, build up population of biocontrol agents by providing artificial structures, food, alternate host, suppression of ants, etc., provision of grain sorghum in cotton plot, which serves as a source for natural enemies, etc are some conservation techniques. Though agricultural intensification is known to have a detrimental effect on biodiversity, the real mechanisms underlying the effect of biodiversity on biological control are not well understood. Crowder and Jabbour (2014) suggest experimental frontiers *viz.* evenness, realistic manipulations of biodiversity and functional and genetic diversity which can be used to understand the processes in real world agro ecosystems. Liere *et al* (2017) state that agriculture management practices affect the performances of natural enemies by altering the resources base, species pool and their interactions. It is important to study the cascading effects of landscape drivers on pest control by natural enemies.

Habitat manipulation techniques can be easily incorporated into home gardens and even small-scale commercial plantings, but are more difficult to accommodate in large-scale crop production. There may also be some conflict with respect to pest control because of the difficulty in targeting the pest species as the refuges may be used by the pest insects as well as natural enemies. Habitat manipulation involves altering the cropping system to augment or enhance the effectiveness of a natural enemy. Many adult parasitoids benefit from sources of nectar and the protection provided by refuges such as hedgerows, cover crops and weedy borders. Mixed plantings and the provision of flowering borders can increase the diversity of habitats and provide shelter and alternative food sources. They are easily incorporated into home gardens and even small-scale commercial plantings, but are more difficult to accommodate in large-scale crop production. For leaf and plant hoppers, colonization of mirid predator *Cyrtorhinus lividipennis* has proved to be effective. Weeds like *Cyperus* sp. help in off-season survival of mirid bug through harbouring plant hoppers. Predation by mirid bug was more on BPH resistant rice variety PTB 33. The presence of any combination of 3 nos. / hill of spider *Lycosa preudoannulata, Oxyopus javanus* and *Tetragnatha* sp. checked the population of BPH and WBPH. There may also be some conflict with pest control because of the difficulty of targeting the pest species as the refuges could be used by the pest insects as well as natural enemies.

Natural enemy populations may be enhanced by increasing the diversity of plant species in the vicinity of the crop, changing cultural practices to ensure continuous availability of hosts and by providing alternative food sources (Pawar, 1986). Landscape heterogeneity and complexity generally benefit natural enemies. Marino and Landis (1996) observed parasitism rates to be positively correlated with landscape complexity and Gardiner *et al.* (2009) reported higher predation rates of soybean aphids by coccinellids in soybean fields where landscape heterogeneity was maintained. Tylianakis *et al.* (2007) reported higher parasitism rates across pasture, rice and coffee systems where parasitoid diversity was higher. However, according to Schmitz (2007) in 40.3% cases, predator diversity negatively influences predation, which could be due to interspectific inference or competition.

Silliou and Barnaud (2017) reported that though scientific findings suggest that natural enemy habitats are conserved through maintaining complex landscapes, the farmers' perceptives are totally different. Through interviews conducted with apple growers in southern France the authors concluded that generally farmers considered natural enemies as resources for biological control of pests, especially where there was guidance from public institutions in natural enemy conservation, acclimation and management strategies. However there was no such process for convincing the farmers on the importance of landscape as a resource for conservation biological control. Thus there is a clear need for a dialogue and networking between landscape ecologists and farmers. Growers can be encouraged to conserve biodiversity through ecological engineering, diversified crop rotations, coupling of crop and live-stock production, etc.

Conservation of indigenous parasitoids and predators

Parasitoids:

A successful parasitoid should have a high reproductive rate, good searching ability, host specificity, be adaptable to different environmental conditions, and be synchronized with its host (pest). No parasitoid has all these attributes, but those with several of the above characteristics will be more important for use in suppressing pest populations. In nature, several parasitoids have been observed as the potential bio-agents of serious crop pests (Plate 1). The emphasis should be on documenting the important ones which play a major role in pest suppression and conserve them. Here are a few examples. *Anagyrus dactylopii* was recorded as a dominant parasitoid parasitising up to 90 per cent of citrus mealybug *Nipaecoccus viridis* (Ali, 1957; Subba Rao *et al.*, 1965). On cabbage, cauliflower and other cole crops, diamondback moth (DBM), *Plutella xylostella* is a major pest and *Cotesia plutellae* is an important parasitoid in Gujarat, Karnataka and Tamilnadu (Yadav *et al*. 1975; Jayarathnam, 1977; Nagarkatti and Jayanth, 1982), while *Diadegma semiclausum* in the Nilgiris (Chandramohan, 1994). *Campoletis chlorideae* and *Eriborus argenteopilosus* are important early larval parasitoids of *Helicoverpa armigera* in the pigeonpea and chickpea ecosystems (Bilapate *et al.*, 1988).

On citrus butterfly (*Papilio demoleus* Linnaeus), egg parasitoid *Trichogramma chilonis* Ishii parasitised up to 76 per cent and *Telenomus* sp. nr. *incommodus* 78 per cent in February (Krishnamoorthy and Singh, 1988; Jalali and Singh, 1990). *Distatrix papilionis* is the dominant parasitoid of caterpillars and *T. chilonis*, *T. incommodus* and *D. papilionis* caused a cumulative parasitism of 88 per cent (Krishnamoorthy and Singh, 1988). *T. chilonis, Melalophacharops* sp. and *D. papilionis* could be utilised for the biological suppression of butterflies attacking citrus. The eggs of fruit sucking moth, *Othreis fullonia* are successfully parasitised by *T. chilonis*, which suggests the possibility of utilising *T. chilonis* for the control of this pest (Dodia *et al*., 1986). The two indigenous early larval parasitoids of *H. armigera – Campoletis chlorideae* and *Eriborus argenteopilosus* are important mortality factors, especially in the pulses ecosystem. Strainal variations were observed in *C. chlorideae* based on the geographical location and the Sehore strain was observed to be most efficient (Ballal and Ramani, 1994). Variations were observed in the performance of *C. chlorideae* populations collected from different crop ecosystems. The lab-reared parasitoids which were originally from the pigeonpea ecosystem could not efficiently parasitise *H. armigera* larvae from the cotton ecosystem, whereas the parasitoids from the cotton ecosystem were capable of parasitising more than 40 per cent of the larvae of cotton ecosystem (Ballal *et al.,* 2001a). The studies indicated that the performance of *C. chlorideae* is largely governed by the host plants on which the pest is found. Bajpai *et al.,* (2002) reported that on chickpea plants, the chemical cues released during feeding by the *H. armigera* was essential for *C. chlorideae* to be attracted to the infested plants and to induce parasitism. Parasitism was also governed by host plant variety (Ballal and Gupta, 2003).

Predators:

In India, several predators have been identified as potential bio-control agents (Plate 1). For instance, more than 60 arthropod species have been recorded as predators of *Helicoverpa armigera* (Hübner). The important predators found feeding on *H. armigera* in India are chrysopids, anthocorids, ants, coccinellids and spiders (Manjunath *et al*., 1989; Duffield, 1994, Duffield and Reddy, 1997).

Coccinellids

The important indigenous coccinellids include *Coccinella septempunctata* Linnaeus, *Scymnus coccivora* Ayyar, *Chilocorus nigrita* Fabricius, *Cheilomenes sexmaculata* (Fabricius) and *Brumoides suturalis* (Fabricius). Amongst syrphids, the important ones include *Ischiodon scutellaris* (Fabricius), *Paragus serratus* (Fabricius) and *Paragus yerburiensis* Stuckenberg. Aphidophagous coccinellid, *C. septempunctata* is more abundant in areas with low average temperature viz., northern parts of India. It plays important role in natural suppression of aphids like *Myzus persicae* (Sulzer), *Brevicoryne brassicae* (Linnaeus) and *Lipaphis erysimi* (Kaltenbach) infesting *rabi* oilseeds and cole crops. Similarly, syrphids like *I. scutellaris* and *Paragus* spp. are also found in very high numbers feeding on these aphids. *Cheilomenes sexmaculata*, is more abundant in warmer areas of southern India and keeps *Aphis craccivora* Koch, infesting groundnut and pulses under check during summer and *kharif* season.

Amongst indigenous coccidophagous coccinellids, *C. nigrita* has been utilised through inundative release, not only against *Melanaspis glomerata* (Green) but also on several other diaspine scales including red scale of citrus (Singh, 1994). Other important coccinellids in this group are *Pharoscymnus horni* (Weise) and *S. coccivora*. These two play important role of assisting two major coccinellids viz., *C. nigrita* and *C. montrouzieri*, respectively in different fruit crops. By virtue of their small size, they are able to enter leaf sheath and crevices of bark, where crawlers of coccids generally reside, and feed on them at early stage of crop infestation.

Chrysopids

In India, 65 species of Chrysopids belonging to 21 genera have been recorded from various crop ecosystems. Some species are distributed widely and are important natural enemies for aphids and other soft bodied insects. Amongst them, *Chrysoperla carnea*, *Mallada boninensis*, *Apertochrysa crassinervis* and *Mallada astur* are the most common. The first two have been used in cotton ecosystem for protection from aphids and other soft bodied insects. *C. carnea* has been recorded on cotton, green gram, sorghum, maize, safflower, sunflower and pigeonpea, predating on the pest like safflower aphid, maggots of safflower fruit fly, eggs of pentatomid bugs on green gram, sorghum aphid, eggs of Pyrilla, cotton aphid and leaf hoppers. In Himachal Pradesh, *C. carnea* feeds on woolly aphid *Eriosoma lanigerum* colonies and hibernates in cocoons as prepupae from first week of November to early March.

Anthocorids

Amongst the different anthocorid predators recorded in other countries, *Orius* spp. appear to be the most promising, especially against thrips; examples being *Orius sauteri*, *Orius majusculus*, *Orius laevigatus* and *Orius insidiosus*. In India, anthocorids have been recorded as potential bio-agents of different species of thrips in various ecosystems. *Orius* spp. are the most common anthocorids which have been collected from different crop ecosystems. *Orius tantillus* and *O. maxidentex* are the most common species collected.

Augmentative biocontrol

Biological control which involves the supplemental release of natural enemies which could be inoculative (relatively few natural enemies released at a critical time of the season) or inundative (millions may be released). In India, innumerable attempts have been made to augment the populations of promising indigenous natural enemies (Plate 2) like trichogrammatids, bethylids, chrysopids, ladybird beetles, nuclear polyhedrosis viruses, etc. to control pests of sugarcane, cotton, coconut, coffee, grapevine, tomato, sunflower, etc. To support such augmentative programmes, mass-production of natural enemies is a necessity.

Notable success has been achieved in the bio-suppression of the hopper *Pyrilla perpusilla* in some states by the colonization/redistribution of the lepidopteran parasitoid, *Epiricania melanoleuca*. Misra and Pawar (1984) reported that this parasitoid when released @ 400,000–500,000 eggs or 2000–3000 cocoons ha^{-1} in eastern UP, West Bengal, Orissa, Karnataka, Kerala, Maharashtra, Rajasthan, Andhra Pradesh and Madhya Pradesh gave complete control of the pest. Pawar (1979) reported that in July– September, if

Encarsia flavoscutellum Zehntner

Encarsia guadeloupae Viggiani

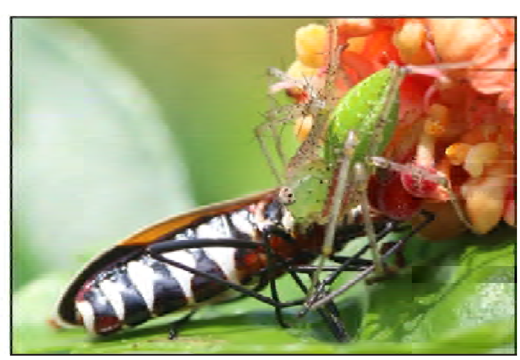
Aenasius arizonensis (Girault)

Cheilomenes sexmaculata (Fabricius)

Coccinella septempunctata Linnaeus

Dipha aphidivora (Meyrick)

Micromus igorotus (Banks)



Peucetia viridana Stoliczka

Plate 1 Some important bioagents for conservation biocontrol

Trichogramma chilonis Ishii

Trichogramma japonicum Ashmead

Chrysoperla zastrowi sillemi (Esben-Petersen)

Goniozus nephantidis (Muesebeck)

Blaptostethus pallescens Poppius

Cryptolaemus montrouzieri Mulsant

Scymnus coccivora Ramakrishna Ayyar

Brumoides suturalis (Fabricius)

Plate 2 Some important bioagents for augmentative biocontrol

Acerophagus papayae Noyes & Schauff

Curinus coeruleus (Mulsant)

Trichogramma pretiosum Riley

Cyrtobagous salviniae Calder & Sands

Neochetina eichhorniae Warner

Neochetina bruchi Hustache

Zygogramma bicolorata Pallister

Smicronyx lutulentus Dietz

Plate 3 Some important exotic bioagents for classical biological control

20-60 per cent parasitism of nymphs and adults are recorded there is no need to panic even if outbreak like situation is noticed.

Indigenous parasitoids play a major role in the management of the coconut black-headed caterpillar in the coconut ecosystem. Field release of the three stage specific *Opisina arenosella* parasitoids *viz Goniozus nephantidis, Elasmus nephantidis* and *Brachymeria nosatoi* at fixed norms and intervals in a heavily infested coconut garden (2.8 ha) for a period of five years resulted in highly significant reduction in *Opisina* population (Sathiamma *et al.*, 2000). Follow up observations revealed that even after three years no build-up of the pest was noted in the released site. The anthocorid predator *Cardiastethus exiguus* and *G. nephantidis* have been observed to be highly amenable to mass production and they have also proved to be highly effective against the egg and larval stages of *O. arenosella* as indicated in the recent field trials conducted at Kerala and Karnataka (Venkatesan *et al.*, 2008).

Production and utilisation of biocontrol agents

Success with field releases of natural enemies requires appropriate timing, release of the correct number of natural enemies per unit area or depending on pest density and release of quality bio-agents. In many cases, the most effective release rate has not been identified as it will vary depending on crop type and target host density. Table 1 lists some of the parasitoids and predators, which could be released for the management of some major pests on different crop ecosystems.

Trichogramma spp. and *Trichogrammatoidea* spp. are egg parasitoids widely used against the lepidopteran pests infesting sugarcane, paddy and vegetables. They are mass reared on factitious hosts *viz. Corcyra cephalonica* Stainton, *Sitotroga cerealella* (Olivier) and *Ephestia kuehniella* Zeller. Recent studies indicate that the production of *T. chilonis* on eri silkworm *Samia cynthia ricini* eggs is a farmer friendly system (Lalitha et al., 2013) and it could potentially yield trichogrammatids with superior biological attributes.

Biological control through augmentation has gained maximum acceptance among sugarcane farmers of India. Use of *T. chilonis* has been effectively utilized for the management of sugarcane borers. Sugar mills have their own co-operative parasitoid production units and have contributed in a big way in adoption of bio-control. Inundative releases of *Isotima javensis* gave good results in the control of top borer, *Scirpophaga excerptalis* in north India.

In rice ecosystem, conservation and inundative release of the egg parasitoid *T. japonicum* and *T. chilonis* along with the predator *Cyrtorhinus lividipennis* have given promising results. Weekly releases of *T. japonicum* and *T. chilonis* @ 100,000 ha^{-1} starting after a month of transplanting is recommended for the control of stem borer, *Scirpophaga incertulas* and leaf roller, *Cnaphalocrocis medinalis*. A total of three releases for *Rabi* and *Kharif* crops are sufficient. The trials conducted at Tamil Nadu, Maharashtra, Punjab, Assam and Kerala proved that Biocontrol Based Integrated Pest Management (BIPM) was either at par or better than farmers' practice in all the places. The BIPM schedule for pest management includes releases of *Chrysoperla carnea* for sucking pests. This schedule was successful in Karnataka, Maharashtra and Gujarat.

Production techniques are available for some potential parasitoids like Trichogrammatids, *Leptomastix dactylopii, Copidosoma koehleri, Telenomus remus,* etc. and predators like *Chrysoperla carnea, Scymnus coccivora, Pharoscymnus horni, Curinus coeruleus, Coccinella septempunctata, Cheilomenes sexmaculata, Chilocorus nigrita, Brumoides surturalis, Ischiodon scutellaris, Cardiastethus exiguus,* etc. (Joshi *et al.*, 1998; Singh *et al.*, 2001; Ballal *et al.*, 2003a; Joshi *et al*., 2003).

Now potential parasitoids which are amenable to mass production are being reared and marketed by some insectaries, both Government and Private. These are being released against several crop pests. Success with such releases requires appropriate timing, dosage and sufficient number of releases. Trichogrammatids and *Cryptolaemus montrouzieri* are two agents which are widely utilized in India.

Cryptolaemus montrouzieri

Mealy bugs like the common mealy bug (*Planococcus citri*), grape mealy bug (*Maconellicoccus hirsutus*), mango mealy bug (*Rastrococcus iceryoides*), spherical mealy bug (*Nipaecoccus viridis*), striped mealy bug (*Ferrisia virgata*), oriental mealy bug (*Planococcus lilacinus, P. pacificus, P. robustus*) and pineapple mealy bug (*Dysmicoccus brevipes*) cause serious damage and decrease the productivity and marketability of the produce (Mani and Shivaraju, 2016). Some mealybugs have also developed resistance to insecticides.

Cryptolaemus montrouzieri was introduced from Australia into India in June, 1898 for the control of soft green scale *Coccus viridis.* It could not establish on soft green scale. Later, it was reported as an effective predator on many species of mealy bugs and to some extent on scale insects in Karnataka (Rao *et al*., 1971). In 1977 an insectory was established at Central Horticultural Experiment Station, Chethalli, Kodagu, Karnataka for its multiplication. This coccinellid can now be successfully mass produced and field released (Joshi *et al*., 2003). Now commercial insectaries are also procuring and supplying *C. montrouzieri* to the growers. In fruit and plantation crops, the beetles are released @ 5-50 per plant, depending upon the severity of infestation and crop canopy. On each mealy bug infested plant of coorg mandarin, robusta coffee, arabica coffee and san ramon coffee release of 10, 5, 3 and 2 beetles per plant resulted in reduction of mealy bug population and by 5th week the pest population reduced to negligible level. Beetles were released in 13 mixed planted orchards (citrus & coffee) and satisfactory results obtained. Field releases of *C. montrouzieri* @ 20 adults tree^{-1} gave excellent control of *F. virgata, M. hirsutus* and *P. lilacinus* on guava within 50 days in the presence of other local natural enemies. It was also found to be highly effective in suppressing the populations of *M. hirsutus* in grapes within 75 days. It was effective in suppressing the mealy bugs on citrus, guava, grapes, mulberry, coffee, mango, pomegranate, custard apple, ber etc. and green shield scale on sapota, mango, guava, brinjal and crotons in Karnataka. It did not seriously impair the efficiency of local biocontrol agents. Table 2 provides information on the pest species (with host plants) against which *C. montrouzieri* was observed to be a promising bioagent.

Chrysopids

Chrysoperla carnea can be multiplied on the eggs of *C. cephalonica* by adopting a two-step rearing procedure; an itial group rearing procedure and later individual rearing to avoid cannibalism. A monocrotophos tolerant strain of *C. carnea* has been selected by Gujarat Agricultural University, Anand. Attempts have also been made to rear *C. carnea* larvae on semi synthetic diet, which includes the utilization of wastes from other insect production units.

Normally, chrysopids are recommended for use against different crop pests @ 50,000 or 100,000 1st instar larvae / hectare, 4 6 larvae/plant or 10 20 larvae /fruit plant are released. Depending on the situation, two releases are recommended. The cost of production and application of *C. carnea* @ 1,00,000/ ha is high and hence the focus is on reducing the cost involved in field use through either manipulation of the dosages or reduction in production cost.

Anthocorids

An annotated catalogue on Indian anthocorids has been compiled by Ballal *et al.* (2018). In India, very few attempts were made to rear anthocorid predators. Mukherjee *et al*., (1971) tried a synthetic diet for the rearing of *Xylocoris*

Table 1. Some biological control systems utilizing parasitoids

Crop/Pest	Biotic agents	Dose ha^{-1}	Frequency of application
SUGARCANE			
Chilo spp.	*Trichogramma chilonis*	50,000	Every 10 days, 8 times starting from 30-day-old crop for shoot borer and 60 days for other borers or during egg laying period
Pyrilla perpusilla	*Epiricania melanoleuca*	2-3 egg masses or 5-7 cocoons in 40 selected spots/ha	The releases to be initiated before the onset of rainy season
RICE			
Scirpophaga incertulas & *Cnaphalocrocis medinalis*	*Trichogramma japonicum* *T. chilonis*	100,000	30, 37 and 44 days after transplanting (DAT)
COTTON			
Helicoverpa armigera, *Earias* spp., *Pectinophora gossypiella*	*T. chilonis*	1,50,000	Weekly 6 times starting from 40th day after planting or during the egg laying period
TOBACCO			
Spodoptera litura	*Telenomus remus*	1,20,000	Five times at weekly interval
COCONUT			
Opisina arenosella	*Goniozus nephantidis*	3,000 adults	Need based or for each generation
	Cardiastethus exiguous	50 adults/tree	To coincide with egg or freshly hatched larval stage of the pest
APPLE			
Eriosoma lanigerum	*Aphelinus mali*	1000 adults or mummies/ infested tree	Once, as soon as infestation is noticed
Quadraspidiotus perniciosus	*Encarsia perniciosi*	2000 adults /infested tree	Once, in spring
Cydia pomonella	*Trichogramma embryophagum*	2000 adults/tree	Releasing at weekly interval
CITRUS			
Planococcus citri	*Leptomastix dactylopii*	3000 adults	Need based; under expert supervision
TOMATO			
Helicoverpa armigera	*Trichogramma brasiliense* *T.pretiosum / T. chilonis* BioH$_1$	50,000	Weekly interval/6 times from 25th day after transplanting or during egg laying period

flavipes (Reut.). Mass rearing methods have been standardised for four potential anthocorid predators, *Cardiastethus exiguus* Poppius (Ballal *et al.* 2003a), *Blaptostethus pallescens* Poppius (Ballal *et al.*, 2003b) and *X. flavipes* (Reuter) (Ballal *et al.*, 2013) and *Orius tantillus* Motshulsky (Gupta and Ballal, 2006).

The anthocorid species which are now being commercially produced and field utilized in other countries are *Anthocoris nemoralis* (Fabricius) and *Orius* spp. In India, *C. exiguus* has been field evaluated against *O. arenosella* and *B. pallescens* against spider mites and thrips. Both the anthocorids have proved to be potential predators for field use (Lyla *et al.*, 2006; Ballal *et al.*, 2009).

Classical biological control

To tackle exotic pests, we may have to turn to classical biological control. Unfortunately, classical biological control does not always work, the reasons for failure may include the release of too few individuals, poor adaptation of the natural enemy to environmental conditions at the release location, and lack of synchrony between the life cycle of the natural enemy and the pest.

A worldwide review reveals that there have been altogether 120 successful cases of classical biological control of insect pests of which 42 have been completely controlled, 40 substantially controlled and 30 partially controlled. These include pests, diseases and weeds. There are also a number of successful cases by augmentation of exotic natural enemies in several countries. India is rated as one of the top 10 countries in the world in the area of biological control. Where success has been achieved in classical biological control, the underlying ecological mechanisms are not always clear.

Exotic parasitoids that have successfully established in our country (Plate 3) include the encyrtids *Encarsia perniciosi* and *Aphytis diaspidis* for control of San Jose scale, *Quadraspidiotus perniciosus* and similarly, *Leptomastix dactylopii* against citrus mealybugs.

Leptomastix dactylopii introduced from the West Indies in 1983 is a fairly specific parasitoid of *Planococcus citri*, possessing excellent host searching ability. Field release of *Leptomastix* resulted in its establishment in mixed plantations of citrus and coffee, and also in citrus orchards in several parts of Karnataka, resulting in control of *P. citri* within 3-4 months. No insecticidal sprays were required subsequently for the control of *P. citri* in the following season (Manjunath, 1985; Krishnamoorthy and Singh, 1987; Nagarkatti *et al*., 1992).

Three strains of *E. perniciosi viz*., Californian, Russian and Chinese, were introduced for the control of *Q. perniciosus*.

Table 2. Biological control of mealy bugs and scale insects utilising *Cryptolaemus montrouzieri*

Crop	Species	Place
Araucaria	*Uhleria araucariae*	Karnataka
Brinjal	*Coccidohystrix insolita*	Karnataka
Crotons	*Planococcus minor*	Karnataka
Ficus	*Pulvinaria psidii*	Karnataka
Hibiscus	*Aphis gossypii*	Karnataka
Jacaranda	*Saissetia coffeae*	Karnataka
Jasmine	*Pseudococcus longispinus*	Karnataka
Mulberry	*Insignorthezia insignis*	Karnataka
Mussaenda		
Neem	*Megapulvinaria maxima*	Karnataka
Sapota	*Coccus viridis*	Karnataka
	Planococcus citri	
Tomato	*Planococcus citri*	Karnataka
Ber	*Nipaecoccus viridis, P. lilacinus, P. citri M. hirsutus* and *Drepanococcus chiton*	Karnataka
Chow-chow	*P. lilacinus*	Karnataka
Citrus	*Planococcus citri* and *Nipaecoccus viridis*	Karnataka
Coffee	*Planococcus* spp.	Karnataka
Custard apple	*M. hirsutus, P. citri, P. lilacinus, F. virgata* and *N. viridis.*	Karnataka and Andhra Pradesh
Grapevine	*Maconellicoccus hirsutus* and *Planococcus citri*	Karnataka and Andhra Pradesh
Guava	*Pulvinaria psidii, Aphis gossypii, Drepanococcus chiton, Ferrisia virgata, Planococcus citri* and *P. lilacinus*	Karnataka and Tamil Nadu
Mango	*Pulvinaria polygonata, Ferrisia virgata, Planococcus citri, Rastrococcus iceryoides* and *R. invadens*	Karnataka
Pomegranate	*Siphoninus phillyreae Maconellicoccus hirsutus, Planacoccus citri, P. lilacinus, Ferrisia virgata* and *Nipaecoccus viridis*	Karnataka

In addition, *A. diaspidis* (origin: Japan) was introduced from California. All the strains could establish and the Russian strain of the parasitoid gave 89 per cent parasitism in Himachal Pradesh. *A. diaspidis* in combination with *E. perniciosi* gave 86.5 per cent parasitism. In Kashmir, the Russian and Chinese strains appeared to be superior. American and Chinese strains of *E. perniciosi* were also released in the Kumaon hills of Uttar Pradesh; the population of the pest was reduced by about 95 per cent. In Kashmir, releases of *E. perniciosi* and *Aphytis proclia* resulted in an increase of parasitism from 8.9 to 64.3 per cent. Studies on the biology of *E. perniciosi* revealed that the multiplication rate of the parasitoid was over 10 times. In apple, release of *E. perniciosi* or *A. proclia* @ 2000 / infested tree gave effective control of San Jose scale (Rao *et al*., 1971; Singh, 1989).

The spiraling whitefly, *Aleurodicus disperses*, a native of the Caribbean region and Central America, probably came to India from Sri Lanka or the Maldives. It was first reported in 1993 from Kerala and later from other parts of peninsular India and the Lakshadweep islands. The pest is highly polyphagous and has been recorded on 253 host plants in India. Two aphelinid parasitoids, *Encarsia guadeloupae* and *E*. sp. nr. *meritoria*, have been fortuitously introduced together with the host into India. With the accidental introduction of both species of *Encarsia* into India, there has been a perceptible reduction in the population of *A. disperses* (Ramani *et al*., 2002).

The invasive papaya mealybug, *Paracoccus marginatus*, an alien mealybug native to Mexico, was first reported on papaya in Coimbatore, and soon it spread to neighboring districts infesting cassava (tapioca), mulberry, teak and more than 100 other plant species. Papain, sago and silk industries were significantly affected by this pest. ICAR–NBAIR with help from the United States Department of Agriculture (USDA) imported three natural enemies of the papaya mealybug, namely, *Acerophagus papayae, Anagyrus loecki* and *Pseudleptomastix mexicana*, from the laboratory of Animal and Plant Health Inspection Services (APHIS) at Puerto Rico. A large-scale production technology was developed and one of the parasitoids *A. papaya* was distributed to all the states which reported infestation by the papaya mealybug. Within a period of six months, the papaya mealybug was controlled successfully. The total economic benefit over five years was estimated to be $ 1,340 million. It is estimated that an annual saving of Rs 1,623 crores has accrued to the farmers in Tamil Nadu, Karnataka and Maharashtra.

Management of invasives through conservation

The sugarcane woolly aphid, *Ceratovacuna lanigera,* was observed as a serious pest of sugarcane and reported in outbreak proportions from western and southern India (Rabindra *et al.,* 2002; Joshi and Viraktamath, 2004). The parasitoids which were recorded on this pest in Nagaland included *Aphelinus desantisi*, *Encarsia falvoscutellum*, *Diaeretiella rapae*, *Anagyrus* sp. and *Antocephalus* sp. (Tripathi, 1995). In Assam, Jorhat *Encarsia flavoscutellum* was observed in abundant numbers parasitising woolly aphids. The heavy incidence of this parasitoid could prevent the further spread of the woolly aphid population. *Dipha* and *Micromus* were recorded as potential predators of SWA in nature. Since natural enemies were found to control the woolly aphid effectively, farmers were advised not to apply chemical pesticides. In areas where chemicals were not applied, the natural enemies multiplied rapidly and devoured the woolly aphid, thus preventing outbreaks.

Invasive rugose spiraling whitefly (RSW) *Aleurodicus rugioperculatus* Martin (Hemiptera:Aleyrodidae) was found in-festing coconut, banana, coconut, banana, custard apple and several ornamental plants in Tamil Nadu, Andhra Pradesh and Kerala. Several natural enemies were recorded on this pest and maximum parasitism was recorded by *Encarsia guadeloupae* Viggiani. Through recommendations on a non-chemical pesticidal approach, the pest population has drastically reduced in most of the areas (Selvaraj *et al.* 2017).

Superior strains of natural enemies

In a successful attempt to bridge the gap between research and commerce, a strain of *T. chilonis* 'endogram" with physiological tolerance to 0.07% of endosulfan was developed for control of cotton bollworm (Jalali *et al*., 2006; Ballal *et al*., 2009). This strain was commercialized and in three three years, 29700 hectares of cotton and vegetables crops were treated with endogram in 6 different states.

This strain was further developed for multiple tolerances to the recommended dosages of monocrotophos and fenvalerate. A strain of *T. chilonis* which can tolerate a temperature of 36° C was also developed, which could be utilized in states like Punjab and Tamil Nadu. High host searching strains of *T. chilonis*, *T. japonicum*, *T. achaeae* and *T. bactrae* were also developed which were more efficient in field situations.

Commercial production of parasitoids and predators

Standard techniques are now available for the successful production of several parasitoids and predators, which could be followed by commercial insectaries. India's first private insectary, Biocontrol Research Laboratory was established at Bangalore in 1981. Since then numerous companies have come up country-wide, which produce parasitoids, predators, entomopathogens, plant disease antagonists, weed killers, etc. As per "Infobase" (Biswas *et al.*, 2000) and Singh (2002), there are 128 organisations producing bio-agents. However, though microbial biopesticides are available commercially in India, very few companies are producing macrobials.

Biological control workers have to face several major technical constraints in the process of production. These problems get further compounded by artificial selection forces and the conflicting requirements for natural enemies in a mass production programme. These technical obstacles include lack of: a) long term storage techniques for the alternate laboratory host insect *Corcyra cephalonica* and also for Tricho cards, b) mechanized production and application technology of parasitoids and predators, c) effective *in-vitro* mass production techniques for natural enemies on artificial diets, d) techniques that prevent selection pressures and behavioural changes leading to genetic deterioration of the mass-produced natural enemies, and loss of vigour / effectiveness and f) good standards to measure the quality of the bioagents and their performance. The hurdles faced during rearing also include problems faced in: a) male-biased sex-ratio in the laboratory cultures, b) maintenance of cultures during summer and winter due to unfavourable temperature and humidity conditions, c) cannibalism in chrysopids and in some coccinellid larvae which necessitates individual rearing d) *in vivo* rearing of predators as it necessitates continuous production of host insects and host plants, e) *Bracon* and mites in *Corcyra* culture, f) microbial contaminants in laboratory host insect cultures g) higher costs involved in preparing semi-synthetic diets

Some of the above issues have been addressed through research at NBAIR. Long term storage techniques for host insects and biocontrol agents are of great relevance for commercial acceptance of biocontrol technologies. Eggs of *C. cephalonica* stored for 20 days (10 days prior to UV and 10 days post UV) were effectively parasitized by *T. chilonis* with upto 88.4% parasitism and when stored for 30 days, parasitism ranged 70-80% (Ghosh and Ballal, 2017a). Jalali et al. (2007) devised a method of vacuum packing UV irradiated *C. cephalonica* eggs. Successful long term storage (up to 95 days) of *T. chilonis* strains was enabled through a novel technology of diapause induction (Ghosh and Ballal, 2017b; 2018). Rearing structures and units have been devised and protocols have been standardized to maintain optimum temperature and humidity and hygienic conditions, prevent cannibalism and entry of hypers, disease and contaminants into the rearing facilities, mechanical collection of moths and simulate field conditions. For rearing some of the parasitoids like *Encarsia* spp. and predatory mites, rearing of host insects / phytophagous mites on host plants is essential. Methods have been devised to either re-distribute the bioagents from areas of occurrence to new areas and rearing of predatory mites on astigmatid mites, thus trying to minimize the cost involved in maintaining host plants continuously in polyhouses. Though in-vitro mass production techniques have been attempted, they may not be feasible in Indian conditions considering the cost involved. In order to prevent biodeterioration of cultures due to continuous laboratory rearing, the stage at which rejuvenation has to be done with wild cultures has been identified. Studies have also clearly indicated the importance of maintaining quality parameters in mass reared insects (Ballal et al., 2001b, c; 2005).

Concerns, constraints and future thrusts

After 100 years of effort, we still do not fully understand the mechanisms by which a successful natural enemy operates in nature, or why a particular organism is successful in one situation and unsuccessful in another. In augmentation, we urgently need a coherent theory of inundative/inoculative release as well as basic efficacy data in order to more readily incorporate commercially available predators and parasitoids of arthropod pests into IPM systems. Global warming has now been accepted as a serious threat to our natural and agroecosytems. It will be imperative that biological control scientists watch for the effects of climate change on arthropod pests that have been kept in check by natural enemies and on the natural enemies themselves. Interactions between transgenic crops and biological control species have also to be considered.

In classical biocontrol, there is a concern whether the chosen exotic bioagent would be able to provide sufficient control. A long debated issue is also whether one, a few or many species of natural enemies should be released against invasive pests (Ehler, 1990). Some evidences were brought forth on the competitive exclusion of introduced bioagents by the indigenous bioagents (Ehler and Hall, 1982). Classical biological control is ideally expected to predict (1) the appropriate species (or biotype) or combination of species (and/or biotypes) to release for control of a target pest in a given situation; and (2) the environmental impact resulting from the introduction of an exotic enemy. Non-target impacts to plants or insects from biocontrol agents are of great concern to conservation biologists, environmentalists, and federal agencies. Biological control agents that are not host specific may pose threats to at-risk species and constraints have been applied to the types of organisms that may be used. The requirement for increased host specificity means exotic polyphagous predators are less appropriate for introduction and thus more research emphasis has been placed on parasitoid species (Goldson *et al.,* 1994).

Evans (2016) states that biodiversity affects ecosystem functioning in general and classical biological control in particular. In classical biological control, the question is whether we should build a move diverse or a less diverse natural enemy community to attack the invasive pest in its new geographic range. Some studies indicate that successful suppression of target pest occurs through integrated contributions of multiple introduced species termed as "cumulative stress."(Denoth et al, 2002). Alternately, in several cases, a single introduced species of natural enemy has succeeded in managing the pest (Myers et al. 1989). Still another approach termed as the "lottery approach" is to release multiple species hoping that the "best" species or the combination of species would be sorted out in the field (Ehler and Hall, 1982). However, this approach has come under scrutiny due to concerns regarding non-target effect and negative interactions among competing natural enemies. The complementary of natural enemies was observed in the case of two seed feeding insects – a fly *Urophora quadrifasciata* (Meigen) and a weevil *Larinus minutus* Gyllenhal which together inflicted greater seed destruction of the invasive squarrose knapweed is Utah desert (Evans, 2016). Complementarity between natural enemies becomes clear and consistent when temporal and spatial scales are expanded.

Though increased species richness generally strengthens biological control, negative effects have been reported in some cases. Jonsson et al (2017) have tried to bring out the factors which are responsible for the different outcomes. Resource partitioning, facilitation and positive selection effects are the factors which link species richness to increased biological control, while factors like intraguild predation, behavioral interference and negative selection effects are responsible for greater enemy diversity leading to weakened prey suppression.

Research at NBAIR indicated that combinations of biological control agents can enhance the overall suppression of pests on crops, for instance, for the management of brinjal fruit and shoot borer and brinjal mealy bug, *T. chilonis* and *C. montrouzieri* can be effectively utilized. Northfield et al (2010) evaluated their experiments with a model where they could demonstrate that through niche partitioning, two predators could perform in a complementary manner and could suppress aphid population infesting collard plants. The compatibility of anthocorid and geocorid predators with *T. chilonis* was proved by Gupta and Ballal (2007) and Varshney and Ballal (2017). *Cryptolaemus montrouzieri* was observed to be compatible with parasitoids *Anagyrus dactylopii* and *Aenasius advena* for management of grape mealy bug (Mani et al., 1990). However, interaction studies between parasitoids *Chelonus blackburni* Cam and *Copidosoma koehleri* Blanch. (Ballal *et al.,* 1989), *Cotesia kazak* Telenga and *Hyposoter didymator* (Thunb.) (Jalali *et al.* 1988) and *Campoletis chlorideae* Uchida and *Eriborus argenteopilosus* (Cameron) (Bajpai *et al.* 2006), indicated that when one of the parasitoids emerged as the dominant one, it is advisable not to release them together against the target pest. Finke and Snyder (2008) demonstrated complementarity by directly manipulating the niche breadth of natural enemy species. This can be done through manipulation of niche overlap or spatial niche partitioning.

Intrinsic and extrinsic ecological factors are known to moderate the effect of natural enemy diversity. Biological practitioners can predict the effect of natural enemy diversity on biological control if they can understand the traits of the natural enemies (eg. body size, for aging mode, microhabitat use, diet breadth, phenology, diel activity and relative abundance) and the extrinsic factors which include prey traits (life cycle, diversity, density, patchiness) and environmental variables (plant composition, habitat complexity, host plant taxon, temperature, spatial and temporal scale). Within a species, the occurrence of both active and sedentary individuals can increase prey suppression (Royaute and Pruitt, 2015). In the case of a sedentary target pest, roaming natural enemies are expected to provide effective control. "Sit and wait" predators may not always encounter the prey and is expected to function more as an intraguild predator (Roseinheim and Corbett 2003).

The general inferences on the factors affecting the relationship between biodiversity and biocontrol can vary depending on the context. A high diversity in the microhabitat use of the natural enemies can be advantageous only if the pest also uses a diversity of microhabitats (Schmitz and Barton, 2014). Environment variables can also influence the relationship. The differences in body size of the natural enemies, generally considered as a disadvantage can prove to be advantageous for biological of holometabolous pests who have size variations during development or while tackling multiple pests of varying sizes (Wilby et al 2005).

Transcending the coordination and cooperation on a given pest is an important shared need for advances in regulatory policy, general methodologies for release and evaluation of natural enemies, and the need to develop sound ecological theory concerning pest population dynamics, predator-prey interactions, and the genetics of colonization in biological control. Future biocontrol attempts must consider climate variables in evaluating long term effectiveness. Biological control scientists are expected to provide management professionals with sustainable and effective tools with which to manage the relentless pressure of invasive species and indigenous pest outbreaks on natural and agricultural ecosystems.

REFERENCES

Ali MS. 1957. Some biological studies on *Pseudococcus vastator* (Maskell). *Indian Journal of Entomology*. **19:** 54-58.

Bajpai NK, Ballal CR, Rao NS, Singh SP, Bhaskaran TV. 2006. Competitive Interaction between two ichneumonid parasitoids of *Spodoptera litura*. *Biocontrol*. **51:** 419: 438.

Bajpai NK, Ballal CR, Singh SP, Srinivasan R. 2002. Net house studies on performance of *Campoletis chlorideae* on *Helicoverpa armigera* larvae infesting chickpea. *Indian Journal of Applied Entomology*. **16:** 22-24.

Ballal, C. R., Akbar, S. A., Yamada, K., Wachkoo, A. A. and Varshney, R. 2018. Annotated catalogue of the flower bugs from India (Heteroptera: Anthocoridae, Lasiochilidae). *Acta Entomologica Musei Nationalis Pragae*, **58**(1): 207–226

Ballal CR, Gupta T. 2003. Influence of chickpea varieties on oviposition by *Helicoverpa armigera* and parasitising efficiency of *Campoletis chlorideae* p. 81, In *Proceedings of the National Symposium on Bio-Management of Insect Pests* 29th to 31st March, 2003, Annamalai University, Annamalainagar, Tamil Nadu, 121 pp.

Ballal CR, Ramani S. 1994. Studies on four geographical strains of *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae). In *Biological Control of Insect Pests* (Ed. S. C. Goel), U. P. Zoological Society, Muzaffarnagar, pp. 87 90.

Ballal CR, Singh SP. 2001. Effect of insectcide applications on the populations of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and natural enemies in sunflower ecosystem. *Proceedings of the International Meet Entomocongress 2000: Perspectives for the New Millennium*, held at Trivandrum from 5-8 November, 2000. *Entomon* (Spl. Issue). 37- 42.

Ballal CR, Singh SP. 2003. The effectiveness of *Trichogramma chilonis* Ishii, *Trichogramma pretiosum* Riley and *Trichogramma brasiliense* (Ashmead) (Hymenoptera: Trichogrammatidae) as parasitoids of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on sunflower (*Helianthus annuus* L.) and redgram (*Cajanus cajan* (L.) Millsp.). *Biocontrol Science and Technology*. **13:** 231-240.

Ballal CR, Gupta T, Joshi S, Chandrashekhar K. 2009. Evaluation of an anthocorid predator *Blaptostethus pallescens* against two-spotted spider mite *Tetranychus urticae*. *Integrated Control in Protected Crops. IOBC/WPRS Bulletin*. **49:** 127-132.

Ballal CR, Gupta T, Joshi S. 2013. Production and evaluation of the warehouse pirate bug *Xylocoris flavipes* (Reuter) (Hemiptera: Anthocoridae). In: *Proceedings of the International Congress on Insect Science 2013*, 14th to 17th February, 2013 at GKVK, Bangalore.

Ballal CR, Jalali SK, Sunil Joshi, Rao NS. 2001a. Variations in populations of *Campoletis chlorideae* Uchida and *Helicoverpa armigera* (Hubner) from different crop ecosystems pp. 11-12, In *Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium*, July 18-19, 2001. at Punjab Agricultural University, Ludhiana. (Eds. Darshan Singh, MS Mahal, AS Sohi, VK Dilawari, KS Brar, SP Singh). 224 pp.

Ballal CR, Joshi S, Rao NS. 2001b. Bio-deterioration of laboratory cultures of *Campoletis chlorideae* Uchida pp. 210-213, In *IPM in Horticultural Crops: Emerging Trends in the New Millennium; Proceedings of the Second National Symposium on Integrated Pest Management (IPM); New molecules, Bio-Pesticides and Environment*; October 17 to 19, 2001 at Bangalore. (Eds. A Verghese, PP Reddy). 257 pp.

Ballal CR, Joshi S, Jalali SK, Rao NS. 2001c. Quality control parameters in mass produced bioagents. pp. 141-161, **In** *Augmentative Biocontrol*, *Proceedings of the ICAR-CABI Workshop on Augmentative Biocontrol* SP Singh, ST Murphy, CR Ballal (Eds). 250 pp.

Ballal CR, Singh SP, Jalali SK, Kumar P. 1989. Parasitising efficiency of *Chelonus blackburni* Cam. and *Copidosoma koehleri* Blanch. singly and in combination against the potato tuber moth. *J. Biol. Control*. **3:** 4 6.

Ballal CR, Singh SP, Poorani J, Tripti Gupta. 2003a. Feasibility of mass multiplication and utilization of *Cardiastethus exiguus* Poppius, a potential anthocorid predator of *Opisina arenosella* Walker (Lepidoptera : Oecophoridae). pp. 29-33. **In** *Biological Control of Lepidopteran pests* (Eds. Tandon PL, Ballal CR, Jalali SK, Rabindra RJ) 354 pp.

Ballal CR, Singh SP, Poorani J, Tripti Gupta. 2003b. Biology and rearing requirements of an anthocorid predator, *Blaptostethus pallescens* Poppius (Heteroptera: Anthocoridae). *Journal of Biological Control*. **17(1):** 29-33.

Ballal CR, Srinivasan R, Chandrashekhar B. 2005. Evaluation of quality of *Trichogramma chilonis* Ishii from different production units in India. *Journal of Biological Control*. **19 (1):** 1-8.

Ballal CR, Srinivasan R, Jalali SK. 2009. Evaluation of an endosulfan tolerant strain of *Trichogramma chilonis* on cotton. *Biocontrol*. **54:** 723-732.

Bengtsson JJ, Ahnstorm, AC Weibul. 2005. Effect of organic agriculture on biodiversity and abundance: A meta-analysis. *Journal of Applied Ecology*. **42:**261-69. doi.10.1111/j.1365-2664.2005.01005.x.

Bilapate GG, Mokat RB, Lovekar RC, Bagade DN. 1988. Population ecology of *Heliothis armigera* (Hubner) and its parasites on pulses. *Journal of Maharashtra Agricultural Universities*. **13:** 299-302.

Biswas SR, Tandon PL, Singh SP. 2000. Biocontrol Resource Infobase, Preoject Directorate of Biological Control, Bangalore (CD).

Chandramohan N. 1994. Seasonal Incidence of Diamondback moth, *Plutella xylostella* L. and its Parasitoids in Nilgiris. *Journal of Biological Control.* **8:** 77-80.

Crowder DW, Jabbour R. 2014. Relationships between biodiversity and biological control is agro ecosystems: Current status and future challenges. *Biological control.* **75:**8-17.

Denoth M, Frid L, Myers JH. 2002. Multiple agents in biological control: Improving the odds? *Biological control.* **24:**20-30.

Dodia JF, Yadav DN, Patel RC. 1986. Management of fruit sucking moth, *Othreis fullonica* L. (Lepidoptera: Noctuidae) in citrus orchards at Anand (Gujarat) *GAU Research Journal.* **11:** 72 73.

Duffield SJ. 1994. Trichogramma egg parasitism of Helicoverpa armigera on short duration pigeonpea intercultured with sorghum. *Entomologia Experimentalis et Applicata.* **72:** 289 – 296.

Duffield SJ, YVR Reddy. 1997. Distribution and movement of predators of Helicoverpa armigera in intercropped sorghum and short-duration pigeonpea. *Crop Research.* **14:** 315–335.

Ehler LE. 1990. Introduction strategies in biological control of insects. In: Mackauer M, Ehler LE, Roland J. (eds.) *Critical issues in biological control*. Intercept, ndover, pp. 111-134.

Ehler LE, Hall RW. 1982. Evidence for competitive exclusion of introduced natural enemies in biological control. *Environmental Entomology.* **11:** 1-4.

Ehrlich PR, Ehrlich AH. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York.

Evans EW. 2016. Biodiversity, ecosystem functioning and classical biological control. *Applied Entomology and Zoology.* **51:** 173-184.

Finke DF, Snyder WE. 2008. Niche partitioning increases resource exploitation by diverse communities. *Science.* **321:**1488-1490

Gardiner MM, DA Landis, C Gratton, CD DiFonzo, M O Neal, JM Chacon, MT Wayo, NP Schmidt, EE Mueller, GE Heimpel. 2009. Landscape diversity enhances biological control of an introduced crop pest in the north-central USA. *Ecological Applications.* **19:**143-54. doi:10.1890/07-1265.

Goldson SL, Philips CB, Barlow ND. 1994. The value of parasitoids in biological control. *Newzealand Journal of Zoology*. **21:** 91-96.

Ghosh E, Ballal CR. 2017a. Effect of age dependent cold storage of factitious host *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) for their continuous production and *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) rearing. *Journal of Asia Pacific Entomology.* **20:** 928-934.

Ghosh E, Ballal CR. 2017b. Diapause induction and termination in Indian strains of *Trichogramma chilonis* (Hymenoptera: Trichogrammatidae). *The Canadian Entomologist.* **149 (5):** 607-615. doi.org/10.4039/tce.2017.35.

Ghosh, E, Ballal, C. R. 2018 Maternal influence on diapause induction: an approach to improve long term storage of *Trichogramma chilonis Phytoparasitica* DOI: 10.1007/s12600-018-0665-7

Gupta T, Ballal CR. 2006. Biology and feeding potential of an anthocorid predator, *Orius tantillus* (Heteroptera: Anthocoridae) on *Sitotroga cerealella Indian Journal of Plant Protection.* **34(2):** 168-172.

Gupta T, Ballal CR. 2007. Feeding preference of anthocorid predators for parasitised and un-parasitised eggs. *Journal of Biological Control.* **21**: 73-78.

Jalali SK, Singh SP. 1990. A new record of *Ooencyrtus papilionis* (Hymenoptera: Encyrtidae) on the eggs of *Papilio demoleus* (Linn.) from India. *Journal of Biological Control.* **4:** 59-60.

Jalali SK, Singh SP, Ballal CR, Kumar P. 1988. Competitive interaction between *Cotesia kazak* and *Hyposoter didymator*, exotic parasitoids of *Heliothis armigera*. *Entomol. exp.et appl.* **46:** 221 225.

Jalali SK, Singh SP, Venkatesan T, Murthy KS, Lalitha Y. 2006. Development of endosulfan tolerant strain of an egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae). *Indian Journal of Experimental Biology.* **44:** 584-590.

Jalali SK, Venkatesan T, Murthy KS, Rabindra RJ, Lalitha Y. 2007. Vacuum packaging of *Corcyra cephalonica* (Stainton) eggs to enhance shelf life for parasitisation by the egg parasitoid *Trichogramma chilonis*. *Biological Control* **41(1):** 64-67.

Jayarathnam K. 1977. Studies on the population dynamics of the diamondback moth *Plutella xylostella* (Linnaeus) (Lepidoptera: Yponomeutidae) and crop loss due to the pest on cabbage. *Ph.D. thesis, UAS, Bangalore*. 215 pp.

Jonsson M, Kaartinen R, Straub CS. 2017. Relationships between natural enemy diversity and biological control. *Current opinion in Insect science.* **20:**1-6.

Joshi S, Viraktamath CA. 2004. The sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae): its biology, pest status and control. *Current Science.* **87:** 307-316.

Joshi S, Ballal CR, Rao NS. 1998. An efficient and simple mass culturing technique for *Ischiodon scutellaris* (Fabricus), an aphidophagous syrphid. *Indian Journal of Plant Protection* **26(1):** 56-61.

Joshi S, Prashanth Mohanraj, Rabindra RJ, Rao NS. 2003. Production and use of coccinellid predators. Project Directorate of Biological Control, Bangalore, India. *Technical Bulletin* No. 32. 26 pp.

Krishnamoorthy A, Singh SP. 1987. Biological control of citrus mealubug with an introduced parasite, *Leptomastix dactylopii* in India. *Entomophaga*, **32:** 143 148.

Krishnamoorthy A, Singh SP. 1988. Observational studies on the occurrence of parasitoids of *Papilio* spp in citrus. *India Journal of Plant Protection*. **16:** 79 81.

Liere H, Jha S, Philpott SM. 2017. Intersection between biodiversity conservation, agroecology, and ecosystem services. *Agroecology and Sustainable Food systems*. **41:**7, 723-760

Losey JE, M Vaughan. 2006. The economic value of ecological services provided by insects. *Bioscience*. **56**:311-23. doi.10.1641/0006-3568(2006)56[311:TEVOES] 2.0. CO; 2.

Lalitha Y, Ballal CR, Patel VN. 2013. Quality assessment of mass reared *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) based on field performance. p. 60, In Abstracts of the IOBC *MRQA 13th workshop on "Emerging Opportunities for the Mass Production and Quality Assurance of Invertebrates"*, Bangalore, India, 94 pp.

Lyla KR, Pathummal Beevi, Ballal CR. 2006. Field evaluation of anthocorid predator, *Cardiastethus exiguus* Poppius against *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) in Kerala. *Journal of Biological Control*. **20**: 229-232.

Mani M, Krishnamoorthy A, Singh SP. 1990. The impact of the predator, *Cryptolaemus montrouzieri* Mulsant on pesticide-resistant populations of the striped mealybug, *Ferrisia virgata* (Ckll.) on guava in India. *International Journal of Tropical Science*. **11**: 167–170.

Mani M, Shivaraju, C. 2016. Mealybugs and their Management in Agricultural and Horticultural crops. Springer India, 10.1007/978-81-322-2677-2, XXIII, 655 pp.

Manjunath TM. 1985. *Leptomastix dactylopii* in India. *Biocontrol News and Information*. **6:** 297.

Manjunath TM, Bhatnagar VS, Pawar CS, Seethanantham S. 1989. Economic Importance of Heliothis spp. in India and an Assessment of Their Natural Enemies and Host Plants, pp. 197-228. In EG King, RD Jackson. (Eds) - *Proceedings of the Workshop on Biological Control of Heliothis: Increasing the Effectiveness of Natural Enemies* jointly organized by Far Eastern Regional Research Office, U. S. Dept. of Agriculture (FERRO-USDA) and Indian Council of Agricultural Research (ICAR), New Delhi, India. 11-15 Nov 1985, 550 pp.

Meehan TD, BP Werling, DA Landis, C Gratton. 2011. Agricultural landscape simplification and insectiside use in the Midwestern United States. *Proceedings of the Natural Academy of Science of the United States of America*. **108:**11500-05. doi.10.1073/pnas.1100751108.

Misra MP, Pawar AD. 1984. Use of *Epipyrops melanoleuca* Fletcher (Lepidoptera: Epipyropidae) for the biocontrol of sugarcane pyrilla, *Pyrilla perpusilla* (Walker) (Hemiopetra: Fulgoridae) *Indian Journal of Agricultural Science*. **54:** 742-750.

Mukherjee AB, Chaudhury AKS, Bronniman H, Chu Y. 1971. Artificial diets for rearing of *Xylocoris flavipes* (Reuter), a predator of some pests of stored cereals. *Indian Journal of Entomology*. **33:** 356–358.

Myers JH, Higgins C, Kovacs E. 1989. How many insect species are necessary for the biological control of insects? *Environmental Entomology*. **18:**541-547.

Nagakatti S, Jayanth KP. 1982. Population dynamics of major pests of cabbage and their natural enemies in Bangalore district (India). In *Proceedings of the InternationalConference of Plant Protection of Tropics*, Malaysian Plant Protection Society, Kula Lumpur, Malasyia. pp. 325-347.

Nagarkatti S, Singh SP, Jayanth KP, Bhumannavar BS. 1992. Introduction and establishment of *Leptomastix dactylopii* How. against *Planococcus* spp. in India. *Indian Journal of Plant Protection*. **19:** 102-104.

Nicholls CI, MA Altieri. 2013. Plant biodiversity enhances bees and other insect pollinators in agro ecosystems. A review. *Agronomy for Sustainable Development*. **33:**257-74. doi.: 10.1007/s13593-012-0092-y.

Northfield TD, Snyder GB, Ives AR, Snyder WE. 2010. Niche saturation reveals resource partitioning among consumers. *Ecology*. **13:** 338-348.

Pawar AD. 1979. Sugarcane pyrilla and its biological control. *Plant Protection Bulletin*. **13:** 157-163.

Pawar AD. 1986. Role of natural enemies in the integrated pest management of rice. *Plant Protection Bulletin, India*. **38:** 15-26.

Rabindra RJ, Mohanraj P, Poorani J, Jalali SK, Joshi S, Ramani S. 2002. *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae), a serious pest of sugarcane in Maharashtra and attempts at its management by biological means. *Journal of Biological Control*. **16:** 171-172.

Ramani S, Poorani J, Bhumannavar BS. 2002. Spiralling whitefly, *Aleurodicus dispersus*, in India. *Biocontrol News and Information*. **23:** 2, 55N-62N.

Rao VP, Ghani MA, Sankaran T, Mathur KC. 1971. A review of the biological control of insects and other pests in South East Asia and the pacific region. *CIBC Technical communication*. No. **6:** 149 pp.

Rosenheim JA, Corbett SA. 2003. Omnivory and indeterminancy of predator function: Can knowledge of for aging behavior help? *Ecology*. **84:** 2438-2548.

Royaute R, Pruitt JN. 2015. Varying predator personalities generates contrasting prey communities in an agro ecosystem. *Ecology*. **96:** 2902-2911.

Salliou N, Barnaud C. 2017. Landscape and biodiversity as new resources for agro ecology? Insight from farmers' perspective. *Ecology and Society*. **22 (2):** 16. http:// doi.org/ 10.5751/ES-09249-220216

Sathiamma B, Chandrika Mohan, Murali Gopal. 2000. Biological potential and its exploitation in coconut pest management. In *Biocontrol potential and its exploitation in sustainable agriculture*, Volume-2: Insect pests. Upadhyay, RK Mukerji, KG, Chamola BP (eds.), Kluwer Academic / Plenum Publishers, New York, USA. 421 pp.

Schmitz OJ, Barton B. 2014. Climate change effects on behavioral and physiological ecology of predator-prey interactions: implications for conservation biological control. Biological control. **75:**87-96.

Schmitz OJ. 2007. Predator diversity and trophic interactions. *Ecology*. **88:**2415-26. doi:10.1890/06-0937.1.

Selvaraj KR, Sundararaj, T. Venkatesan, CR Ballal, SK Jalali, Ankita Gupta, HK Mridula. 2017. Potential natural enemies of the invasive rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin in India. *Journal of Biological Control*. **30:** 236-239.

Singh SP. 1989. Achievements of AICRP on Biological Control. *Technical Bulletin*, No. 2. Biological Control Centre, NCIPM, Faridabad. 20 pp.

Singh SP. 1994. Fifteen years of AICRP on Biological Control. *Technical Bulletin* No. 8, Project Directorate of Biological Control. 320 pp.

Singh SP. 2002. Progress and potential of Biological Control in India. *Thirteenth Dr. C. P. Alexander Memorial Lecture 2001*, Dept of Zoology, University of Delhi, Delhi. 32 pp.

Singh SP, Joshi S, Ballal CR. 2001. Innovations in mass rearing technology and techniques for mass releases, transportation and storage of natural enemies. In: Singh SP, Bhumannavar BS, Poorani J, Singh D (eds) *Biological control - symposium on biocontrol based pest management for quality crop protection in the current millennium* (July 18th to 19th, 2001). pp 1–33; 181 pp.

Subba Rao BR, Sangwar HS, Abbasi OA, Singh Y, Ksheer Sagar AM. 1965. New records of hymenopterous parasites of *Nipaecoccus vastator* (Maskell) (Homoptera: Coccidae), a serious pest of *Citrus* spp. from India. *Indian Journal of Entomology*. **27:** 109 110.

Tripathi GM. 1995. Record of parasitoid and predator complex of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner in Nagaland. *Indian Sugar*. **44:** 883-885.

Tylianakis JM, T Tscharntke, OT Lewis. 2007. Habitat modification alters the structure of tropical host-parasitoid food webs. *Nature*. **445:**202-05. doi.10.1038/nature05429

Varshney R, Ballal CR. 2017. Intraguild predation on *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) by the generalist predator *Geocoris ochropterus* Fieber (Hemiptera: Geocoridae). *Egyptian Journal of Biological Pest management* (In Press).

Venkatesan T, Ballal CR, Rabindra RJ. 2008. Biological control of Coconut Black-Headed Caterpillar *Opisina arenosella* using *Goniozus nephantidis* and *Cardiastethus exiguus* Technical Bulletin No. 39, Project Directorate of Biological Control, Bangalore. 14 pp.

Wilby A, Villareal SC, Lan LP, Heong KL, Thomas MB. 2005. Functional benefits of predator species diversity depend on prey identity. *Ecological Entomology*. **30:**497-501.

Yadav DN, Patel RC, Manjunath TM. 1975. Seasonal activity of *Apanteles plutellae* (Kurdj.), a larval parasite of *Plutella xylostella* (L.) at Anand (Gujarat, India). *Indian Journal of Plant Protection*. **3:** 111-115.

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Biodynamic agriculture: An advance stage of organic farming

R A Ram and Archit Kumar

ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow - 226 101

ABSTRACT

Biodynamic farming refers to "working with the energies which create and maintain life. Bio dynamics is process of healing earth with vital forces through human efforts. Using biodynamic preparations regularly opens the soil to cosmic activities and allows these to work through soil into the plants. The aim of biodynamic concept is to establish a system that brings balance into all factors, which maintain life. In biodynamic farming energy harnessed from cosmos, plant earth and cow. Biodynamic compost, BD-500, 501, cow pat pit and biodynamic liquid manure/ pesticides is produced at the farm for nutrient and insect pest management.

Key words: Biodynamic, agriculture, organic farming

Biodynamic agriculture, conceptualized by Rudolf Steiner in 1924, is a super organic farming system in which all the inputs required for crop production are produced at the farm and is being practiced on 161,074 hectares in 60 countries (Paul, 2016). Steiner (1997) emphasized that one must nourish Earth in such a way that the cosmic influences could continue to flow in freely. The more biologically active Earth, the more beneficial forces can work through plant and animal (Procter, 2008). The degenerative effects of intensive farming practices on soil fertility and ecological balance have now forced the farming community to follows agro-chemical based alternative system of farming. This includes organic/ecological/natural or in the recent years "Biodynamic" system of farming that mainly works on principles of relationship between plant growth and cosmic rhythms and importance of maintaining sustainable soil fertility. In these, maximum reliance is placed on self-regulatory agro-ecosystem locally or 'farm derived' renewable resources minimizing reliance on external inputs. Organic production has gained momentum in countries like Germany, New Zealand, USA Canada etc. In India sporadic attempts are being made at few farms and the results are very encouraging.

Harnessing cosmic energy through use of agriculture calendar

For harnessing cosmic energies, agriculture calendar for the year, based on planetary configuration is made available for use for different agricultural operations. Even few of the BD preparations are prepared as per calendar. On observation, it is evident that human, animal and plant life is strongly dependent on Earth rhythms. Sun travels for six months in ascending and six months in descending mode. Similarly, moon travels in Earth's orbit in 27 days, 14.5 days in ascending and 14.5 days in its descending phase. In ascending phase there is out flow of energy above Earth while in descending phase it is below the Earth.

Maria Thun had developed a procedure of sowing of seeds according to the position of the moon related to the twelve zodiac constellations. These constellations were classified into four groups according to the elemental influence (Earth, Water, Air and Fire) and astrological relationship. Root, leaf, flower and fruit crops showed increased yields, if sown when the Moon stood in front of Earth, Water, Air and Fire constellations, respectively (Thun, 2001). Thun and Heinze worked together on potato, radish, carrot, bean and other crops for eight years and concluded that constellations affects germination rate (Maw, 1967), water absorption (Brown and Chow, 1973) and metabolic activities (Brown, 1960) responded to this cycle. In a systematic study, lemon grass planted as per moon position showed significante increase in plant height, suckers, plant spread and was free from insect pests (Punam *et al.*, 2012). The twelve constellations for which different signs have been assigned are classified in four groups depending upon their similarities in influence. These are related to four basic elements, affected by phase of the Moon are Earth, Water, Air and Warmth (Fire). These four elements can be placed in relation to the four parts of plant i.e. root, leaf-stem, flower and fruit/seed which are influenced by the Moon facing the constellations and enables these particular elemental forces to work more strongly into plant life.

- Water - Pisces (Fishes), Cancer (Crab), and Scorpio (Scorpion) - tendency to watery element. Green vegetative parts are linked to moisture flow, hence ideal for leafy crops;
- Fire - Aries (Ram), Leo (Lion), Sagittarius) Archer- tendency towards warmth element- fruit is slowly ripened by warmth of Sun, which seals seed. Well suited for fruit and seed crops.
- Earth with -Taurus (Bull), Virgo (Virgin) and Capricorn (Goat) - tendency to Earth element (cold tendency) - suited to underground crops.

- Air -Gemini (Twins), Libra (Scales) and Aquarius (Waterman) - a tendency to airy or light element. Flowers opens into airy element well suited for flower crops.

The use of crop calendar (Anneexure-1) is summarize as under:

- Crop activities need to be performed when four elements are energized with cosmic forces as indicated in the calendar;
- Moon opposite to Saturn is ideal day for spraying of BD-501 and sowing/planting of any crop,
- Forty eight to twelve hours before the full moon is ideal time for sowing,
- Four days in a month i.e. node days, apogee, perigee need to be avoided for any farm/crop activities,
- Activities associated with soil need to be performed in descending phase of Moon, while above the soil in ascending phase,

Biodynamic calendar

Agricultural practices (field preparation, sowing, manuring harvesting etc.) done as per constellation are more effective and beneficial. Every constellation has dominant elemental influence and affects four specific parts of the plants.

Agricultural practices for better root activity (manuring, rooting), flowering, growth and fruiting/seed is to be done as per constellation.

Any agricultural practice (spray, propagation, harvesting etc.) performed during the ascending period of moon, when cosmic forces are active above the earth ground, show beneficial effect, while field preparation, sowing, manuring and harvesting of root crops undertaken during the descending period of moon, when cosmic forces are active below the earth, are beneficial.

Elements	Plant parts	Constellation
Earth	Root	Virgo, Capricorn, Taurus
Air	Flower	Gemini, Libra, Aquarius
Water	Leaf	Cancer, Scorpio, Pisces
Fire	Fruit	Sagittarius, Aries, Leo

Biodynamic preparations

Two basic types of biodynamic preparations are known. These are biodynamic compost preparations (BD-502-507), biodynamic field sprays (BD-500-501) and field preparations.

Biodynamic compost preparations (BD 502-507) are special herbal preparation that fixes and mineralizes trace nutrients required for plant growth, facilitates in harnessing the abundant, unused cosmic forces for crop productivity and replenishes/rectify the macro and micronutrient deficiencies. The details of various preparations and the substances from which these are produced as also as its application are given in as under:

All these preparations are prepared during the descending period of moon, except the BD-507, which is prepared in the air/light day. These were fermented for a specific period and stored at dark place with optimum moisture. 1 g compost of each and 10 ml of BD-507 were added in compost heap, cow pat pit and biodynamic liquid pesticides to catalyse the fermentation process (Koepf *et al*., 1990; Steiner, 1993).

BD-502-507 is included in one to provide a safer and balanced invigorating spray for plants and soil. The biodynamic preparations are made from garden herbs like valerian, stinging nettle, chamomile, yarrow, dandelion and oak along with cow manure and silica. These have speeded up soil development, composting and strengthen plants to resist insect pests. Two sets per 60 kg of cow dung, 1 set per 200 liters and 1 set per 5 M^3 were required for specific preparation of cow pat pit (CPP), liquid manure/pesticides and biodynamic compost, respectively.

Biodynamic field sprays (BD 500-501) and field preparations

BD-500 (Horn manure)

Preparation-500 is made by burying cow horns filled with cow dung for six months during autumn and winter in the soil. Those prepared using indigenous cow dung in indigenous cow horn are more effective. The cow horn has the ability to absorb the life energies during the decomposition of cow dung tilled in it and burried in the soil during winter.

Preparations	Substances	Effects
BD-502	Fermented flower heads from Yarrow (*Achilles millefolium*)	Activates potassium and sulphur effect in the soil.
BD-503	Fermented heads of Chamomile (*Matricaria chamomilla)*	This being combination of lime and sulphur acts as fungicide.
BD-504	Stinging Nettle (*Urtica dioica*) fermented in the soil	Balances iron into soils
BD-505	Fermented Oak bark (*Ouercus robur*)	Helps the calcium process in the cell wall of plants.
BD-506	Fermented flower heads of Dandelion (*Taraxacum officinale*)	Make plants to absorb required nutrients.
BD-507	Valerian or garden heliotrope flower juice (*Valeriana officinalis)*	Enable plants by making available phosphoric substances in rhizosphere.
BD-508	Common horse tail (*Equisetum arvense*)	Has antifungal properties.

The manure so prepared is dissolved in water by making vortex in clock and anti clockwise direction for an hour. Spraying of BD-500 (@ 25 grams acre^{-1} dissolved in 13.5 liters of water) should be done at least twice in a year in spring and autumn at the time of field preparation in evening during descending period of the moon (Pathak and Ram, 2004). The best time of application is the descending period of the moon rhythm in the afternoon. Microbial analysis of biodynamic preparations showed that it contained fungi, actinomycetes, *Pseudomonas*, gram positive bacteria, gram negative bacteria, p-solubilizing bacteria, Rhizobium, *Azotobacter and Azospirillum* (Ram and Singha, 2017).

BD-500 promotes soil texture, earthworm activity, porosity, and activity of humus forming bacteria, crumb structure, nodulation, and root penetration. It has been noticed that regular applications over the years provide four-fold increase in moisture-absorbing capacity, that extended down the humus depth up to about 30 cm, at four-leaf stage and again at the flowering or fruit maturation stage.

501-Horn silica

501 horn silica is made by filling the horns with 'mealy' silica powder and burying them in the soil during spring (March/April) at a time when BD-500 is taken out. The preparation gets ready for use within 6 months. Light yellowish silica powder is taken out from the horn and stored in light near the house window in glass jars (Pathak and Ram, 2003). 1 g is dissolved in 13.5 liters of water is sprayed on the leaves in the form of 'mist spray' at the sunrise when moon is opposite to saturn.

It is traditionally used to harden and strengthen plants. This aids in fungal control, nutrition, and ripening, keeping quality and drought resistance. However, by itself it can cause reduction in fruit size and burning when the weather is very dry. It is used where an extra burst of ripening is needed in the autumn or in dull seasons. BD-501 spray can be applied every few days to speed up ripening and enhancing the quality of vegetables, fruits and the herbs. It effectively controls powdery mildew appearing during opposite weather conditions. The spray is applied at the first sight of dry weather or when the mildew first appears. The application may be repeated after a fortnight when infections reappear. However, ripening is slowed down with over use. Spraying of seedlings few days before transplanting or through irrigation water is beneficial. A spray after transplanting is also good. Quicker plant establishment and successful plant propagation can be achieved with the use of BD-501. Cuttings before planting may be soaked in BD-501 solution for faster root growth.

Cow pat pit (CPP)

CPP also called as "soil shampoo" is a strong soil conditioner that enhances seed germination, promotes rooting in cutting and grafting, soil texture, provides resistance against pests and diseases and replenishes and rectifies the trace element deficiency. It is used in the seed treatment and foliar applications.

The CPP may be prepared throughout the year in pits of 90 x 40 x 30 cm lined by the bricks, in a root zone free area having good drainage. These pits are filled with mixture of 60 kg cow dung, 250 grams eggshell powder and 250 g of basalt/bentonite powder up to a maximum depth of 25 cm (any deeper will delay the break down into humus). Three sets of BD preparations 502-507 are injacted by pressing them into the dung to a depth of 5 cm. Two sets of valerian preparation BD 507, stirred in one liter of water, is sprinkled over the mixture and later covered with the gunnysack bags to retain the moisture. Depending upon the weather and temperature, the preparation becomes ready for use in approximately three months. 500 grams of CPP dissolved in water is used per acre of land. This has showed highest load of *Rhizobium* (1.9 x 10^{6}), *Azospirillum* (0.2 x 10^{6}), *Azotobacter* (8.0 x 10^{5}) and fungi (2.5 x 10^{6}) (Ram *et al*., 2010). It also contained the highest amount of *B. subtilis* (1.9 x 10^{6}) responsible for disease tolerance (Proctor, 2008) in plants. Cow pat pit is reported to contain plant growth hormones such as indole acetic acid IAA (28.6 mg kg^{-1}), kinetin (7.6 mg kg^{-1}) and gibbrerllic acid (23.6 mg kg^{-1}) (Perumal *et al*., 2006). Stalin *et al*., (2014) have enumerated microorganisms in organic and biodynamic manures and showed that cow pat pit contained highest bacterial load (4.8 x 10^{6} cfu g^{-1}) with predominance of *Bacillus subtilis.*

Biodynamic compost heap

Biodynamic compost is an effective soil conditioner and is an immediate source of nutrient for a crop. If can be prepared by using green (nitrogenous material) and dry leaves (carbonaceous material) piled up in an alternative layers of 15-25 cm thickness in the size of 5 x 2 x 1.5 meters in 8-12 weeks. Integrating these with cow dung is always good in the decomposition process. For enriching the compost with different nutrients, rock phosphate-P, slacked lime - Ca, wood ash-K etc. can be used as per the need. The composition of air, moisture and warmth is very important in the breakdown and decomposition of the material. Its use has been summarized in the chart below:

Dandelion (506)			Yarrow (502)
	Nettle (504)	Oak bark (505)	
Valerian (507)			Chamomile (503)

Biodynamic tree paste

The biodynamic tree paste is prepared by mixing of cow dung, farm soil (clay) and sand in the ratio of 1:1:1 and BD-500. It is used for the management of orchards and gardens. This when pasted on the tree trunks nourishes, strengthens and protects the bark and cambium of tree to make it healthy, seals and heals wounds, prevents and control diseases and on its application after pruning stimulates tree growth.

Biodynamic liquid pesticides

These are prepared using cow dung, cow urine and neem, *Pongamia,* Calotropis and some medicinal plant leaves having pesticidal properties. A plastic drum of of 200 liters capacity is taken, filled with 5 liters of cow urine, 5 kg of cow dung, 150 liters of water and 20-25 kg chopped plant leaves and later, of one set BD-502-506 is hanged in the drum (like a tea bag) or put inside in folded leaves. BD-507 (10ml) is mixed in 2-3 liters of water for 15-20 minutes and later poured in the drum. Liquid is stirred every day in the morning and evening. The drum is covered with gunnysack bags and the preparation gets ready for use within 10-15 days depending upon the temperature and humidity.

Spraying of one liter of liquid, dissolved in 2-3 liters of water, sprayed on the plants to manage insect pests. In an experiment, this liquid pesticide has been found managing mango hopper effectively. The hopper population before spray (3.07 hoppers panicle^{-1}) reduced to 0.95 hopper panicle^{-1} up to 15th SMW (standard meteorological week). The second spray taken up at 14th SMW reduced hopper population to 0.4 hoppers panicle^{-1} up to 19th SMW. Powdery mildew was managed with spraying of BD-501 and 02 per cent wettable sulphur (Ram *et al.*, 2017).

Peppering

'Peppering', a method of pest control suggested by the founder of the biodynamic agricultural movement, Rudolf Steiner in 1924, has been used to manage everything from weeds to insects to possums, rabbits and rats successfully in many different circumstances. This is prepared using insects essentially its ash, obtained after their burning and processing it into liquid form (diluted to D-6 to D-8 level). This can be easily sprayed over orchards by incorporating it into existing spraying rounds.

The aim of 'peppering' is to inhibit the reproductive potential of any plant, insect or animal. Steiner suggested that this method of crop management may take up to four years to become fully effective. However, few experiments have shown effective results within days. With the passion vine hopper, Jane Cooks orchard has reported that she used the pepper for the first time 3 seasons ago. The vine hopper infestation level in the first season was very small, while, in the last year it was observed to have no great concern. Several other growers have also reported good level of control.

References

Brown, F. 1960. The rhythmic nature of animals and plants. Cycles, April: 81-92.

Brown, F.; Chow, C.S. 1973. Lunar-correlated variations in water uptake by bean seeds. *Biological Bulletin*, 145:265-278.

Proctor, P. 2008. Biodynamic Farming and Gardening, Other India Press, Goa, India.

Steiner, R. 1997. Theosophy. An introduction to the supersensible knowledge of the World and the Destination of man. Anthrosophic Press, Hudson, New York.

Thun, M. 2001. Working with stars, a Bio dynamic Sowing and Planting Calendar. 26th edn. Launceston, U.K.; Lanthorne Press.

Ram, R. A. and Singha, A. 2017. Report of Net work project on organic horticulture. P 12-14.

Ram R.A., Singha A. and Bhriguvanshi S.R. 2010. Annual Report, Central Institute for Subtropical Horticulture, Lucknow, 27p.

Perumal, K.V., Varadarajan, S., Murugappa, A. 2006. Production of Plant Growth Hormones and Subtilin from Organic Biodynamic Manures Organic Farming - Advantages & Disadvantages for soils, water quality and sustainability. 18th World Congress of Soil Science, July, 9-15, 2006 held at Philipadaia, USA, 162:4. 1A.

Paull John. 2016. Organics Olympiad 2016: Global Indices of Leadership in Organic Agriculture, *Journal of Social and Development Sciences* **7**:79–87.

Pathak, R. K. and Ram, R. A. 2004. Organic farming systems prevalent in India. *(In) Proceedings of National Symposium on Organic Farming in Horticulture for Sustainable Production*, pp 18-26.

Pathak, R. K. and Ram, R. A. 2003. Role of cow in agriculture, (In) *National Seminar on Cow in Agriculture and human health*. Organized by Asian Agri-History Foundation. p59.

Koepf, H. H., Pettersson, B. D., Schaumann, W. 1990. Bio-Dynamic Agriculture: Practical Applications of the Bio-Dynamic Method. Anthroposophic Press, Hudson, New York.

Steiner, R. 1993. Agriculture: Spiritual Foundations for the Renewal of Agriculture. Anthroposophic Press, Hudson, New York.

Stalin, V., Perumal, K., Stanley, Abraham, L., Kalaichelvan, P. T. 2010. Screening and production of subtilin from *Bacillus subtilis* isolated from nutrient-rich organic and biodynamic manures. *IUP Journal of Life Science* **4**:34–44.

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Comparative growth and yield performance of bush pepper (*Pepper nigrum* L.) cuttings and grafts under shade condition and pepper in open plantation

V.V. Shinde, S.L. Ghavale, J.J. Dubale, P.C. Haldavanekar and P.B. Sanap

ICAR-All India Coordinated Research Project on Palms, CPCRI, Kasaragod, Kerala
Regional Coconut Research Station, Bhatye, Ratnagiri (M.S.), India
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-415 712
Author's Email: vaibhavvilasshinde@yahoo.co.in, sunillg72@gmail.com

ABSTRACT

The field experiment, carried out at Agriculture Research Station, Awashi, Khed, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli during 2012 to 2016 for assessing the comparative growth and yield performance of bush pepper cuttings and grafts under shade condition and pepper in open plantation, revealed that the growth and yield of bush pepper cuttings planted at 1.0 m x 1.0 m. spacing in 50 per cent green shade net condition was significantly superior over the bush pepper grafts under 50 per cent green shade net condition and black pepper under open plantation. It being an eco-friendly farming practice can be performed as backyard crops with judicious use of manures.

Key words: *Bush pepper cutting, shadenet, grafts, growth, yield*

Black pepper (*Piper nigrum* L.), of the family piperaceae, is a perennial export oriented spice crop in India. It is gaining popularity world-wide as an indispensable food adjunct due to its unique pungency and associated flavour. It is regarded as "King of Spices" and "Black Gold" (Parthasarathy *et al*., 2008) and having great socio-economic importance. The crop has socio-economic importance in some other countries viz. Thailand, Indonesia, Malaysia and Brazil. The productivity of black pepper in India is being challenged by countries like Malaysia and it is ascribed basically to improper management practices (Hamza and Sadanandan, 2005). It is the largest foreign exchange earner among spices and the average quantity exported from India accounts for more than 70 per cent of the total production. At present the productivity in India is very low due to the non-adoption of good agricultural practices (Thangaselvbal *et al*., 2008). It is documented that less fertilizers use, low fertilizers use efficiency and micro nutrient deficiency of all spices grown in India including black pepper (Parthasarathy *et al*., 2008 and Peter *et al*., 2000). Pepper is the world's most important and valued spices. It is used as an important component of many recipes and to flavour foods. From the berries of *Piper nigrum* L. several condiments are produced like black pepper, white pepper, green pepper etc. Other important commercial products derived from the pepper plant are pepper oil, cookies & crackers, pepper tea, perfumes, sausage preservation etc. (Bhattacharya and Bandyopadhyay, 2017). It is mainly grown in Kerala, Tamil Nadu, Karnataka, Maharashtra and West Bengal. It has got potential varietal wealth grown in India. It performs well under hot and humid coastal area throughout the country. Among all varieties Panniuar-1 performs better in Konkan region of Maharashtra State. In 2016-2017 (Est.), India produces 55500 tons of Black pepper from 131230 ha area with a productivity of 2.36 t ha^{-1} (Spices Board of India, 2016-17). The Konkan region of Maharashtra is a potential pocket for cultivating the black pepper. Usually it is trained on coconut, arecanut, bottle brush, silver oak or even mango trees in the orchards. The area under this crop is scattered and not exact figure is available as there is no systematic plantation is done so far.

Indian Institute of Spices Research (IISR), Calicut has come out with a new technology which can relish the culinary needs for pepper-throughout the year. Black pepper vines are usually cultivated by allowing them to climb on either living (on trees) or non-living (RCC posts, granite pillars, teak poles etc.) supports. Black pepper vines while climbing on these supports put forth fruiting branches called laterals which produce flowers and fruits. The normal way of producing planting material of black pepper is to use rooted cuttings (single or 3 nodded) of runner shoots or climbing shoots. This ensures that the plant turn into vine after climbing on a support and produce fruiting branches (Plagiotropes) all around the support. But when the laterals are used as planting material, the resultant plants grow like a "Bush". These plants produce numerous laterals throughout the year, unlike vines. As compare to black pepper trained on standard plant the bush pepper require limited area, easy spikes harvesting and bearing throughout year with no quality difference between both peppers. Being a shade loving plant and of climbing growth habit, it is trained on either live standard or dead standard. Now a day, most of the growers demands pepper as bush pepper, as it shows bushy growth habit, and can accommodate more number of plants per unit area. It is growing either by cutting or grafted on its own rootstocks. However, it needs to study the growth and yield of cutting as well as grafts performance under shade for its commercialization in the Konkan. Accordingly, the present investigation was carried out for assessing the comparative growth and yield performance of bush pepper cuttings and grafts under shade condition and pepper in open plantation for Konkan agro-climatic condition of Maharashtra State.

MATERIAL AND METHODS

The field experiment was carried out at Agriculture Research Station, Awashi, Khed, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (MS) during 2012 to 2016. The experiment was laid out by randomized block design having three treatments viz., T_1-bush pepper cuttings under 50 per cent shade net, T_2 -bush pepper grafts under 50% shade net and T_3-black pepper trained on open plantation of live standard and which was replicated by eight times. For the purpose of assessing the comparative growth and yield performance of bush pepper cuttings and grafts under shade condition and pepper in open plantation, the variety Pannuyr-1 was tested. The experiment was laid in blocks under 50 per cent shade net conditions at 1.0 m x 1.0 m spacing while that of 7.5 m x 7.5 m spacing i.e. trained in coconut garden. The pit of 30 cm^3 were dug and filled with well decomposed FYM and 50g single super phosphate. The well grown uniform bush pepper grafts and cuttings were planted in the pits. The partial support was given to the graft. The irrigation was given with the help of dripper and micro-sprinkler. Plant population for the treatments T_1 and T_2 were 100 for 100 m^2 area. However, for treatment T_3 it was 1.7 (i.e. 2 plants) plants per 100 m^2 area. Other cultural practices followed to maintain the better field standards. Different climatic parameters including atmospheric temperature, relative humidity, soil temperature and crop growth parameters in relation to bush height (cm), number of new sprouts, number of new spikes, length of spikes (cm) and yield (kg) per 100 m^2 were measured at different growth stages. Bush pepper was prepared by two methods i.e. two nodes cutting of plagiotropic shoots (T_1), grafting plagiotropic shoots on seedling prepared by two nodes runner cutting (T_2) and black pepper seedling by two node runner cutting (T_3). The crop growth parameters were recorded at an interval of seven days during the course of study. The data of pest and diseases were also recorded regularly. The data were analysed statistically as per the method suggested by Panse and Sukhatme, 1985 using RBD and valid conclusions were drawn only on significant differences between treatment mean at 0.05% level of significance.

RESULTS AND DISCUSSION

The various growth aspects of bush pepper as influenced by shade net condition and pepper in open plantation under Konkan agro-climatic condition of Maharashtra State have been studied and the results of these findings have been presented in this paper.

Bush height (cm)

Data in Table 1 showed that the bush height was significantly different among all the treatments under study. Treatment T_3 recorded significantly the highest (309.8 cm) plant height as compare to T_1 and T_2. It was because of vine type natural growth habit. However, in the treatments T_1 and T_2, the treatment T_1 recorded significantly the higher plant height (102.90 cm) and was superior over T_2. This may be attributed to profuse vegetative growth due to higher availability sufficient absorb photo-synthetically active radiation under 50% shade intensity. Analogous observation to these finding were reported by Bhattacharya and Bandyopadhyay (2017) in bush pepper under New Alluvial Zone of West Bengal.

Number of new sprouts plant^{-1}

With regards to new sprouts per plant per year (Table 1), the maximum number of new sprouts per plant per year (46.45) was observed in treatment T_1, while in open plantation of black pepper it was observed 12.13 sprouts per plant per year. The maximum numbers of sprouts per bush may be due to shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper; Thankamani *et al.,* (2002) in bush pepper and Balakrishan and Abraham (1986) in black pepper.

Number of spikes plant^{-1}

Number of spikes plant^{-1} also varied significantly (Table 1). The treatment T_1 noticed significantly the highest number of spikes plant^{-1} (75.84) during the period of investigation and pooled data. It was superior over rest of the treatments. The maximum numbers of spikes bush^{-1} may be due to 50 per cent shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results

Table 1: Plant height (cm), number of new sprouts and number of spikes per plant as affected by 50 per cent shade net and pepper in open plantation

Treatments	Height of plants (cm)					No. of new sprouts $plant^{-1}$ $year^{-1}$				Number of spikes $plant^{-1}$			
	Initial height	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled
T_1-bush pepper cuttings under 50% shade net	36.32	61.63	112.65	134.58	102.90	16.12	36.13	87.10	46.45	42.20	58.20	127.12	75.84
T_2-bush pepper grafts under 50% shade net	35.12	54.78	90.12	123.12	89.34	15.11	34.93	62.75	37.60	14.78	27.71	81.64	41.37
T_3-black pepper trained on open plantation of live standard	35.56	213.10	344.21	372.2	309.8	2.7	11.3	22.4	12.13	1.00	1.10	1.80	1.30
S.E. m±	**0.006**	**3.20**	**3.88**	**5.09**	**2.20**	**0.96**	**1.12**	**0.63**	**0.51**	**1.87**	**2.09**	**3.05**	**0.96**
C.D. at 5%	**NS.**	**9.49**	**11.07**	**15.88**	**6.49**	**2.69**	**3.37**	**1.89**	**1.61**	**5.43**	**6.17**	**9.15**	**3.07**

were also noticed by Sadanandan and Hamza (1996) in bush pepper; Thankamani *et al.*, (2002) in bush pepper; Balakrishan and Abraham (1986) in black pepper; Belger (1977) in black pepper and Sadanandan *et al.*, (1990) in black pepper.

Length of spike (cm)

Length of spike showed the significant variation due to different planting methods. It is revealed from the pooled data (Table 2) that the maximum spike length (16.45cm) was recorded in T_1 follow by T_2 (16.04 cm), whereas the lower spike length (6.78cm) was noticed in open plantation of black pepper. The maximum length of spikes per bush may be due to 50% shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper; Thankamani *et al.*, (2002) in bush pepper; Parthasarathy *et al.*, (2008) in black pepper; Reddy *et al.*, (1992) in black pepper and Peter *et al.*, (2000) in black pepper.

Number of berries $spike^{-1}$

Data presented in table 2 revealed that the number of berries per spike was significantly the highest (70.75 berries) in treatment T_1 during the period of investigation. The maximum numbers of berries per spikes may be due to 50 per cent shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper and Thankamani *et al.*, (2002) in bush pepper.

Weight of 100 green berries

Even through weight of 100 green berries (Table 2) significantly the highest in the treatment T_1, it was at par with the treatment T_2 during the period of 2014-15 and 2016, it was significantly superior over T_2 during 2015-16 and pooled data. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper.

Yield of green berries (kg) $plant^{-1}$

The treatment T_1 had obtained significantly the highest yield of green berries (1.19 kg/plant) during the period of investigation over rest of the treatments (Table-3). The highest yield of green berries per plant may be due to 50 per cent

Table 2: Length of spikes (cm), number of berries $spike^{-1}$ and weight of 100 green berries (g) as affected by 50 per cent shade net and pepper in open plantation

Treatments	Length of spikes (cm)				Number of berries $spike^{-1}$				Weight of 100 green berries (g)			
	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled
T_1-bush pepper cuttings under 50% shade net	16.81	16.56	16.00	16.45	72.00	72.25	68.00	70.75	17.5	17.63	17.16	17.43
T_2-bush pepper grafts under 50% shade net	15.77	16.48	15.88	16.04	61.75	65.50	60.50	62.58	17.38	16.63	17.2	17.07
T_3-black pepper trained on open plantation of live standard	6.90	6.73	6.73	6.78	47.10	43.75	38.00	42.45	15.67	14.8	14.64	15.03
S.E. m±	**0.95**	**0.76**	**0.76**	**0.48**	**2.11**	**2.63**	**3.41**	**1.59**	**0.04**	**0.03**	**0.06**	**0.01**
C.D. at 5%	**2.80**	**2.12**	**2.12**	**1.49**	**6.42**	**7.78**	**10.18**	**4.70**	**0.12**	**0.09**	**0.19**	**0.03**

Table 3: Yield of pepper as affected by 50 per cent shade net and pepper in open plantation

Treatments	Yield of green pepper (kg plant^{-1})				Yield of processed pepper (kg plant^{-1})				Yield of pepper (kg 100 m^2)			
	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled
T_1	0.452	0.762	2.343	1.19	0.16	0.25	0.78	0.40	16.0	25.0	78.0	39.67
T_2	0.372	0.638	2.095	1.04	0.12	0.21	0.70	0.34	12.0	21.0	70.0	34.33
T_3	0.08	0.08	0.09	0.08	0.030	0.030	0.032	0.03	0.051	0.051	0.054	0.052
S.E. m±	**0.10**	**0.12**	**0.11**	**0.07**	**0.03**	**0.02**	**0.04**	**0.01**	**0.92**	**0.49**	**1.7**	**0.48**
C.D. at 5%	**0.31**	**0.35**	**0.32**	**0.21**	**0.09**	**0.06**	**0.13**	**0.03**	**2.71**	**1.47**	**3.29**	**1.52**

shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper and Thankamani *et al.*, (2002) in bush pepper.

Yield of processed black pepper (kg plant^{-1})

The yield of processed black pepper was also significantly the highest (0.40 kg) in the treatment T_1 (Table-3) which was superior over all treatment during the period of 2014-15 and 2015-16. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper and Thankamani *et al.*, (2002) in bush pepper.

Table 4: Percentage of pest incidence as affected by 50 per cent shade net and pepper in open plantation

Treatments	Percentage of pest incidence (2014-2015)	
	Scale insects	Pollu beetle
T_1	2.50 *(4.61)*	1.66 *(3.74)*
T_2	5.00 *(9.22)*	3.33 *(7.48)*
T_3	15.00 (22.50)	11.66 *(19.47)*
S.E. m±	**4.81**	**4.075**
C.D. at 5%	**14.83**	**12.55**

(Figures in parenthesis indicates arcsine values)

Yield (kg) per 100 m^2 area

During the period of investigation and pooled data (Table 3), the treatment T_1 was significantly superior over all the treatments. Significantly the lowest yield was recorded by the treatment T_3. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper and Thankamani *et al.*, (2002) in bush pepper.

Incidence of pest

While observing the experimental plot the pests like scale insects and Pollu beetles were seen at very low magnitudes. Scale insects and Pollu beetles incidence were observed during 2014-15 only (Table 4). The lowest pest incidence was recorded in the treatment T_1 i.e. 2.50 and 1.66 per cent only than rest of the treatments respectively. There were no severe diseases found during the course of investigation. These results are in conformity with the research findings of Duarte and Albuquerque (1991) with respect to Fusarium disease of black pepper in Brazil.

Economics of different treatments in 100 m^2

While observing the economics, the treatment T_1 (bush pepper cuttings under 50 per cent shade net) noticed the highest B:C ratio of 3.04 followed by T_2-bush pepper grafts under 50 per cent shade net (2.09). The least B:C ratio was noticed by T_3 (1.68) i.e. black pepper trained on open plantation of live standard. Thus, the values for most of the

Table 5: Economics of different treatments in 100 m^2 area as affected by 50 per cent shade net and in open plantation of black pepper

Treatments	Yield (kg)	Gross income (Rs.)	Return from coconut (Rs.)	Grand total	Cost of production (Rs.)	Net income (Rs.)	B:C ratio
T_1-bush pepper cuttings under 50% shade net	39.67	23796	-	23796	7825	15971	**3.04**
T_2-bush pepper grafts under 50% shade net	34.33	20598	-	20598	9825	10773	2.09
T_3-black pepper trained on open plantation of live standard	0.052	31.2	1520	1551.2	925	595	1.68

Note: Selling price of processed black pepper @ Rs. 600 kg^{-1} and coconut @ Rs. 10 nut^{-1}.

growth as well as yield contributing were found in the treatment T_1 i.e. bush pepper cuttings under 50 per cent shade net followed by T_2 i.e. bush pepper grafts under 50 per cent shade net and T_3 i.e. black pepper trained on open plantation of live standard. The highest B:C ration might be due to 50 per cent shade net condition. These results are in conformity with the research findings of Bhattacharya and Bandyopadhyay (2017) in bush pepper. Similar results were also noticed by Sadanandan and Hamza (1996) in bush pepper and Thankamani *et al*., (2002) in bush pepper.

CONCLUSION

It may be concluded that the growth and yield of bush pepper cuttings planted at 1.0 m x 1.0 m. spacing in 50 per cent green shade net condition was significantly superior over the bush pepper grafts under 50 per cent green shade net condition and black pepper under open plantation.

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REFERENCES

Balakrishan, R. and Abraham, J. (1986). A technique for estimating yield in black pepper (*Pipper nigrum* L.). *The Journal of Plantation Crops*, **14**, 115-118.

Belger, E.U.(1977). Pepper cultivation in Sarawak. *Ind. Arecanut, Spices & Cocoa J*., **1**, 1-14.

Bhattacharya, S. and Bandyopadhyay, A. (2017). Performance of Bush pepper under New Alluvial Zone of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences,* **6**:2546-2550.

Duarte, M.L. and Albuquerque, F.C. (1991). Fusarium disease of black pepper. *In* Y. Sarma & T. Premkumar (eds.), Diseases of Black pepper, NRC for Spices, Calicut, pp.39-54.

Hamza, S. and Sadanandan, A.K. (2005). Effect of source and method of application of zinc on yield and quality of black pepper. *Journal of Spices and Aromatic Crops.* **14**:117-121.

Panse, V.G. and P.V. Sukhatme (1985). Statistical methods for Agriculture workers. ICAR, New Delhi.

Parthasarathy, V.A., Chempakam, B. and Zachariah, T.J. (2008). Black Pepper. *In*: Chemistry of spices. CAB International, USA, pp.21-40.

Peter, K.V., Srinivasan, V., and Hamza, S.(2000). Nutrient Management in spices. *Fertilizer news*. **45**:13-28.

Reddy, B., Sadanandan, A., and Abraham, J. (1992). Effect of planting density in black pepper on yield and nutrient availability in soil. *Journal of Planation crops*, **20** (Suppl.), 10-13.

Sadanandan, A.K., Abraham, J., and Anandaraj, M. (1990). High production Technology in black pepper. National Research Centre of Spices, Calicut, p.6.

Sadanandan, A.K., and Hamza, S. (1996). Studies on nutritional requirement of bush pepper for yield and quality (Abst.). Pro. PLACROSYM-XII, RRII, Kottayam, 1996.p.48.

Thangaselvabal, T., Justin, C.G.L. and Leelamathi, M. (2008). Black pepper (*Piper nigrum* L.). 'The king of spices'-A review. *Agricultural Review,* **29**: 89-98.

Thankamani, C.K., Rema, J. and Rajeev, P. (2002). Bush pepper. A text book published by Y.R. Sarma, Director, Indian Institute of Spies Research, Calicut, Kerala.

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Neem coated urea as a source of nitrogen for plants

Bijay Singh

Punjab Agricultural University, Ludhiana 141 004, Punjab, India

ABSTRACT

In 2015, the Government of India directed that all fertilizer urea manufactured in the country or imported will have to be coated with neem oil at the rate of 0.5 kg per tonne. Urea coated with neem cake (200 kg per tonne) (NCU) or neem oil (NOCU) possesses nitrification inhibition properties and can increase yield and N use efficiency in field crops more than untreated urea, although quality of neem oil and neem cake in terms of concentration of triterpenoids can vary in different lots. So far more than 75 studies have been conducted to study the performance of NCU or NOCU in increasing the yield of rice, wheat, and several other crops. In rice and wheat to which more than 50% of the urea consumed in India is applied, mean increase in grain yield by replacing urea with NCU or NOCU is 5 to 6% in plots managed by researchers. In about 30% comparisons, no increase was observed. As level of crop management and plant protection in farmer's fields is generally lower than in the researcher's plots, the achievable yield increase by using NOCU should be substantially less than that observed in researcher's plots. Farmers applying high and above optimal levels of urea-N in different crops may not observe significant improvement in yield levels by applying NOCU. Positive impact of NOCU in increasing crop production is likely to be further lowered by the fact that effect of nitrification inhibitors depends also upon the soil texture, pH and whether the crops are irrigated or rainfed. Nitrification inhibitors work better in acidic soils than in neutral or alkaline soils, in coarse textured soils than in fine textured soils, and in irrigated crops than in rainfed crops. More than 30% of total urea consumed in India is applied to crops grown under rainfed conditions. Thus, on an overall basis, replacing all urea being supplied to farmers in the country with NOCU is not likely to show a significant impact on food production levels. Till new recommendations for using NOCU are formulated for different crops and regions, no reduction in demand for NOCU should be expected. Possibly, applying NOCU following the site-specific nutrient management principles will lead to crop production of higher or similar levels as observed with untreated urea but with lower fertilizer application rates.

Key words: Neem coated urea, nitrogen, plants

With consumption of fertilizer-nitrogen (N) increasing from 0.6 Million tonnes (Mt) in 1965-66 to 16.74 Mt in 2016-17, India has emerged as the second largest consumer of N in the world. Since 1970s, urea is the major source of fertilizer-N; 81.4 % fertilizer-N was consumed as urea in 2016-17 (FAI, 2017). With urea production of 24.2 Mt in 2016-17, its dominance as source of fertilizer N in India is likely to continue. While urea provides the most N at the lowest cost, has no storage risks and can be used for all types of crops and soils with little or no harm to the soil, use efficiency of urea-N by different crops can be as low as 20% and it rarely exceeds 50%.

When urea is applied to the soil, a cascade of chemical and biological reactions transform urea-N into several other N forms, of which some are susceptible to loss and therefore lead to reduced availability of N to crop plants. Most notable two broad categories of transformations are: (i) *hydrolysis of urea* by urease enzyme which rapidly converts urea-N to ammonium-N and (ii) *nitrification* brought about by a group of nitrifying bacteria that leads to conversion of ammonium-N to nitrate-N. Although plants can use both ammonium-N and nitrate-N with equal ease, ammonium-N is susceptible to loss via ammonia gas, and nitrate-N can escape soil-plant system through leaching below the rooting zone and in gaseous forms via denitrification leading to reduced fertilizer N use efficiency. From an agronomic perspective, controlling the losses of urea-N should lead to increased crop productivity. Some chemicals categorized as nitrification inhibitors temporarily delay/inhibit the bacterial oxidation of the ammonium-N by depressing over a certain period of time (4 to 10 weeks) the activity of *Nitrosomonas* bacteria in the soil. Thus nitrification inhibitors control the loss of nitrate by leaching and/or denitrification from the topsoil by keeping N in the ammonium form longer and thereby increasing the fertilizer N use efficiency and yield of crops. Although some nitrification inhibitors are available, these are expensive and farmers in countries like India cannot yet afford these.

The oil extracted from the seeds of neem (*Azadirachta indica* A. Juss), a tall perennial tree growing widely in tropical and subtropical areas of Asia, Africa, America and Australia (Schmutterer, 1990), and the cake left after oil extraction possess nitrification inhibition properties. Both the oil and the cake can be used to coat urea for increasing urea N use efficiency in cropping systems. Nitrification inhibiting property of neem and its role in increasing urea N use efficiency in rice was first reported in early 1970s (Bains et al., 1971). In most of the studies conducted up till 1990, neem cake was used for coating of urea. Neem cake coated urea (NCU) was produced either manually on a small scale or in factories by mixing 0.1–0.2 t neem cake per tonne urea. Although promising results in terms of increased crop yields were obtained, coating urea with neem cake manually or in factories did not turn out to be practically feasible on a large scale. Quality assurance of the neem cake coated urea was another problem. Therefore neem oil as an alternative to neem cake has been used to coat urea granules to retard nitrification of ammonium-N in the soil. The neem oil coated urea (NOCU) has two advantages: (i) only 0.5 kg neem oil is needed per tonne of urea and (ii) the N content in urea meets the Fertilizer Control Order standards (Prasad et al., 2002).

On the basis of the performance of NCU and NOCU in studies carried out with several crops in different parts of the country, the Government of India allowed urea manufacturers to coat granular urea with neem oil to produce NOCU up to 35 per cent of total capacity of their plants. In March 2015, the government made it mandatory for fertiliser firms to produce NOCU up to 70 per cent of capacity and finally in May 2015 directed to manufacture full capacity. This decision was motivated not only by the better performance of NOCU vis-à-vis uncoated urea in terms of crop production, but also by an expectation that it will lead to reduced consumption of urea. With NOCU already being supplied to farmers as fertilizer N in India, it is not yet clear as to what extent it will lead to increased food production and/or reduced demand for urea. Therefore, research investigations based on scientifically-sound experiments and published in peer-reviewed journals have been critically analyzed to better understand the agronomic benefits of neem coated urea vis-à-vis ordinary urea.

Composition of neem oil and neem cake

Fruits of neem tree are the major source of compounds that can inhibit nitrification in the soil. Biologically active principles isolated from neem seed include azadirachtin, meliacin, gedunin, slanin, nimbin, valassin and their derivatives (Schmutterer, 1990). These compounds belong to natural products called triterpenoids or limonoids and constitute the bitter principles of neem seed oil. These are slightly hydrophobic but freely lipophilic and highly soluble in organic solvents like alcohols and esters. Neem oil is obtained by cold-pressing neem seeds followed by extraction with organic solvents (Nicoletti et al., 2012). Quality and composition of neem oil can vary according to the origin of the raw material and the different oil extraction processes. For example, the concentration of triterpenoid in neem oil changes with the geographical area and the season in which seed are harvested (Ermel, 1995; Nicoletti et al., 2012). Neem cake is the final by-product of oil extractions from neem kernels and also contains substantial amounts of triterpenoids. As for neem oil, its composition changes with the raw material used for the oil extraction. In India, 80,000 tons of oil and 330,000 tons of neem cake are produced annually from 14 million naturally growing trees (Nicoletti et al., 2012). Rengasamy et al. (1996) observed that the neem ecotypes growing in regions with moderate climate and in red, lateritic and shallow black soil at altitudes less than 500 m above sea level (as in central and southern India) were richer in triterpenoids than the ecotypes growing at higher altitudes and on alluvial soils in hot and cold climates (northern and western India). Sridharan and Venugopal (1998) observed a negative influence of total rainy days during fruiting season (April to August) on the content of triterpenoids and a significant positive influence of sunshine hours during off-season (September-March) on the oil content in neem seeds.

Neem cake coated urea (NCU) and neem oil coated urea (NOCU)

Reddy and Prasad (1975) coated urea with neem cake by moistening the urea lots with acetone (25 ml kg^{-1} urea) and thoroughly mixing with powdered neem cake (200 g kg^{-1} urea). Later a more efficient technique of coating urea with neem cake was developed (Sharma and Prasad, 1980) in which a coal tar-kerosene solution (100 g/200 ml) was used to stick neem cake powder on to urea. In most of the field experiments conducted during last three decades, NCU was prepared following this technique. However, this practice did not attract farmers mainly due to cumbersome methodology and lack of ready availability of raw materials at farm level. Also, the finished product contained only 35% N because fairly large amount (20% w/w of NCU) of neem cake was required to achieve desirable coating level.

After noticing the promising performance of NCU under field conditions and limitations associated with its preparation, several commercial neem based products were developed and marketed in India. Three such products, Nimin containing at least 5 per cent triterpenes (Godrej Agro Pvt. Ltd., Mumbai) (Vyas et al.1991), Neemex (Agro Extracts Ltd., Bangalore) and Ralli Neem (Naturelle Biotech Ltd., Hyderabad) were based on extracts of neem seeds and/or neem cake and industrial-grade neem oil, and were reasonably successful. Nimin with ensured higher concentration of triterpene than neem cake was the most successful among these. Considering lack of standardization encountered when different neem extract-neem oil emulsions were hand mixed by farmers, NOCU as an industrial product was conceived in late 1990s. Micro-emulsion was developed using industrial grade neem oil with Bureau of Indian Standards specifications, and right type and proportion of emulsifier to coat urea prills were defined (Prasad et al., 1999). An Indian patent was secured for producing NOCU using this process (Saxena et al. 2003). This technique required only 0.5 kg neem oil per tonne of urea which was acceptable to fertilizer industry. Suitable nozzles and other equipment for coating urea at the factory as a small appendage to the existing urea plants were also developed (Suri, 1995; Suri et al., 2000). Kumar et al. (2007) found that cold pressed and expeller grade neem oils were the best for the production of NOCU. Kumar et al. (2010) conducted field experiments to investigate the optimal load of neem oil in enhancing agronomic efficiency of NOCU in lowland irrigated rice. In the first year, the 0.5 mg neem oil kg^{-1} urea was not significantly different from the uncoated urea. And in the second year, it was the 1.0 g neem oil kg^{-1} urea, which was significantly better than the 0, 0.5 or 2 g neem oil kg^{-1} urea. It suggests that NOCU produced by fertilizer plants by coating 0.5 kg neem oil per ton of urea may not perform adequately under all situations.

Nitrification inhibition/retardation in soils treated with neem cake or oil coated urea

In several studies, extent of nitrification inhibition associated with NCU or NOCU has been compared with well proven nitrification inhibitors such as DCD (dicyandiamide) and Nitrapyrin [2-chloro-6-(trichloromethyl) pyridine]. Reddy and Prasad (1975) found that 2 weeks after incubation NCU was only 50 per cent as effective as Nitrapyrin in retarding nitrification in the soil. Thomas and Prasad (1983) observed that in five different soils the performance of NCU was inferior to that of Nitrapyrin. Kumar et al. (2007) observed that percent nitrification inhibition of different NOCUs prepared with various neem oils ranged from 4.0 to 30.9 per cent. In another study, Kumar et al. (2008) reported that NOCU prepared from expeller grade neem oil was consistently superior to that derived from hexane extracted oil. Majumdar (2005) observed that Nimin coated urea could substantially conserve soil ammonium and was inferior only to DCD when applied to rice. But when applied to wheat, Nimin coated urea inhibited nitrification better than urea +DCD (Majumdar et al., 2002). Malla et al. (2005) found that NOCU and DCD were equally effective in rice but NOCU was more effective than NCU. In wheat, DCD was more effective than both NOCU and NCU which were at par. In a meta-analysis based on 113 data sets from 35 field studies (Akiyama et al., 2010), while DCD and nitrapyrin could reduce N_2O emission observed with conventional fertilizer by 38 and 50 per cent, the effectiveness of NOCU, NCU and Nimin coated urea was only 14%.

Neem coated urea vis-à-vis urea: Effect on crop yields

Performance of NCU/NOCU vis-à-vis urea has been evaluated in more than 75 field experiments conducted with different crops all over India. About 60% of these studies used NCU and were conducted up to 2000. It was only after 2000 that performance of NOCU was studied. About 60% of all the published research papers to evaluate NCU/NOCU vis-à-vis urea have used rice as the test crop. And about 40% of the studies on rice have been carried out at IARI, New Delhi.

Rice

Agronomic performance of NCU, Nimin coated urea or NOCU in terms of per cent increase in the yield of rice over that obtained with urea at the same N level has been reviewed by Prasad et al. (1993, 2007). Prasad et al. (1993) reported a rice yield increase in the range of -26.30 to 54.2 % with only 3 negative values. The positive values ranged from 0.9 to 54.2% with an average value of 9.6%. Prasad et al (2007) worked out average increase in grain yield due to application of NCU/NOCU over urea to be 8.5%. In several research papers, although NCU and urea did not differ significantly but there was an increase in yield of rice obtained with NCU as compared to urea. In such cases, per cent yield increase should be taken as no increase. The data as compiled in Table 1 lists results reported in 48 publications. Wherever insignificant difference between the two sources was reported, it has been listed as 'no increase' or 0 %. Besides all the publications cited by Prasad et al. (1993, 2007), Table 1 also includes results from several recent studies and from a few more publications not included by earlier reviews. Out of 55 comparisons listed in Table 1, in 18 instances there was no significant difference between the performance of urea and different variants of NCU. As performance of NCU, Nimin coated urea or NOCU in increasing yield of rice was almost similar, it suggests that there is a 30% probability of registering no increase in yields when urea is replaced with NOCU for supplying N to rice.

Average increase in yield obtained by applying NCU to rice in 55 comparisons is 8.9 per cent over the yield produced by applying urea. However, when five abnormal increases in yield (54.2 per cent at Rahuri, 30.5 per cent at Thanjavur, 36 per cent at New Delhi, 24.7 per cent at Faizabad, 29 per cent at New Delhi) recorded by Surve and Daftardar (1985), Govindasamy and Kaliyappa (1986), Singh and Singh (1991), Prasad *et al.* (1998), and Kumar *et al.* (2010) were excluded, the average increase turned out to be 6.3% with a range of values between 0 and 18.4. In a meta-analysis using data extracted from the literature where the effect of nitrification inhibitors on rice yield or plant N uptake was

Table 1. Per cent increase in yield of rice and nitrogen use efficiency by applying different variants of neem coated urea over untreated urea

Neem coated urea product†	Coating thickness	Location	Per cent increase in grain yield over that obtained with urea¶	Difference between % recovery efficiency of N applied as NCU and uncoated urea§	Reference
NCU	20% neem cake	New Delhi	11.1	2.9	Reddy and Prasad (1977)
NCU	20% neem cake	New Delhi	5.4	4.7	Prasad and Prasad (1980)
NCU	20% neem cake	Dholi	15.3	-	Sinha *et al.* (1980)
NCU	20% neem cake	New Delhi	14.0	19.4	Sharma and Prasad (1980)
NCU	20% neem cake	New Delhi	No increase	13.5	Prakasa Rao and Prasad (1982)
NCU	20% neem cake	New Delhi	11.1	-	Singh *et al.* (1984)
NCU	20% neem cake	Rahuri	54.2	-	Surve and Daftardar (1985)
NCU	20% neem cake	Coimbatore	No increase	-	Latha and Subramanian (1986)
NCU	20% neem cake	Thanjavur	30.5	-	Govindasamy and Kaliyappa (1986)
NCU	20% neem cake	Pantnagar	No increase	-	Mahapatra *et al.* (1987)
NCU	20% neem cake	Coimbatore	4.7	-	Budhar *et al.* (1987)
NCU	20% neem cake	Smastipur	5.0		Pandey and Singh (1987)
NCU	20% neem cake	Dholi	11.4		
NCU	20% neem cake	Pantnagar	18.4	-	Awasthi and Mishra (1987)
NCU	20% neem cake	New Delhi	No increase	-	Thomas and Prasad (1987)
NCU	20% neem cake	Aduthurai	No increase		Velu *et al.* (1987)
NCU	20% neem cake	Coimbatore	No increase		
NCU	20% neem cake	Pusa	16.4	-	Prasad *et al.* (1989)
NCU	20% neem cake	Philippines	No increase (1986) 7.4 (1987)	- 15.0	John *et al.* (1989)
NCU	20% neem cake	New Delhi	4.1	-	Singh *et al.* (1990a)
NCU	20% neem cake	Kanpur	5.2	-	Agarwal *et al.* (1990)
NCU	20% neem cake	Pantnagar	-	3.1	Mishra *et al.* (1990)
NCU	20% neem cake	Varanasi	7.0	-	Singh *et al.* (1990b)
NCU	20% neem cake	Vellanikkara	No increase	-	Joseph *et al.* (1990)
NCU	20% neem cake	Faizabad	24.7	-	Singh and Singh (1991)
NCU	20% neem cake	Bhubaneswar	9.4	-	Panigrahi and Dixit (1991)
NCU	20% neem cake	Pusa	No increase		Mishra *et al.* (1991)
NCU	20% neem cake	Aduthurai	15.7	-	Budhar *et al.* (1991)
Nimin	1% Nimin	Raipur	No increase		Pandey and Tripathi (1994)
Nimin	1% Nimin	Kota	16.0	-	Tomar and Gupta (1996)
PNGU	12% neem oil	New Delhi	36.0	-	Prasad *et al.* (1998)
NCU	20% neem cake	Faizabad	13.2	-	Shukla and Chauhan (1998)
PNGU	12% neem oil	New Delhi	7.5	-	Prasad *et al.* (1999)
Nimin	1% Nimin	Cuttack	No increase		Rath *et al.* (1999)
NOCU	0.5 kg neem oil t^{-1}	New Delhi	12.5	-	Prasad *et al.* (2001)
NOCU	0.5 kg neem oil t^{-1}	New Delhi	9.3	11.8	Shivay *et al.* (2001)
NOCU	0.5 kg neem oil t^{-1}	9 on-farm sites in Delhi	9.1	-	Prasad *et al.* (2001)
NOCU	0.5 kg neem oil t^{-1}	Modipuram	3.8		Jat and Pal (2002)
NOCU	0.5 kg neem oil t^{-1}	New Delhi	No increase	5.6	Singh and Shivay (2003)
NCU	20% neem cake	New Delhi	No increase	4.8	
PNGU	12% neem oil	New Delhi	10.0	10.3	
Nimin	1% Nimin	New Delhi	No increase	No increase	Majumdar (2005)
PNGU	12% neem oil	New Delhi	12.0	8.2	Kumar *et al.* (2007); Kumar and Prasad (2004)
NCU	20% neem cake	New Delhi	9.6	-	Kumar *et al.* (2007)
Nimin	1% Nimin	Mymensingh	No increase	-	Hoque and Sultana (2008)
PNGU	12% neem oil	New Delhi	15.3	-	Kumar and Shivay (2009)
NOCU	0.5 kg neem oil t^{-1}	Ludhiana	5.6 (3 splits); 8.6 (using LCC‡)	3.4 (3 splits); 7.1 (using LCC)	Thind *et al.* (2010b)
NOCU	0.5 kg neem oil t^{-1}	Gurdaspur	No increase (3 splits or using LCC)	No increase (3 splits); 7.5 (using LCC)	
NCU	20% neem cake	5 on-farm (Haryana)	1.7	-	Nehra and Dhindwal (2010)
NOCU	0.5 kg neem oil t^{-1}	New Delhi	No increase	-	Kumar *et al.* (2010)
NOCU	1.0 kg neem oil t^{-1}	New Delhi	29.0	-	
NOCU	0.5 kg neem oil t^{-1}	New Delhi	12.6	11.9	Kumar *et al.* (2011)
NCU	30% neem cake	Dharwad	9.1	-	Sannagoudra *et al.* (2012)
NOCU	500 ml (100 kg urea)$^{-1}$	Dharwad	No increase	-	
Nimin	1% Nimin	Kandhamal	6.8	13.9	Mohapatra *et al.* (2015)

†NCU-Neem cake coated urea (200 g neem cake powder kg^{-1} urea), NOCU –Neem oil coated urea (0.5 kg neem oil t^{-1} urea), PNGU – Pusa neem golden urea (urea-neem oil adduct containing 35% N and 12% neem oil), Nimin – a blend of neem oil and neem seed extract
‡site specific N management using leaf colour chart
¶ $100 \times (Y_N - Y_U) / Y_U$, where Y_N and Y_U represent yield of rice obtained by applying neem coated urea and uncoated urea at same N level, respectively
§ $100 \times (U_N - U_U) / F$, where F represents the N level, and U_N and U_U represent N uptake by rice by applying neem coated urea and uncoated urea, respectively

compared in side-by-side field experiments to an identical fertilizer without nitrification inhibitor (Linquist *et al.*, 2013), based on 22 observations from 9 studies, NCU produced about 8 per cent higher yield of rice as compared to 6.4 per cent increase observed with DCD from 6 observations from 4 studies.

Tomar and Verma (1990) observed nearly equal yield of rice with NCU at 80 kg N ha^{-1} as with urea at 120 kg N ha^{-1}. Vyas *et al.* (1991) reported similar yields of rice with 70 kg N ha^{-1} in form of NCU as with 100 kg N ha^{-1} applied as uncoated urea. De *et al.* (1992) concluded that more than 30 kg N ha^{-1} can be saved in rice with Nimin coated urea in comparison to untreated urea. Similar results have been reported by Awasthi and Mishra (1987), and Singh and Singh (1991) but in many studies positive effect of NCU on rice yield was not large enough (Panigrahi and Dixit, 1991; Budhar *et al.*, 1987; Shivay, 2007; Mohapatra *et al.*, 2015).

Thind *et al.* (2010b) reported statistically similar yields of rice with 96 kg N ha^{-1} as NCU and 120 kg N ha^{-1} as urea in a coarse textured soil but not in a fine textured soil. In the meta-analysis carried out by Abalos *et al.* (2014), acidic soils (pH d" 6) showed a higher positive response to application of nitrification inhibitors than neutral (pH 6–8) and alkaline soils (pH e" 8). Soil pH regulates efficiency of nitrification inhibitors via its effect on ammonia volatilization. Kim *et al.* (2012) showed that application of nitrification inhibitors may increase ammonia volatilization because ammonium-N remains in the soil for a longer period. Since neutral to alkaline soils have inherently high losses through ammonia volatilization (Singh *et al.*, 2008), use of nitrification inhibitors in these soils can induce the losses as ammonia further due to the increased residence time in the soil. Also, lower nitrification rates as caused by nitrification inhibitor may reduce soil acidification, which in alkaline soils may result in a prolongation of an elevated pH and a consequent increase in ammonia volatilization (Kim *et al.*, 2012). Therefore, application of nitrification inhibitors to neutral and alkaline soils may increase N losses through ammonia volatilization thereby decreasing the overall effect of inhibitors on crop yield and N use efficiency in these soils. Ketkar (1974) could observe that on acid soils NCU at the rate of 50 kg N ha^{-1} significantly increased rice yield over that recorded with uncoated urea. But at higher N level, increases in yields were not significant. The opposite was true in case of neutral soils; NCU at the rate of 100 kg N ha^{-1} significantly increased the yield of rice, but the increase in yield was not significant at lower levels of N application. It seems that because nitrification rates are favoured by neutral to slightly alkaline soils (Norton, 2008), nitrification inhibitors could potentially be beneficial in these soils and at high N levels may reduce the net N losses via both nitrification–denitrification and ammonia volatilization. It is possible that nitrification inhibitors may be less effective in higher pH soils, where the risk of ammonia volatilization is greater (Francis *et al.*, 2008).

Wheat

In six published works in which comparative performance of different variants of neem coatings on urea was studied vis-à-vis uncoated urea on wheat, no difference between the two sources of N was observed in 2 out of 7 comparisons (Table 2). In the 5 comparisons where NCU performed better than urea, the per cent increase in wheat grain yield ranged from 4.3 to 12.7. Although Prasad *et al.* (2007) have reported this range as 3.6 to 23.8 per cent, it is not adequately supported by the published data. Thus based on 7 comparisons, average increase in yield by applying NCU over that obtained with urea is 5.3 per cent and as in case of rice, there is possibility that in more than 25 per cent cases NCU may not outperform urea.

Rice-wheat system

Reddy and Prasad (1977), Sharma and Prasad (1978), Prasad *et al.* (1981), Mishra *et al.* (1991) and Singh *et al.* (1999) have reported that NCU applied to rice leaves a positive residual effect on the following crop of wheat grown in an annual rotation. However, 5 reports published in 1999 and later reveal a different picture of the effect of NCU/NOCU in rice-wheat cropping system. As listed in Table 3, no consistent effect was observed by researchers (Table 3). Only when NCU was applied to both rice and wheat, Chauhan (1999) could obtain significant yield increases in both rice and wheat over uncoated urea in two consecutive years. In four out of the remaining seven comparisons, no increase in yield of both rice and wheat was recorded by applying NCU over urea. In three instances, a yield benefit only in rice was observed, possibly because NCU/NOCU was applied to rice and residual effect was tested in wheat.

Crops other than rice and wheat

Comparative performance of NCU and urea for crops other than rice and wheat has not been studied by many researchers. The data available from published research papers are summarized in Table 4. Mean per cent increase in the economic yield of potato, sugarcane, cotton, maize and finger millet by supplying N via NCU over urea works out to be 10.5, 8.7, 4.3, 0.0 and 5.4, respectively. However, for sugarcane and cotton in one out of four comparisons and for maize in one out of three comparisons no significant increase in yield was observed by supplying N as NCU rather than urea. After rice and wheat, potato, sugarcane, cotton and

Table 2. Per cent increase in yield of wheat and nitrogen use efficiency by applying different variants of neem coated urea over untreated urea

Neem- urea product†	Coating thickness	Location	Per cent increase in grain yield over that obtained with urea¶	Difference between % recovery efficiency of N applied as NCU and uncoated urea§	Reference
NCU	20% neem cake	Kanpur	5.4	-	Agarwal et al. (1990)
NCU	20% neem cake	Hisar	4.3	-	Bhatia et al. (1985)
NCU	20% neem cake	Pusa	12.7	-	Prasad et al. (1986)
NCU	20% neem cake	Pantnagar	-	4.1	Singh and Singh (1986)
NCU	20% neem cake	Pusa	5.3	-	Mishra et al. (1991)
NCU	20% neem cake	New Delhi	No increase	1.1	Majumdar et al (2002)
Nimin	1% Nimin	New Delhi	9.1	7.3	
NOCU	0.5 kg neem oil t^{-1}	Ludhiana	No increase	No increase	Thind et al. (2010a)

†NCU-Neem cake coated urea (200 g neem cake powder kg^{-1} urea), NOCU –Neem oil coated urea (0.5 kg neem oil t^{-1} urea), Nimin – a blend of neem oil and neem seed extract
¶ $100 \times (Y_N - Y_U) / Y_U$, where Y_N and Y_U represent yield of wheat obtained by applying neem coated urea and uncoated urea at same N level, respectively
§ $100 \times (U_N - U_U) / F$, where F represents the N level, and U_N and U_U represent N uptake by wheat by applying neem coated urea and uncoated urea, respectively

Table 3. Per cent increase in yield of rice and wheat grown in annual rice-wheat rotation by applying different variants of neem coated urea over untreated urea

Neem- urea product†	Location	Year	Per cent increase in rice yield over that obtained with urea‡	Per cent increase in wheat yield over that obtained with urea‡	Reference
NCU	Faizabad	1993-94	10.51	24.61	Chauhan (1999)
		1994-95	9.42	25.71	
PNGU	New Delhi	1999-2000	No increase	No increase	Bharde *et al.* (2006); Bharde *et al.* (2003)
PNGU	New Delhi	2000-01	No increase	No increase	
NOCU	New Delhi	1999-2000	24.09	No increase	
NOCU	New Delhi	2000-01	24.24	No increase	
NCU	New Delhi	2001-02	14.23	No increase	Malla *et al.* (2005)
NOCU	New Delhi	2001-02	No increase	No increase	
NOCU	9 on-farm locations, Kapurthala	2006-2008	No increase	No increase	Bhatt (2012)

†NCU-Neem cake coated urea (200 g neem cake powder kg^{-1} urea), NOCU –Neem oil coated urea (0.5 kg neem oil t^{-1} urea), PNGU – Pusa neem golden urea (urea-neem oil adduct containing 35% N and 12% neem oil)
‡$100 \times (Y_N - Y_U) / Y_U$, where Y_N and Y_U represent yield obtained by applying neem coated urea and uncoated urea at same N level, respectively

maize are the crops to which significant amount of fertilizer N is applied. Although better performance of NCU was also observed for finger millet, jute, Japanese mint, tomato and French bean, very small proportion of total N consumed in India is applied to these crops.

Neem coated urea vis-à-vis urea: N use efficiency

Only in 16 studies comparing NOCU/NCU vs. urea in rice, N uptake by the test crop was estimated (Table 1) so that the difference between per cent recovery efficiency of NOCU and untreated urea in rice could be estimated. It ranged from 0 to 19.4 with a mean value of 7.4. The difference between agronomic efficiency of NOCU and urea for 43 comparisons ranged from 0 to 11.0 kg grain per kg N applied with a mean value of 2.1 kg grain per kg N applied. It may be mentioned here that both agronomic and recovery efficiency of N were determined by the rate of application of fertilizer N. In case of wheat, only four comparisons as listed in Table 2 are available. Difference between per cent N use efficiency of NCU and that for urea ranged between 0 and 7.3 with a mean value of 3.3. The data in Tables 1 and 2 suggest that NCU was able to supply N more efficiently than urea in rice than in wheat. In a meta-analysis based on a global data set consisting of 21 studies with 94 observations (Abalos *et al.*, 2014), the mean effect sizes of widely used nitrification inhibitors [3,4-dimethylepyrazolephosphate (DMPP) and DCD] was about 11% increase in N use efficiency.

Will coating all urea sold in India with neem oil lead to significant increase in crop production and reduction in the demand for urea?

Urea constituted 82 per cent of the total fertilizer N consumed in India during 2015-16 (FAI, 2015). According to a report based on input survey for India for 2011-12 (Anonymous, 2016), 30.0, 24.9, 5.0, 9.7 and 4.9 per cent of total urea consumed in the country was applied to rice, wheat, sugarcane, cotton and maize, respectively. This trend is not expected to change substantially in the near future. When all urea being supplied for agricultural use has been replaced by NOCU in India, the mean increases in the yield of rice, wheat, sugarcane, cotton and maize by applying NCU or NOCU over urea by 6.3, 5.3, 8.7, 4.3 and 0 per cent, respectively (Tables 1, 2 and 4) should lead to more than 5 per cent increase in the overall crop production. But these yield increases have been recorded in experiments conducted by researchers under optimum agronomic and plant

Table 4. Per cent increase in yield of different crops other than rice and wheat by applying different variants of neem coated urea over untreated urea

Crop	Neem- urea product†	Location	Per cent increase in yield over that obtained with urea‡	Reference
Potato	NCU	Simla	2.8 (40 kg N ha^{-1})	Sharma et al. (1980)
	NCU	Simla	12.6 (80 kg N ha^{-1})	
	NCU	Palampur	16.0	Sharma et al. (1986)
Sugarcane	NCU	New Delhi	20.9	Parashar et al. (1980)
	NCU	Pusa	10.2	Singh et al. (1987)
	NCU	Lucknow	No increase	Yadav et al. (1990)
	NCU	Coimbatore	3.87	Mani et al. (2008)
Cotton	NCU	New Delhi	No increase	Sheshadri and Prasad (1979)
	NCU	Coimbatore	5.2	Sivaraj and Iruthayaraj (1980)
	NCU	Indore	6.1	Jain et al. (1982)
	NCU	Surat	5.8	Desai et al. (2014)
Maize	NCU	Ratlam	No increase	Joshi et al. (2014)
Finger millet	NCU	Jobner	5.0	Yadav et al. (1989)
	NCU	Coimbatore	5.7	Subbiah et al. (1982)

†NCU-Neem cake coated urea (200 g neem cake powder kg^{-1} urea)
‡100 × (Y_N - Y_U) / Y_U, where Y_N and Y_U represent yield obtained by applying neem coated urea and uncoated urea at same N level, respectively

protection management conditions. Even the reported efficiency of urea in researcher's plots is not achievable under on-farm trials supervised by researchers and extension workers because water, fertilizer and crop management level are rarely up to the mark. Dobermann *et al.* (2004) observed that fertilizer N use efficiency in rice fields in Asia was smaller by 25 per cent than the average reported values determined in researcher-managed plots in farmer's fields.

Among cereals, per hectare N use in India is the maximum in wheat (119.2 kg) followed by rice (90.7 kg). Intensity of N use is the highest in sugarcane (174.7 kg ha^{-1}) (FAI, 2015). However, there is large variation in fertilizer N rates for different crops depending upon land holding size and whether crop is irrigated or unirrigated. As per the input survey for India for 2011-12 (Anonymous, 2016), the mean N use level was 128.9 kg N ha^{-1} in irrigated crops against 76.4 kg N ha^{-1} in rainfed crops. The corresponding rates of consumption of fertilizer N for marginal (< 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (> 10 ha) holdings in irrigated areas were respectively, 174.4, 118.3, 110.6, 106.2 and 114.6 (kg N ha^{-1}) against 119.9, 76.3, 62.3, 52.7 and 44.0 kg N ha^{-1}) in unirrigated areas. According to fertilizer evaluation principles, at higher N rates the yield response to NOCU would be less pronounced because N rates may be above optimal and as such extent of positive response of crop yields may be minimal. Thus farmers who are accustomed to use high and above optimal levels of urea-N in different crops may not observe significant improvement in yield levels by applying NOCU.

In India, 32.8 per cent of the total urea consumed was applied to rainfed crops grown on 53.6 per cent of the gross cropped area (Anonymous, 2016). Respectively, 6.5, 3.3 and 4.1 per cent of the total amount of urea consumed was applied to rice, maize and cotton grown under unirrigated conditions. Since in terms of crop productivity, irrigated systems show a significantly higher response than rainfed systems to the application of nitrification inhibitors (Abalos *et al.,* 2014), about one-third of the total NCU being applied to rainfed crops in India is not expected to substantially increase the yield of crops. Nitrate leaching is frequently the most important N loss process in irrigated agriculture whereas very little drainage may occur in rainfed systems. Further, nitrification inhibitors act more efficiently in acidic soils rather than in alkaline soils in which urea is prone to be lost via ammonia volatilization and nitrification inhibitors enhance the accumulation of urea. In India, about 30 per cent arable soils have acidic reaction but very little fertilizer including urea is applied to these soils. Also nitrification inhibitors perform better in coarse textured soil than in fine textured ones. Thus, extent of yield increase due to application of NCU in place of urea as observed in different studies listed in Tables 1 to 4 is likely to result in very little impact on the overall yield increase in the country.

In India, fertilizer recommendations for crops in different regions of the country are formulated as well as improved over time by agricultural universities and ICAR institutes. When a new fertilizer material is introduced, it is evaluated in terms of rate, time, method and place of application before it is given to farmers. Although urea has been completely replaced with NOCU in the country, hardly any recommendation has been given as to how much less NOCU than urea should be applied to achieve similar or higher yield levels for different crops. In such a scenario, it does not seem that demand for NOCU will be reduced as compared to urea. Perhaps, there is a perception that when farmers will get higher yields they will reduce the dose of NOCU as compared to urea. But the yield gains due to replacing of urea with NOCU are likely to be small and many times not visible. Also, farmers will never like to cut down the fertilizer dose to avoid any risk for obtaining lower yields. Thus it is unlikely that demand for urea will decrease in the near future due to coating it with neem oil.

As per fertilizer evaluation principles, differences in the performance of two fertilizer sources diminish at higher levels of application. Thus, when NCU will be applied at lower rates as per SSNM principles or blanket recommendation, benefits of coating urea with neem oil will become visible. Several (for example, Tomar and Verma, 1990; Vyas *et al.*, 1991; Chauhan, 1999; Jat and Pal, 2002) have shown that per cent increase in yield of rice or wheat was conspicuously higher when comparison was made at low N levels rather than at 120 kg N ha^{-1} or the general recommendation for rice and wheat growing regions in India.

Managing NOCU in food crops like rice, wheat and maize following principles of site-specific nutrient management (SSNM) is possibly the only way that can lead to increased crop production and/or reduced demand for NOCU as compared to urea. For example, applying N to rice, wheat and maize on the basis of maintaining adequate leaf greenness as measured by leaf colour chart to individual fields will lead to application of doses of NOCU which should be less than urea and/or result in higher yield levels than those obtained with urea. Thind *et al.* (2010b) applied urea and NOCU to rice at 110 kg N ha^{-1} in a coarse textured soil and at 80 kg N ha^{-1} in a fine textured soils using leaf colour chart; the blanket recommendation for rice was 120 kg N ha^{-1} at both the sites. Although, in the fine textured soil both NOCU and urea were at par in increasing rice yield, NOCU could produce significantly higher rice yield than urea in the coarse textured soil. Thus, as farmers adopt SSNM principles for applying NOCU to crops in individual fields, both yield benefits and reduced demand of NOCU will become visible. Also, SSNM will be able to take into account the effects of factors like soil texture, pH and irrigation in determining the amount of NOCU to be applied in a given field.

CONCLUSIONS

Based on published research, mean increase in the grain yield of rice and wheat by applying NCU/NOCU is around 5 to 6 per cent over the yields obtained by urea at same N level; in about 30 per cent comparisons no increase was observed. As observed increase in yields have been obtained in researcher's plots, the yield benefits of using NOCU should be considerably less when managed by farmers. Same applies to other crops such as sugarcane, cotton where also respectively, 8.7 and 4.3 per cent increase in yields have been recorded in researcher's plots. According to principles of fertilizer evaluation, the difference between the performances of the two sources narrows down at high application rates. Further, the nitrification inhibitors perform better in irrigated than in rainfed crops and in acidic soil conditions than in neutral and alkaline soils. As more than 50 per cent of the total urea consumed in India is applied to rice and wheat, and more than 30 per cent is applied to rainfed crops, overall impact of coating all urea supplied to farmers with neem is likely to be small. With same general recommendations for managing urea and NOCU, a reduction in demand in fertilizer N cannot be expected. A perception that when farmers will get higher yields they will reduce the dose of NOCU as compared to urea may not work if the yield gains due to replacing of urea with NOCU are small and many a times not visible. Also, farmers will not readily cut down the fertilizer dose to avoid any risk for obtaining lower yields. Possibly, applying NOCU following the site-specific nutrient management principles will lead to production of yield levels higher than or similar to that obtained with untreated urea but with lower rates of application.

REFERENCES

Abalos, D., Jeffery, S., Sanz-Cobena, A., Guardia, G. and Vallejo, A. (2014) Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. *Agriculture, Ecosystem and Environment* **189**: 136-144.

Agarwal, S.K., Shankar, H. and Agarwal, M.M. (1990) Effect of slow-release nitrogen and nitrification inhibitors on rice-wheat sequence. *Indian Journal of Agronomy* **35**:337-340.

Akiyama, H., Yan, X. and Yagi, K. (2010) Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N_2O and NO emissions from agricultural soils: meta-analysis. *Global Change Biology* **16**:1837–1846.

Anonymous (2016) All India Report on Input Survey 2011-12, Agricultural Census Division, Ministry of Agriculture and Farmers Welfare, New Delhi, India. p. 520.

Awasthi, R.K. and Mishra, B. (1987) Yield and nitrogen uptake of rice in relation to nitrogen release from modified urea materials in a submerged soil. *Journal of Indian Society of Soil Science* **35**: 52-57.

Bains, S.N., Prasad, R. and Bhatia, P.C. (1971) Use of indigenous materials to enhance the efficiency of fertiliser nitrogen for rice. *Fertilizer News* **16**:30-32.

Bharde, N.M., Shivay, Y.S., Prasad, R., Kumar, D. and Singh, S. (2006) Effect of blending urea with neem-oil with and without biogas slurry on rice-wheat cropping system. *Indian Journal of Fertilizer* **2**:37-42.

Bharde, N.M., Shivay, Y.S. and Singh, S. (2003) Effect of biogas slurry and neem oil-treated urea sources on rice (*Oryza* *sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **48**:73-77.

Bhatia, K.B., Kumar, V. and Dahiya, S.S. (1985) Effect of methods of urea application with farmyard manure and neem cake on wheat yield and nitrogen uptake. *Indian Journal of Agronomy* **30**:150-153.

Bhatt, R. (2012) Relative performance of neem coated urea vis-à-vis ordinary urea applied to rice-wheat cropping in sub-tropical soils. *Asian Journal of Soil Science* **7**:353-357.

Budhar, M.N., Ramaswami, C. and Abdul Kareem, A. (1987) Effect of nitrogen and forms of urea on rice yield. *Indian Journal of Agronomy* **32**:453-464.

Budhar, M.N., Ramaswami, C. and Abdul Kareem, A. (1991) Relative efficiency of coated N fertilizers in lowland rice. *Indian Journal of Agronomy* **36**:124-126.

Chauhan, R.P.S. (1999) Efficiency of coated-urea materials in rice (*Oryza sativa*) - wheat (*Triticum aestivum*) system under partially reclaimed sodic soil. *Indian Journal of Agricultural Sciences* **69**:311-316.

De, G.C., Das, S. and Pal, D. (1992) Efficiency of neem-extract-coated urea on transplanted summer rice (*Oryza sativa*). *Indian Journal of Agronomy* **37**:163-163.

Desai, M.K., Usadadiya, V.P., Thanki, J.D., Patel, K.G. and Arvadia, K. (2014) Growth, yield and quality of Bt cotton (*G. Hirsutum*) as influenced by nitrogen application under South Gujarat condition. *International Journal of Agriculture Innovations and Research* **2**:871-873.

Dobermann, A., Witt, C. and Dawe, D. (2004) Increasing Productivity of Intensive Rice Systems through Site Specific Nutrient Management. Science Publishers, Inc., International Rice Research Institute, Enfield, NH (USA) and Los Baños (Philippines).

Ermel, K. (1995) Azadirachtin content of neem seed kernels from different regions of the world. In: The Neem Tree *Azadirachtin indica* A. Juss and other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and other Purposes, Schumutterer, H. (Ed.), VCH Verlagsgesellschaft, Weinheim, Germany. pp. 89-92.

FAI (2017) Annual Review of Fertiliser Production and Consumption 2016-17. *Indian Journal of Fertilisers* October 2017, 97-99.

Francis, D.D., Vigil, M.F. and Mosier, A.R. (2008) Gaseous losses of nitrogen other thanthrough denitrification. In: Nitrogen in Agricultural Systems, Schepers, J.S., Raun, W.R. (Eds.), Agronomy Monograph 49. American Society of Agronomy, Madison, WI, USA, pp. 255–279.

Govindasamy, K.N. and Kaliyappa, R. (1986) Effect of modified urea on lowland rice. *Madras Agriculture Journal* **73**:17-22.

Hoque, S.S. and Sultana, Z. (2008) Efficiency of meister-10 and urea-Nimin as controlled release nitrogen fertilizers on rice. *SAARC Journal of Agriculture* **6**:31-37.

Jain, S.C., Katty, G.V., Jain, N.K. and Iyer, B.J. (1982) Efficacy of blended urea in upland cotton under different nutrient levels and field conditions. *Journal of Indian Society of Soil Science* **30**: 224-226.

Jat, M.L. and Pal, S.S. (2002) Relative efficiency of Pusa neem micro-emulsion-coated and prilled urea in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system on Ustochrepts of Indo-Gangetic Plain. *Indian Journal Agricultural Sciences* **72**:548-550.

John, P.S., Buresh, R.J., Pandey, R.K., Prasad, R. and Chua, T.T. (1989) Nitrogen-15 balances for urea and neem coated urea applied to lowland rice following two cowpea cropping systems. *Plant Soil.* **120**:233-241.

Joseph, K., Menon, P.K.G. and Anil Kumar, K. (1990) Studies on the comparative efficiency of nitrogen sources in lowland rice. *Indian Journal of Agronomy* **36**:122-123.

Joshi, A., Gupta, J.K., Choudhary, S.K. and Paliwal, D.K. (2014) Efficiency of different nitrogen source, doses and split application on growth and yield of maize (*Zea mays* L.) in the Malwa region of Madhya Pradesh. *IOSR Journal of Agriculture and Veterinary Science* **7**:39-42.

Ketkar, C.M. (1974) Neem cake blended urea for nitrogen economy. *Fertilizer News* **19**:25-26.

Kim, D.G., Saggar, S. and Roudier, P. (2012) The effect of nitrification inhibitors on soil ammonia emissions in nitrogen managed soils: a meta-analysis. *Nutrient Cycling in Agroecosystems* **93**:51–64.

Kumar, D., Devakumar, C., Kumar, R., Das, A., Panneerselvam, P. and Shivay, Y.S. (2010) Effect of neem-oil coated prilled urea with varying thickness of neem-oil coating and nitrogen rates on productivity and nitrogen-use efficiency of lowland irrigated rice under Indo-Gangetic plains. *Journal of Plant Nutrition* **33**:1939–1959.

Kumar, D., Devakumar, C., Kumar, R., Panneerselvam, P., Das, A. and Shivay, Y.S. (2011) Relative efficiency of prilled urea coated with major neem (*Azadirachta indica* A. Juss) oil components in lowland irrigated rice of the Indo-Gangetic plains. *Archives of Agronomy and Soil Science* **57**: 61-74.

Kumar, N. and Prasad, R. (2004) Effect of levels and sources of nitrogen on concentration and uptake of nitrogen by a high yielding variety and a hybrid of rice. *Archives of Agronomy and Soil Science* **50**:447-454.

Kumar, N., Prasad, R. and Zaman, F.U. (2007) Relative response of high yielding variety and a hybrid of rice to levels and sources of nitrogen. *Proceedings of Indian National Science Academy* **73**:1-6.

Kumar, R., Devakumar, C., Kumar, D., Panneerselvam, P., Kakkar, G. and Arivalagan, T. (2008) Influence of edaphic factors on the mineralization of neem oil coated urea in four Indian soils. *Journal of Agriculture and Food Chemistry* **56**:10183-10191.

Kumar, S. and Shivay, Y.S. (2009) Effect of eco-friendly modified urea materials and nitrogen levels on growth and productivity of aromatic hybrid and an aromatic high yielding variety of rice. *Annals of Agriculture Research New Series* **30**:4-8.

Latha, K.R. and Subramanian, S. (1986) Response of rice to fertilizer N and Azolla and its economics. *Madras Agriculture Journal* **73**:622-626.

Linquist, B.A., Liu, L., van Kessel, C. and van Groenigen, K.J. (2013) Enhanced efficiency nitrogen fertilizers for rice systems: Meta-analysis of yield and nitrogen uptake. *Field Crops Research* **154**:246-254.

Mahapatra, B.S., Sharma, K.C. and Sharma, G.L. (1987) Effect of bio-organic source of nitrogen and chemical nitrogen fertilizer on the yield and its contributing characters in lowland rice. *Indian Journal of Agricultural Sciences* **57**: 635-639.

Majumdar, D. (2005) Crop yield and soil nitrogen dynamics in an intermittently flooded rice field affected by nitrification inhibitors. *Archives of Agronomy and Soil Science* **5**:645–653.

Majumdar, D., Kumar, S., Pathak, H., Jain, M. C. and Kumar, U. (2000) Reducing nitrous oxide emission from an irrigated rice field of North India with nitrification inhibitors. *Agriculture Ecosystem and Environment* **81**:163-169.

Majumdar, D., Pathak, H., Kumar, S. and Jain, M.C. (2002) Nitrous oxide emission from a sandy loam Inceptisol under irrigated wheat in India as influenced by different nitrification inhibitors. *Agriculture Ecosystem and Environment* **91**:283-293.

Malla, G., Bhatia, A., Pathak, H., Prasad, S., Jain, N., Singh, J. (2005) Mitigating nitrous oxide and methane emissions from soil in rice–wheat system of the Indo-Gangetic plain with nitrification and urease inhibitors. *Chemosphere* **58**:141–147.

Mani, S., Jayaraman, C. and Durai, R. (2008) Yield and quality of sugarcane as influenced by organic manures and chemical fertilizers on long term basis. *Madras Agriculture Journal* **95**:462-466.

Mishra, B., Sharma, R.D. and Murthy, J.R. (1990) Effect of neem cake and shellac coating of urea and green manure on ammonia volatilization and nitrogen use efficiency for rice. *Journal of Indian Socety of Soil Science* **38**: 224-228.

Mishra, S.S., Singh, S.J., Gogoi, A.K. and Sinha, K.K. (1991) Nitrogen-use efficiency by nitrogen and weed management in rice-wheat sequence. *Indian Journal of Agronomy* **36**: 308-312.

Mohapatra, S., Mukhi, S.K. and Mishra, P. (2015) Measuring the effect of Nimin-coated urea application on yield and nitrogen use efficiency (NUE) in rice. *Journal of Community Mobilization and Sustainable Development* **10**:50-52.

Nehra, O.P. and Dhindwal, A.S. (2010) Evaluation of neem cake coated urea in rice at farmer's fields. *Haryana Journal of Agronomy* **26**:62-68.

Nicoletti, M., Mariani, S., Maccioni, O., Coccioletti, T. and Murugan, K. (2012) Neem cake: chemical composition and larvicidal activity on Asian tiger mosquito. *Parasitology Research* **111**: 205-213.

Norton, J.M. (2008) Nitrification in agricultural soils. In: Nitrogen in Agricultural Systems, Schepers, J.S. and Raun, W.R. (Eds.), Agronomy monograph 49. *American Society of Agronomy,* Madison, WI, USA, pp. 173–199.

Pandey, J. and Singh, R.P. (1987) Effect of urea, slow release fertilizers and nitrification inhibitors on the yield of rainfed lowland rice. *Indian Journal of Agronomy* **32**: 303-305.

Pandey, N. and Tripathi, R.S. (1994) Effect of coated nitrogen fertilizers, their levels and time of application on grain yield of rice (*Oryza sativa*) in Vertisols. *Indian Jounal of Agronomy* **39**:290-292.

Panigrahi, B.K. and Dixit, L. (1991) Relative efficiency of slow-release nitrogenous fertilizers in rainfed rice (*Oryza sativa*). *Indian Journal of Agronomy* **36**:401-403.

Parashar, K.S., Prasad, R., Sharma, R.P., Sharma, S.N. and Singh, S. (1980) Efficiency of urea, nitrification treated urea and slow-release nitrogen fertilizers for sugarcane. *Z. Pflanzen. Bodenkd.* **143**:262-267.

Prakasa Rao, E.V.S. and Prasad, R. (1982) Relative efficiency of N carriers and methods of increasing their efficiency in lowland rice. *Journal of Agronomy and Crop Science* **151**:329–337.

Prasad, B., Prasad, R. and Prasad, J. (1986) Evaluation of nitrification retardation property of non-edible oils and their influence on yield and N uptake by wheat in calcareous soil. *Journal of Indian Society of Soil Science* **34**:282-285.

Prasad, M. and Prasad, R. (1980) Yield and nitrogen uptake by rice as affected by variety, method of planting and new nitrogen fertilizers. *Fertilizer Research* **1**:207–213.

Prasad, R., Devakumar, C. and Shivay, Y.S. (1993) Significance in increasing fertilizer nitrogen efficiency. In: Neem Research and Development, Randhawa, N.S. and Parmar, B.S. (Eds.) Society of Pesticide Science, India. pp. 97-108.

Prasad, R., Prasad, B. and Prasad, J. (1989) Effect of some non-edible oils on retardation of nitrification, yield and nitrogen uptake by rice in calcareous soil. *Indian Journal of Agricultural Sciences* **59**:291-294.

Prasad, R., Saxena, V.C. and Devakumar, C. (1998) Pusa neem golden urea for increasing nitrogen-use efficiency in rice. *Current Science* (India) **75**: 15.

Prasad, R., Sharma, S.N., Prasad, M. and Reddy, R.N.S. (1981) Efficient utilization of nitrogen in rice-wheat rotation. In: Proc. Symp. Crop Management to Meet the New Challenges. *Indian Society of Agronomy,* 14-16 March, 1981, Hisar, India.

Prasad, R., Sharma, S.N., Singh, S., Devakumar, C., Saxena, V.S. and Shivay, Y.S. (2002) Neem coating of urea for environment and agriculture. *Fertilizer News* **47**:63–67.

Prasad, R., Sharma, S.N., Singh, S., Saxena, V.S. and Devakumar, C. (2001) Pusa neem emulsion as an eco-friendly coating agent for urea quality and efficiency. *Fertilizer News* **46**:73-74.

Prasad, R., Shivay, Y.S., Kumar, D., Sharma, S.N. and Devakumar, C. (2007) Neem for sustainable agriculture and the environment. *Proceedings of National Academy of Science* (India) **77**(Sect B): 313-330.

Prasad, R., Singh, S., Saxena,V.S. and Devakumar, C. (1999) Coating of prilled urea with neem (*Azadirachta indica* Juss.) for efficient nitrogen use in rice. *Naturwissensch* **86**:538–539.

Rath, A.K., Swain, B., Ramakrishnan, B., Panda, D., Adhya, T.K., Rao, V.R. and Sethunathan, N. (1999) Influence of fertilizer management and water regime on methane emission from rice fields. *Agriculture Ecosystems and Environment* **76**:99–107.

Reddy, R.N.S. and Prasad, R. (1975) Studies on the mineralization of urea, coated urea, and nitrification inhibitor treated urea in soil. *Journal of Soil Science* **26**:304-312.

Reddy, R.N.S. and Prasad, R. (1977) Effect of variety, rates and sources of nitrogen on growth characters, yield components and yield of rice. Il Riso **26**:217-224.

Rengasamy, S., Kaushik, N., Kumar, J., Koul, O. and Parmar, B.S. (1996). Azadirachtin content and bioactivityof some neem ecotypes in India. In: Neem and Environment, vol .1, Singh R.P., Chari, M.S., Raheja, A.K.and Kraus W. (Eds.), Oxford and IBH Publishing Co., New Delhi, India. pp. 207-217.

Sannagoudra, H.M., Dasog, G.S., Patil, P.L. and Hanamaratti, N.G. (2012) Yield and nitrogen uptake by drill sown paddy as affected by different coatings of urea under two row spacings. *Karnataka Journal of Agricultural Science* **25**:535-536.

Saxena, V.S., Devakumar, C. and Prasad, R. (2003) A method for the preparation of micronized emulsion of neem oil suitable for coating prilled urea. Indian Patent No IN190909 (August 30, 2003).

Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Annual Review of Entomology* **35**:271-297.

Sharma, H.L., Singh, C.M. and Kapur, B.L. (1986) Effect of neem cake blended urea on germination and yield of potato. *Indian Journal of Agricultural Sciences* **56**: 802-804.

Sharma, R.C., Grewal, J.S., Sharma, A.K. and Sharma, H.C. (1980) Relative efficiency of calcium ammonium nitrate, dimethyl urea, urea and urea mixed with neem cake for potato. *Indian Journal of Agricultural Sciences* **50**:152-157.

Sharma, S.N. and Prasad, R. (1978) Nitrogen management and its economics in rice–wheat rotation. *Agricultural Research and Rural Development* **1**:1–6.

Sharma, S.N. and Prasad R. (1980) Relative efficiency of urea, nitrification inhibitor treated urea and sulphur coated urea for rice. *Indian Journal of Agronomy* **25**: 403-409.

Sheshadri, V. and Prasad, R. (1979) Influence of rate and source of nitrogen on growth, nitrogen uptake and yield of cotton. Z. Pflanzen. Bodenkd. **142**: 731-739.

Shivay, Y.S. (2007) Effect of levels and neem (*Azadirachta indica* Juss) coated urea sources of nitrogen on productivity and nitrogen recovery of rice under Indo-Gangetic Plains. *International Journal of Tropical Agriculture* **25**:1111-1123.

Shivay, Y.S., Prasad, R., Singh, S. and Sharma, S.N. (2001) Coating of prilled urea with neem (*Azadirachta indica*) for efficient nitrogen use in lowland transplanted rice (*Oryza sativa*). *Indian Journal Agronomy* **46**:453–457.

Shukla, U.S. and Chauhan, R.P.S. (1998) Efficiency of coated urea materials for rice (*Oryza sativa*) under partially reclaimed sodic soil. *Indian Journal of Agricultural Sciences* **68**:42-43.

Singh, G. and Singh, O.P. (1991) Effect of coated urea materials on rainfed lowland transplanted rice (*Oryza sativa*) and their residual effect on wheat. *Indian Journal of Agronomy* **36** (suppl.): 221-223.

Singh, J., Bolan, N.S., Saggar, S. and Zaman, M. (2008) The role of inhibitors in controlling the biovailability and losses of nitrogen. In: Chemical Biovailability in Terrestrial Environments. Elsevier: Amsterdam, The Netherlands, pp. 329–362.

Singh, K.D.N., Prasad. C.R., Rai, Y., Singh, D. and Sahi, B.P. (1987) Effect of Gamma BHC and blended urea on yield, nutrient uptake and quality of sugarcane in a calcareous soil. *Journal of Indian Society of Soil Sciences* **36**:455-460.

Singh, M. and Singh, T.A. (1986) Leaching losses of nitrogen from urea as affected by application of neem cake. *Journal of Indian Society of Soil Sciences* **34**:766-773.

Singh, M.K., Verma, U.N. and Thakur R. (1999) Efficacy of slow-release N fertilizers for rice and their residual effect on wheat. *Indian Journal of Agronomy* **44**:216-218.

Singh, M.P., Singh, R.P., Singh, V.P. and Verma, S.C. (1990b) Effect of modified urea materials on the performance of rice under varying nitrogen levels. *Indian Journal of Agronomy* **35**:384-390.

Singh, S., Prasad, R. and Ishwaran, V. (1984) New nitrogen carriers for rice. *Madras Agriculture Journal* **71**:371-374.

Singh, S., Prasad, R., Singh, B.V., Goyal, S.K. and Sharma, S.N. (1990a) Effect of green manuring, blue-green algae and neem-cake-coated urea on wetland rice (*Oryza sativa* L.). *Biology and Fertility of Soils* **9**:235–238.

Singh, S. and Shivay, Y.S. (2003) Coating of prilled urea with eco-friendly neem (*Azadirachta indica* A. Juss.) formulations for efficient nitrogen use in hybrid rice. *Acta Agronomy Hungarica* **51**:53-59.

Sinha, N.P., Singh, S.N. and Jha, B.K. (1980) Effect of neem (*Azadirachta indica*) and its various extractives on yield and nutrient uptake in rice. *Journal of Indian Society of Soil Sciences* **28**:535-536.

Sivaraj, A. and Iruthayaraj, M.R. (1980) Effect of nitrogen inhibitors under different levels and time of application on seed cotton yield. *Madras Agriculture Journal* **67**:807-810.

Sridharan, S. and Venugopal, M.S. (1998) Effect of environmental conditions on the yield of Azadirachtin and oil in neem. In: Ecological Agriculture and Sustainable Development, vol. 1. Dhaliwal, G.S., Randhawa, N.S., Arora, R. and

Dhawan, A.K. (eds.) Indian Ecological Society and Centre for Research in Rural and Industrial Development, Chandigarh, India. pp. 510-518.

Subbiah, S., Ramanathan, K.M., Francis, H.J., Suresh Kumar, R and Kothandaraman, G.V. (1982) Influence of nitrogenous fertilizer with and without neem cake blending on the yield of fingermillet. *Journal of Indian Society of Soil Sciences* **30**:37-43.

Suri, I.K. (1995) Coating of urea with neem. *Fertilizer News*. **40**:55-59.

Suri, I.K., Mathews, S. and Saxena, V.S. (2000) Coating of prilled urea with neem – trial at KRIBHCO's Hazira plant. *Fertilizer News* **45**:17-22.

Surve, S.P. and Daftardar, S.Y. (1985) Effect of some neem (*Azadirachta indica*) and karanj (*Pongamia glabra*) products on utilization of urea nitrogen by upland rice. *Journal of Indian Society of Soil Science* **32**:182-186.

Thind, H.S., Bijay-Singh, Pannu, R.P., Yadvinder-Singh, Varinderpal-Singh, Gupta, R.K., Gobinder-Singh, Kumar, A.and Vashistha, M. (2010a) Managing neem (*Azadirachta indica*)-coated urea and ordinary urea in wheat (*Triticum aestivum*) for improving nitrogen-use efficiency and high yields. *Indian Journal of Agricultural Sciences* **80**:960-964.

Thind, H.S., Bijay-Singh, Pannu, R.P.S., Yadvinder-Singh, Varinderpal-Singh, Gupta, R.K., Vashistha, M., Jagmohan-Singh., and Kumar, A. (2010b) Relative performance of neem (*Azadirachta indica*) coated urea vis-à-vis ordinary urea applied to rice on the basis of soil test or following need based nitrogen management using leaf colour chart. *Nutrient Cycling in Agroecosystems* **87**:1-8.

Thomas, J. and Prasad, R. (1983) Mineralization of urea, coated urea and nitrification inhibitor treated urea in different rice growing soils. Zeitschrift Pflanzeneruährung und Bodenkunde. **46**:341-347.

Thomas, J. and Prasad, R. (1987) Relative efficiency of prilled urea, urea super granules, sulphur coated urea and nitrification inhibitor. *Journal of Agronomy and Crop Sciences* **159**:302–307.

Tomar, S.S. and Gupta, P.K. (1996) Use of neem as Nimin to increase N use efficiency in transplanted rice. In: Neem and Environment. Proceedings of World Neem Conference, Bangalore. R.P. Singh et al. (Eds.). Oxford and IBM Publishing Co., New Delhi.

Tomar, S. S. and Verma, J. K. (1990) Yield and yield attributory characters of rice (*Oryza sativa* L.) variety Jaya as affected by nitrogen levels and modified urea materials under transplanted conditions. *Research Development Report* **7**: 59-64.

Velu, V., Saravanan, A. and Ramanathan, K.H. (1987) Efficacy of different sources of nitrogen on lowland rice in Kullankar area of Cauvery delta. *Madras Agriculture Journal* **74**: 488-489.

Vyas, B.N., Godrej, N.B. and Mistry, K.B. (1991) Development and evaluation of neem extract as a coating for urea fertilizer. *Fertilizer News* **36**:19–25.

Yadav, J.P., Singh G.D. and Keshawa, G.L. (1989) Effect of different forms of nitrogenous fertilizers and levels of zinc on nutrient uptake and yield of pearl millet. *Indian Journal of Agronomy* **34**: 428-430.

Yadav, R.L., Kumar, R. and Verma, R.S. (1990) Effects of nitrogen applied through new carriers on yield and quality of sugarcane. *Journal of Agricultural Sciences* **114**:225-230.

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Wheat head armyworm monitoring: a survey and lure dose response in Montana, USA

Anamika Sharma[1], Govinda Shrestha[1], Debra A. Miller[1], Tyler Lane[2] and Gadi V.P. Reddy[1]

[1]*Montana State University-Bozeman, Department of Research Centers, Western Triangle Agricultural Research Center, P.O. Box 656, 9546 Old Shelby Rd., Conrad MT 59425, USA*

[2]*Montana State University-Bozeman, Extension Chouteau County, 1308 Franklin St., PO Box 459, Fort Benton, MT 59442, USA*

Corresponding Author Email: reddy@montana.edu

ABSTRACT

Dargida diffusa (Walker), found throughout the United States, causes sporadic damage to cereal crops. Its larvae feed during summer (May-July) on the heads of the growing crop during night. In the present study, (Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald), as pheromone, was used to attract male adults in two counties of Montana (2015–2018). Lure dose response was assessed by using 1 mg, 3 mg, and 10 mg doses. Sweep netting was also used to the survey the population of *D. diffusa*. The dose response study revealed that although higher dose (10 mg) attracted a numerically greater number of adults no significant difference was found among the treatments. Results indicated that the pheromone attracted the males of *D. diffusa* at all the study sites indicating the presence of this pest in Montana and efficacy of lures at lower dose (1 mg) compared to the control and higher doses.

Key words: *Dargida diffusa*, pheromone, traps, Golden Triangle Area, pest-monitoring

Dargida diffusa (Walker) and *Dargida terrapictalis* (Buckett) (Lepidoptera: Noctuidae) are the two members of the wheat head armyworm complex. *Dargida terrapictalis* is native to the temperate western North America (Buckett 1969) while *Dargida diffusa* is of unknown origin (Roberts *et al.* 2017). Both the species, earlier kept under Faronta and later moved to *Dargida* in 2005 (Rodriguez and Angulo 2005), are found throughout the United States (Roberts 2008; Peairs et al. 2010) and are closely related to each other (Roberts et al. 2017). While *D. diffusa,* considered to be a minor pest with sporadic outbreak causing occasional crop injury (Peairs 2008; Michaud et al. 2007), incur yield loss of 35 per cent in spring wheat in Washington State (Roberts 2009a, 2009b), *D. terrapictalis* does not hold a pest status (Landolt et al. 2011). The adult moths of both the species have apparent differences. However, differentiating them on larval basis being not possible, make the accurate damage assessment by any of the species ambiguous (Peairs 2008).

D. diffusa adult moths are yellowish brown with a prominent chocolate-colored stripe along the length of it each forewing. The color of larvae depends on the maturity of the consumed grain and varies from greenish to cream with a line down each side of the body (Michaud et al. 2007). Adults emerging during the spring season (March-May) lay eggs on a wide variety of members of Poaceae. Larvae go through five instars from May to July. Maximum larval populations are observed around mid-June (Michaud et al. 2007). They pass winter in the soil in the pupal stage (Peairs 2006). The life cycle passes in to two or three generations per year (Peairs 2006; Roberts et al. 2017). The first generation of larvae feeds on maturing heads causing direct damage to kernels, whereas second generation moths emerge and lay eggs in summer (June–August). Adults flying in autumn (October) are considered either a third generation or a late-developing second generation (Michaud et al. 2007).

The damage caused by larvae in the late spring coincides with wheat flag leaf development (Michaud et al. 2007). They feed on wheat heads primarily during night when ambient temperature is cooler and migrate towards the base of the plant with the increase of temperature during the day (Michaud et al. 2007; Royer 2007). Since the damage by these resembles much with that of the stored grain pests, the assessment of extent of damage caused by them becomes tough (Michaud et al. 2007). Cereal crops (wheat and barley) are although its major host, they are reported to feed on timothy grass (*Phleum pretense*; Poaceae) also. The damage caused by *D. diffusa* and *D. terrapictalis* is commonly known as 'insect-damaged kernels (IDK)' and is reported from Washington, Idaho and Oregon in USA (Rondon et al. 2011; Roberts et al. 2017).

For management purposes currently, there are no thresholds levels available (Peairs et al. 2010). Although, no established management strategies for this pest occur as of now, some general control tactics including chemical and biological control methods are in practice. Some natural predators such as ground beetles (Coleoptera: Carabidae), true bugs (Hemiptera), spiders (Arachnida), birds, and rodents predating generally on all armyworms including the true armyworm, *Pseudaletia unipuncta* (Haworth). The fall armyworm, *Spodoptera frugiperda* J.E. Smith (Capinera 2005 and 2006) are also believed to prey on *D. diffusa* and *D. terrapictalis* (Roberts et al. 2017). Parasitoids such as *Meteorus autographae* Muesebeck, and *Cotesia marginiventris* (Cresson) (Hymenoptera: Braconidae), reported on armyworms (Capinera 2005 and 2006), also parasitize wheat head armyworm (Roberts et al. 2017). Moreover, in 2007, an unidentified parasitic wasp from pupae was collected in Washington, USA (Roberts et al. 2017). There are no specific insecticides to manage wheat head armyworm. However, insecticides effective against other armyworms are supposed to control this pest as well. Synthetic pyrethroids are reported to control its population under field conditions in Pacific Northwest (parts of North America and Canada) especially when sprayed during the period of maximum larval activity in the early morning and late evening (Michaud et al. 2007; Roberts et al. 2017). Reddy and Antwi (2016) tested commercially available botanicals and microbial insecticides such as Entrust®WP (spinosad 80%), Mycotrol®ESO (*Beauveria bassiana* GHA), Aza-Direct® (azadirachtin), Met52®EC (*Metarhizium brunneum* F52), Xpectro®OD (*Beauveria bassiana* GHA + pyrethrins), and Xpulse®OD (*Beauveria bassiana* GHA + azadirachtin)] at different rates in the laboratory and found spinosad the best resulting in about 80 percent larval mortality. Combination of *B. bassiana* GHA with pyrethrins and azadirachtin also showed promising results (Reddy and Antwi 2016).

Due to the scarcity of information about *D. diffusa* and *D. terrapictalis* and management strategies to control them, a thorough monitoring of this pest is very necessary (Michaud et al. 2007). For monitoring purposes, Underhill et al. (1977) reported that *D. diffusa* attracted to the lures which were baited with a combination of the sex attractant compounds Z11-16Ac and Z11-16Ald. Further, in 2011, a study showed that the combination of these two compounds also attracted *D. terrapictalis* in wheat fields of Oregon and Washington states of USA (Landolt et al. 2011). Later on, pheromone traps installed in Washington and Oregon states captured both *D. diffusa* and *D. terrapictalis* and the difference in the population of trapped insects depended on seasonal variation in population of both insects (Roberts et al. 2017). The pheromone traps are recommended to be put out when winter wheat enters the boot stage (April–May) and the monitoring be done weekly (Roberts et al. 2017).

Keeping the above facts in view, the effieacy of pheromone and its doses on population of *D. diffusa* in Montana (a part of Pacific Northwest region) was assessed.

MATERIALS AND METHODS

The survey was conducted in the Golden Triangle Area of Montana, USA, a grain producing area with rolling hills and gentle slopes, during 2015 to 2018. The survey and lure dose response was tested at four locations in Pondera county (Ledger (N 48R″35.823' W111R″12.481'), Conrad (N 48R″14.980' W111R″59.926'), Western Triangle Agricultural Research Center (WTARC) (N 48R″18.625' W111R″55.523'), Lothair (N 48R″18.457′ W111R″55.523') and in three locations in Choteau (Highwood (N 47R″35.8' W110R″47.28'), Carter (N 47R″ 80.020′ W111R″20.748′) and Floweree (N 47R″43.47' W111R″01.39') during 2016, 2017, 2018 in the former and during 2015 in the later, respectively. In 2016, 2017 and 2018, the population was monitored at Carter location only.

The survey and the monitoring of the insect pest was performed by using pheromone trap, specifically designed for *D. diffusa males* (Fig. 1A and 1B) and the sweep net sampling done weekly in early morning hours. About 50 sweeps in each replication was done. Four treatments of pheromone traps, comprising of control (no lure), lure with 1 mg, 3 mg, and 10 mg of pheromone (rubber septa impregnated with (Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald) in 9:1 ratio with Hercon Vaportape) at a distance of 5-7 meters between them at each site, were established. PHEROCON® unittraps (Trécé, Oklahoma, USA) with rubber septa, each impregnated with the pheromone compounds [(Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald)], was established at selected sites of Pondera and Choteau counties. The rubber septa were loaded with 0, 1, 3 and 10 mg of pheromone compounds. The trap catches were recorded weekly and the adults were removed and counted. The data were analyzed using One-way ANOVA followed by Tukey's test (R Core Team).

Fig. 1: A: Wheat head armyworm larvae and damaged wheat seeds. B: PHEROCON Unitrap in winter wheat fields at Western Triangle Agricultural Research Center.

RESULTS AND DISCUSSION

The results of both the sites is Pondera and Choteau counties showed that majority of wheat head armyworms adults and larvae were captured during mid-June to early July. The highest adults were captured between last week of June and first week of July, irrespective of locations. (Figure 2A, 2B). Based on one-way ANOVA, the study showed significant effect of treatments on capture of total cumulative *D. diffusa* adults and total average count at both Pondera (total cumulative count; df = 3, 12; F = 7.16; P Â 0.001 and average count; df = 3, 12; F = 8.00; P Â 0.001) and Choteau (total cumulative count; df = 3, 4; F = 19.67; P Â 0.001 and average count; df = 3, 4; F = 6.00; P = 0.4) locations. Regardless of study locations, significantly higher number of wheat head armyworms were captured on pheromone lure treatments against almost zero counts of wheat head armyworms under control (Figure 3A, 3B; Figure 4A, 4B). (Landolt et al. 2011) reported that combination of '(Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald)' attracted both *D. diffusa* and *D. terrapictalis*. In present study, this pheromone also attracted some population of *D. terrapictalis* but the majority were of *D. diffusa*. This indicated a higher

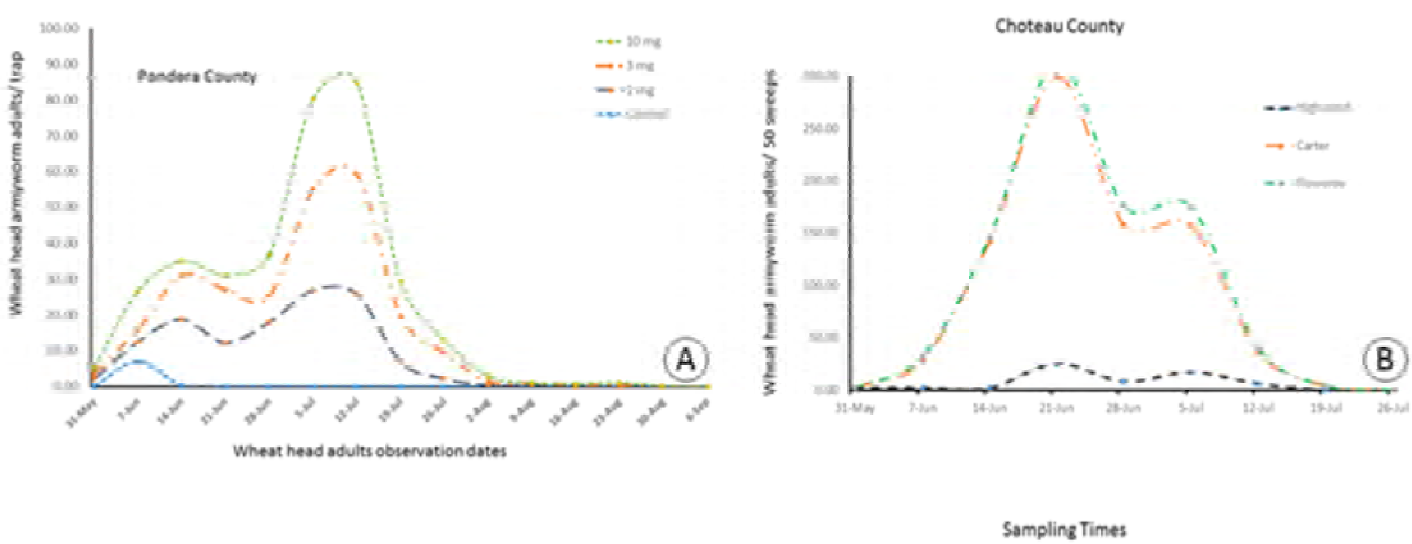

Fig. 2. Population pattern in two counties. A: Wheat head armyworms population pattern at Pondera County, 2016. All data from 4 field sites were pooled for this graph. B: Wheat head armyworms population pattern at Choteau County, 2015.

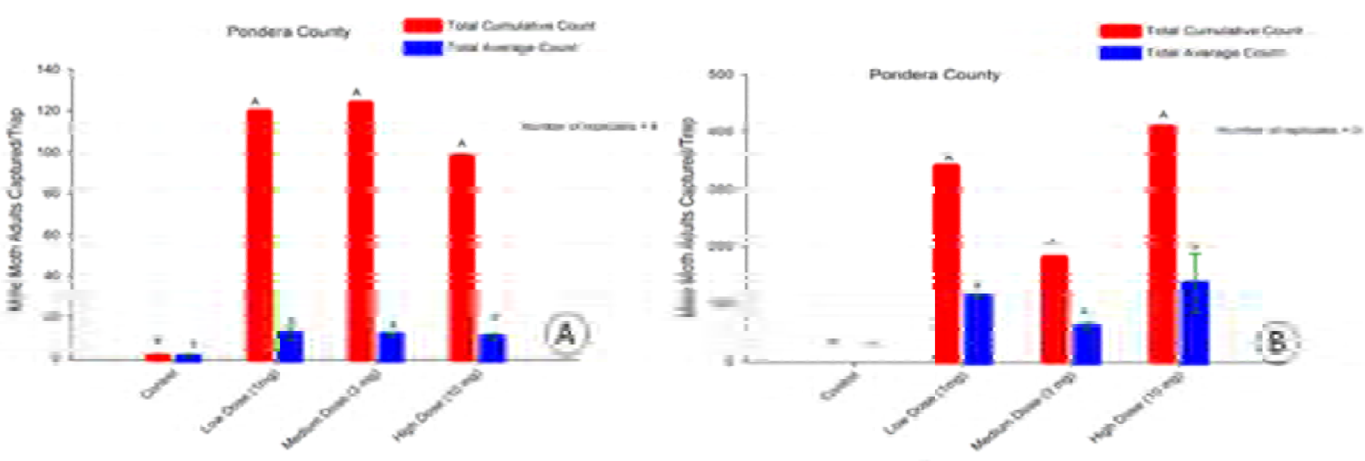

Fig. 3: Lure dose response study at Pondera County (Ledger, Conrad and Lothair). A: Lure dose response study for 2016. B: Lure dose response study for 2017. For both figures, bars bearing the same uppercase or lowercase letters are not significantly different (Tukey test, P > 0.05).

population of *D. diffusa* in the studied region. Underhill et al. (1977) reported that this pheromone attract male of *D. diffusa*. The present study showed that this pheromone acted as a strong attractant for *D. diffusa* indicating it to be the first report from Montana. Overall, pheromone traps showed greater efficiency in predicting the population of *D. diffusa* compared to the control and sweep netting.

Landolt et al. (2011) used 1 mg of this pheromone with 9 to 1 mixture of Zll-16Ac and Zll-16Ald. In the present study, the combination of both the compounds in the same ratio was used. In Pondera no significant difference between the number of adults collected in traps with three different lure doses was observed during 2016 and 2017. However, numerically greater number of male *D. diffusa* were trapped with 1 mg of pheromone in 2016 and 10 mg of pheromone in 2017 (Figure 3A, 3B). In 2017 cumulative number of adults collected in traps was overall greater compared to 2016 in Pondera County. In the year 2018, a negligible number of adults were trapped and hence data is not included in the study. In Choteau county, in the year 2016 and 2017 (combined data), there was no significant difference in the number collected in three traps but numerically trap with 10 mg of lure collected more adults (Figure 4A). Whereas in 2018, trap with 1 mg lure attracted more adults (Figure 4B). Nevertheless, in 2018 the numbers were much lower. The results obtained in both counties showed that although a numerically higher number of adults were collected with 10 mg lure, lack of statistical significant variation among the treatments indicated ineffectiveness of higher doses of this pheromone. These results can also be explained by the fact that the behavioral response of mated males can be inhibited by adding pheromone doses above the detection threshold of central neurons of an insect (Barrozo et al. 2010). Furthermore, at higher doses, sex pheromone becomes inhibitory and cannot be detected by insects. Hence, higher number of adults attracted to higher dose of pheromone could be attributed to non-attractiveness of the dose to the mated males (Barrozo et al. 2010; Showler et al. 2005). Nevertheless, low population of *D. diffusa* in 2018 in both counties indicates a reduction in population in Golden Triangle Area of Montana. A similar phenomenon is noted by Landolt et al. (2011), where low populations of *D. diffusa* was indicated as a possible reason for attracting a lower population of *D. diffusa* in Washington and Oregon states of USA.

In conclusion, this baseline monitoring data in Montana may help to alert producers to this new threat. Appropriate monitoring is must for predicting the possible damage to grains in Montana by *D. diffusa* and also by *D. terrapictalis*. Creating accessible resources for growers to forecast the presence of this pest will enable the growers to be prepared with appropriate management and farming practices. Since both *D. diffusa* and *D. terrapictalis* are not widespread to other parts of the world, all preliminary data from Pacific Northwest region will create a much required information resource about these insect pests.

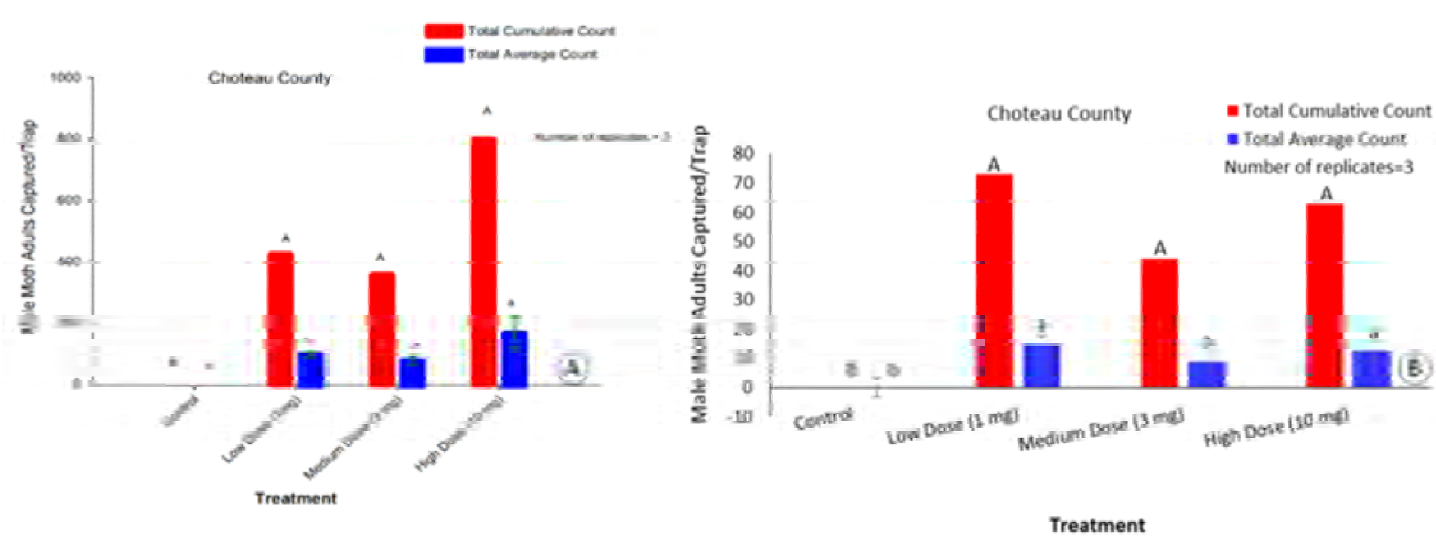

Fig. 4: Lure dose response study at Choteau County (Carter location). A: Lure dose response study data combined for 2016 and 2017. B: Lure dose response study for 2018. For both figures, bars bearing the same uppercase or lowercase letters are not significantly different (Tukey test, P > 0.05).

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REFERENCES

Barrozo, R. B., Gadenne, C., Anton, S. 2010. Switching attraction to inhibition: Mating-induced reversed role of sex pheromone in an insect. *Journal of Experimental Biology* **213**: 2933-2939.

Buckett, J. S. 1969. A new species of armyworm belonging to the genus *Faronta smith* from the western United States (Noctuidae). *Journal of Research on the Lepidoptera* **6**: 266.

Capinera, J.L. 2005. Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Insecta: Lepidoptera: Noctuidae). UF/IFAS Extension. EENY-098.

Capinera, J.L. 2006. Armyworm, *Pseudaletia unipuncta* (Haworth) (Insecta: Lepidoptera: Noctuidae). UF/IFAS Extension. EENY-394.

Landolt, P.J., Roberts, D., Corp, M., Rondon, S.I. 2011. Trap response of *Dargida terrapictalis* (Buckett) (Lepidoptera: Noctuidae) to a sex attractant in wheat-growing areas of eastern Washington and neighboring Oregon. *Journal of the Kansas Entomological Society* **84**: 139–147.

Michaud, J.P., Sloderbeck, P.E., Whitworth, R.J. 2007. Wheat insect management. Kansas State University Research and Extension, Manhattan, KS.

Mickel, C.E. 1932. Armyworms in southern Minnesota. *Journal of Economic Entomology* **25**: 1123-1128.

Peairs, F.B. 2006. Crops: caterpillars in small grains. Insect Series 5.577. Fort Collins, Colorado State University Cooperative Extension.

Peairs F.B. 2008. Wheat pests and their management. In: Capinera J.L. (eds) *Encyclopedia of Entomology* Springer, Dordrecht NL, pp. 4220–4238.

Peairs, F.B., Hein, G.L., Brewer, M.J., 2010. High plains integrated pest management: wheat head armyworm, http://wiki.bugwood.org/HPIPM:Wheat Head Armyworm.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. URL http://www.R-project.org/.

Reddy, G.V.P. and F. Antwi. 2016. Toxicity of natural insecticides on the larvae of wheat head armyworm, *Dargida diffusa* (Lepidoptera: Noctuidae). *Environmental Toxicology and Pharmacology* **42**: 156-162.

Roberts, D. 2008. Alleged wheat head armyworm marching again. Pullman, Washington State University Extension.

Roberts, D. 2009a. Wheat head armyworm update June 22, 2009. Pullman, Washington State University Extension.

Roberts, D. 2009b. Wheat head armyworm update July 1, 2009. Pullman, Washington State University Extension.

Roberts, D., Rondon, S.I. Landolt, P.J. 2017. Integrated Pest Management for the Wheat Head Armyworm Complex in the Pacific Northwest. Pacific Northwest Extension publications. pp. 10.

Rodriguez, M.A., Angulo, A.O., 2005. Cataologo critico y nominal del genero *Dargida walker*, 1856 (Lepidoptera, Noctuidae, Hadeninae). *Gayana* **69**: 10–21.

Rondon, S.I., Corp, M.K., Roberts, D., Pike, K., Landolt, P., Keys, D., 2011. Wheat head armyworm, true or false: a tale from the Pacific Northwest. Oregon State University Extension Service Publication EM 9000-E, http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/21146/em9000.pdf. Last accessed 18 November, 2018.

Royer, T. 2007. Armyworms and wheat head armyworms: how to tell the difference. Oklahoma State University *Plant Disease and Insect Advisory* **6**: 15.

Showler, A.T., E. Salgado, I. Fraser, and D.C. Robacker. 2005. Effect of aging on pheromone emission from a commercial beet armyworm (Lepidoptera: Noctuidae) lure and trap efficiency. *Journal of Economic Entomology* **98**: 373-377.

Underhill, E.W., M.D. Chisholm, and W. Steck. 1977. Olefinic aldehydes as constituents of sex attractants for noctuid moths. *Environmental Entomology* **6**: 333-337.

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Eco-friendly management of pulse beetle, *Callosobruchus chinensis* (Linnaeus) on cowpea in storage

Neenu Augustine and R.A. Balikai

Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad-580 005
E-mail: rabalikai@gmail.com

ABSTRACT

Laboratory studies on evaluation of ecofriendly grain protectants against *Callosobruchus chinensis* (Linnaeus) on cowpea plant powders, oils and inert dust revealed that the sweet flag (*Acorus calamus* L.) rhizome powder @ 5 g kg^{-1} seeds, cow dung ash @ 200 g kg^{-1} and neem oil @ 10 ml kg^{-1} seeds exhibited remarkable protectant ability. The cent per cent adult mortality observed in these as against zero mortality in the control at 4 days after treatment indicated their greater efficacy. Coconut oil @ 10 ml kg^{-1} seeds and groundnut oil @ 10 ml kg^{-1} seed also exhibited their effectiveness showing more than 50.00 per cent mortality of *C. chinensis* 4 days after treatment.

Key words: *Callosobruchus*, Eco-friendly, Management, Pulse beetle, Storage

Pulses are very good source of human dietary proteins, carbohydrates, fats, vitamins and minerals. Cowpea (*Vigna unguiculata* (L.) Walp.), one among the premier pulse crops assuming greater importance, is well-accepted as vegetable, fodder and seed due to its good palatability, high nutrient content and negligible toxic metabolites content. It is attacked by a myriad of pests of which bruchid infestation takes the lion share of the total seed loss in storage. They are cosmopolitan in distribution and poses serious threat in storage and marketing of pulses.

In the family Chrysomelidae, the genera *Callosobruchus* contains about a dozen species and the three species *viz*., *C. chinensis*, *C. maculates* and *C. analis* cause heavy damage to stored pulses (Southgate, 1979). Cowpea is one among the most susceptible hosts of *Callosobruchus chinensis* (Linnaeus) in storage. Generally, pulse beetle infestation starts from field which is carried to the store as hidden infestation. They damage the seeds quantitatively and qualitatively leading to several types of post-harvest losses, *viz*., reduction in seed weight, loss of viability, poor marketability, *etc*. (Hill, 1993). Significant reduction in germination, seedling length and seedling vigour are also reported in bruchid infested cowpea seeds (Deshpande *et al*., 2011). The work on biology, varietal screening and management of pulse beetles in storage has been reviewed by Balikai and Neenu, 2018).

Mostly farmers resort to the use of chemicals for management of this pest. However, increasing awareness on the deleterious effects of using chemical insecticides in storage and the demand for insecticide free food has prompted the development of non-chemical management options. Hence, a laboratory study was undertaken for the evaluation of several plant powders, oils and inert dust as grain protectants against *C. chinensis* on cowpea.

MATERIALS AND METHODS

The matured rhizomes of sweet flag (*Acorus calamus* L.) were chopped into small pieces and dried in oven, ground to powder and sieved through 60 micron sieve to get fine powder for treatment. The leaves of neem (*Azadirachta indica* A. Juss.) and Vitex (*Vitex negundo* L.) were dried under shade separately, ground to powder and sieved for treatment. Coconut, groundnut and neem oils were purchased from local markets and smeared on the grains as per the dosages. Two inert dusts *viz*., cow dung ash and red soil dust were collected in and around Dharwad for evaluation of their efficacy.

To assess the efficacy of treatments, five pairs of freshly emerged adult beetles were released in plastic jars of 500 ml capacity containing 200 g seeds of the cowpea variety DC-15. The seeds in each jar were given various treatments replicated thrice in Completely Randomised Design. An untreated control was also maintained without using any grain protectants. Each of the grain protectants was mixed thoroughly in 200 g of cowpea seeds by shaking well manually for five minutes in a jar so as to ensure uniform coating on the seeds.

The per cent adult mortality was recorded at two days intervals starting from fourth day after treatment up to eight days using the following formula:

$$\text{Per cent adult mortality} = \frac{\text{Number of dead adults}}{\text{Total number of adults released}} \times 100$$

Progeny emergence was observed, if any at 30, 60 and 90 days after treatment. Population build up (number of adults emerged and number of eggs laid) at 30, 60 and 90 days after treatment was observed. Per cent damage and per cent weight loss corresponding to each treatment were also recorded at same intervals by drawing a sample of 100 seeds randomly from each replication.

All the per cent values were transformed to angular transformations before statistical analysis of the data. Further, before analysis of variance, all the zero and 100 values of per cent mortality were replaced by using formula "1/4n" and "100-1/4n", respectively. The per cent mortality was subjected to the analysis of variance by adopting "Fishers Analysis of Variance Technique" as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Results on direct toxicity effect of different treatments manifested in the form of adult mortality of *C. chinensis* are furnished in Table 1. At four days after imposition of treatments, the per cent adult mortality varied significantly in different treatments within the range of 0.00 to 100.00 per cent. The cumulative mortality recorded was cent per cent in sweet flag rhizome powder @ 5 g kg^{-1} seeds, cow dung ash @ 200 g kg^{-1} seeds and neem oil @ 10 ml kg^{-1} seeds. This was followed by coconut oil @ 10 ml kg^{-1} seeds (70.00%), *V. negundo* leaf powder @ 50 g kg^{-1} seeds (63.33%) and groundnut oil @ 10 ml kg^{-1} seeds (60.00%) with the latter two treatments being on par with each other. The next best treatments were neem leaf powder @ 50 g kg^{-1} seeds and red soil dust @ 50 g kg^{-1} seeds which registered 50.00 and 40.00 per cent mortality, respectively. Turmeric rhizome powder @ 5 g kg^{-1} seeds recorded significantly least mortality of 26.67 per cent.

Observations at six days after treatment imposition revealed similar trend as in four days after treatment. The cumulative mortality recorded was cent per cent in cow dung ash @ 200 g kg^{-1} seeds, sweet flag rhizome powder @ 5 g kg^{-1} seeds and neem oil @ 10 ml kg^{-1} seeds. Coconut oil @ 10 ml kg^{-1} seeds recorded a mortality of 86.67 per cent followed by *V. negundo* leaf powder @ 50 g kg^{-1} seeds and groundnut oil @ 10 ml kg^{-1} seeds both recording 80.00 per cent adult mortality. It was followed by neem leaf powder @ 50 g kg^{-1} seeds (73.33%), red soil dust @ 50 g kg^{-1} seeds (70.00%) and the least mortality of 36.67 per cent was observed in turmeric rhizome powder @ 5 g kg^{-1} seeds (Table 1).

The cumulative adult mortality at eight days after release showed a considerable increase in mortality in all treatments as time lapsed. The mortality recorded was cent per cent in cow dung ash @ 200 g kg^{-1} seeds, sweet flag rhizome powder @ 5 g kg^{-1} seeds and neem oil @ 10 ml kg^{-1} seeds. A mortality of 96.67 per cent was recorded in coconut oil @ 10 ml kg^{-1} seeds followed by *V. negundo* leaf powder @ 50 g kg^{-1} seeds and groundnut oil @ 10 ml kg^{-1} seeds with 90.00 per cent mortality in both the treatments. The next best treatments were neem leaf powder @ 50 g kg^{-1} seeds and red soil dust @ 50 g kg^{-1} seeds (80.00% in each) while the most ineffective treatment was turmeric rhizome powder @ 5 g kg^{-1} seeds (73.33%) which were on par with untreated control (70.00%). More than 70.00 per cent mortality was observed in all treatments including untreated control owing to the biology of the pest where the natural adult longevity is around a week (Table 1).

Significant differences were observed among treatments in terms of per cent seed damage at three months after treatment. Sweet flag rhizome powder @ 5 g kg^{-1} seeds was observed to be the statistically superior treatment (0.00%) while the least effective being turmeric rhizome powder @ 5 g kg^{-1} seeds (14.00%) as against 65.00 per cent in the untreated check. The order of effectiveness of other treatments in the descending order was neem oil @ 10 ml kg^{-}

Table 1: Effect of different treatments on per cent adult mortality of *Callosobruchus chinensis* at 4, 6 and 8 days after treatment

Treatments	Dosage		4 DAT	6 DAT	8 DAT
	kg $seeds^{-1}$	per cent			
Sweet flag rhizome powder	5 g	0.50	100.00 $(89.48)^a$	100.00 $(89.48)^a$	100.00 $(89.48)^a$
Cow dung ash	200 g	20.00	100.00 $(89.48)^a$	100.00 $(89.48)^a$	100.00 $(89.48)^a$
Red soil dust	50 g	5.00	40.00 $(39.22)^e$	70.00 $(56.77)^d$	80.00 $(63.41)^{bc}$
Neem leaf powder	50 g	5.00	50.00 $(44.98)^d$	73.33 $(58.89)^{cd}$	80.00 $(63.41)^{bc}$
Vitex negundo leaf powder	50 g	5.00	63.33 $(52.75)^c$	80.00 $(63.41)^{bc}$	90.00 $(71.54)^b$
Turmeric rhizome powder	5 g	0.50	26.67 $(30.98)^f$	36.67 $(37.25)^e$	73.33 $(58.89)^c$
Coconut oil	10 ml	1.00	70.00 $(56.77)^b$	86.67 $(68.56)^b$	96.67 $(79.45)^a$
Groundnut oil	10 ml	1.00	60.00 $(50.75)^c$	80.00 $(63.41)^{bc}$	90.00 $(71.54)^b$
Neem oil	10 ml	1.00	100.00 $(89.48)^a$	100.00 $(89.48)^a$	100.00 $(89.48)^a$
Untreated control	-	-	0.00 $(0.52)^g$	26.67 $(31.08)^f$	70.00 $(56.77)^c$
S.Em. ±	-	-	0.95	1.46	2.06
C.D. (0.01)	-	-	3.80	5.86	8.31

DAT= Days after treatment
Figures in parentheses are arcsine transformed values
Means followed by the same letter in a column are not significantly different (p=0.01) by DMRT

^{1} seeds (3.33%), cow dung ash @ 200 g kg^{-1} seeds (4.33%), coconut oil @ 10 ml kg^{-1} seeds (5.00%), *V. negundo* leaf powder @ 50 g kg^{-1} seeds (6.67%), neem leaf powder @ 50 g kg^{-1} seeds (10.00) and red soil dust @ 50 g kg^{-1} seeds (10.33%) (Table 2).

The seed weight loss among the treatments at 90 days after treatment varied significantly and ranged from 0.00 to 8.33 per cent. Sweet flag rhizome powder @ 5 g kg^{-1} seeds was found to be significantly superior over all the treatments which recorded no weight loss followed by neem oil @ 10 ml kg^{-1} seeds (0.83%), cow dung ash @ 200 g kg^{-1} seeds (1.08%), coconut oil @ 10 ml kg^{-1} seeds (1.33%) and *V. negundo* leaf powder @ 50 g kg^{-1} seeds (1.67%). Neem leaf powder @ 50 g kg^{-1} seeds and red soil dust @ 50 g kg^{-1} seeds were found on par with each other by recording 2.50 and 2.92 per cent loss, respectively. While, turmeric rhizome powder @ 5 g kg^{-1} seeds showed significantly least weight loss of 4.00 per cent indicating its ineffectiveness in preventing seed weight loss by bruchids (Table 2).

All the treatments varied significantly in allowing the eggs to complete development and to reach adult stage. The treatment superiority of sweet flag rhizome powder @ 5 g kg^{-1} seeds with zero adult emergence is reflected in its ability to inhibit adult emergence even at 90 days after treatment. The adult emergence in all other treatments increased as time lapsed. However, the chronological order of efficacy was neem oil @ 10 ml kg^{-1} seeds (10.67%), cow dung ash @ 200 g kg^{-1} seeds (15.67%), coconut oil @ 10 ml kg^{-1} seeds (21.00%), *V. negundo* leaf powder @ 50 g kg^{-1} seeds (29.33%) and groundnut oil @ 10 ml kg^{-1} seeds (31.33%) with the latter two treatments being on par with each other. The highest adult emergence of 71.67 per cent was recorded in turmeric rhizome powder @ 5 g kg^{-1} seeds followed by red soil dust @ 50 g kg^{-1} seeds (61.33%) and neem leaf powder @ 50 g kg^{-1} seeds (52.33%) at 90 days after treatment (Table 3).

At 90 days after treatment, the population build up in different treatments varied significantly with the most effective treatment in preventing population build up being sweet flag rhizome powder @ 5 g kg^{-1} seeds (0.00). The next best treatments were cow dung ash @ 200 g kg^{-1} seeds (5.00) and neem oil @ 10 ml kg^{-1} seeds (31.67) which also recorded significantly lower population build up. The least effective treatment was turmeric rhizome powder @ 5 g kg^{-1} seeds (104.00) followed by neem leaf powder @ 50 g kg^{-1} seeds (92.33) and groundnut oil @ 10 ml kg^{-1} seeds (81.67). Rest of the treatments showed intermediate results in a similar trend as that of 30 and 60 days after treatment (Table 3).

Table 2: Seed damage and weight loss caused by *Callosobruchus chinensis* in cowpea at different periods after treatment

Treatments	Dosage (% w/w)	Per cent seed damage			Per cent weight loss		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Sweet flag rhizome powder	0.50	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.52)^{a}
Cow dung ash	20.00	2.00 (8.13)^{c}	2.67 (9.39)^{b}	4.33 (12.01)^{bc}	0.50 (4.05)^{c}	0.83 (5.24)^{c}	1.08 (5.97)^{bc}
Red soil dust	5.00	6.00 (14.17)^{f}	7.33 (15.71)^{ef}	10.33 (18.74)^{e}	1.67 (7.41)^{f}	2.58 (9.25)^{f}	2.92 (9.83)^{e}
Neem leaf powder	5.00	6.33 (14.57)^{f}	7.67 (16.07)^{f}	10.00 (18.43)^{e}	1.42 (6.83)^{f}	2.25 (8.62)^{f}	2.50 (9.09)^{e}
Vitex negundo leaf powder	5.00	4.33 (12.01)^{e}	5.67 (13.77)^{d}	6.67 (14.96)^{d}	1.00 (5.74)^{de}	1.33 (6.63)^{de}	1.67 (7.41)^{d}
Turmeric rhizome powder	0.50	10.67 (19.05)^{g}	12.67 (20.84)^{g}	14.00 (21.96)^{f}	2.33 (8.78)^{g}	3.50 (10.78)^{g}	4.00 (11.53)^{f}
Coconut oil	1.00	3.33 (10.52)^{d}	4.00 (11.53)^{c}	5.00 (12.92)^{c}	0.83 (5.24)^{d}	1.17 (6.20)^{d}	1.33 (6.63)^{c}
Groundnut oil	1.00	5.33 (13.35)^{f}	6.33 (14.57)^{de}	7.33 (15.71)^{d}	1.17 (6.20)^{e}	1.50 (7.03)^{e}	1.83 (7.78)^{d}
Neem oil	1.00	1.00 (5.74)^{b}	2.00 (8.13)^{b}	3.33 (10.52)^{b}	0.25 (2.86)^{b}	0.58 (4.38)^{b}	0.83 (5.24)^{b}
Untreated control	-	20.33 (26.79)^{h}	42.33 (40.57)^{h}	65.00 (53.71)^{g}	3.17 (10.25)^{h}	5.58 (13.66)^{h}	8.33 (16.77)^{g}
S.Em. ±	-	0.31	0.33	0.46	0.15	0.17	0.19
C.D. (0.01)	-	1.25	1.33	1.84	0.62	0.68	0.77

DAT= Days after treatment Figures in parentheses are arcsine transformed values
Means followed by the same letter in a column are not significantly different (p=0.01) by DMRT

Table 3: Adult emergence and population build up of *Callosobruchus chinensis* in cowpea at different days after treatment

Treatments	Dosage w/w (%)	Per cent adult emergence*			Population build up**		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Sweet flag rhizome powder	0.50	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.52)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}
Cow dung ash	20.00	6.67 (14.96)^{c}	9.33 (17.78)^{c}	15.67 (23.31)^{c}	1.67 (1.47)^{b}	2.33 (1.68)^{b}	5.00 (2.20)^{b}
Red soil dust	5.00	45.00 (42.11)^{h}	50.33 (45.17)^{g}	61.33 (51.53)^{g}	10.67 (3.34)^{d}	23.00 (4.85)^{d}	46.00 (6.82)^{d}
Neem leaf powder	5.00	36.33 (37.05)^{g}	40.67 (39.60)^{f}	52.33 (46.32)^{f}	33.33 (5.82)^{f}	61.33 (7.86)^{f}	92.33 (9.64)^{g}
Vitex negundo leaf powder	5.00	16.67 (24.09)^{e}	22.67 (28.42)^{e}	29.33 (32.78)^{e}	20.33 (4.56)^{e}	41.67 (6.49)^{e}	62.67 (7.95)^{e}
Turmeric rhizome powder	0.50	58.67 (49.97)^{i}	68.67 (55.94)^{h}	71.67 (57.82)^{h}	54.00 (7.38)^{g}	84.00 (9.19)^{g}	104.00 (10.22)^{h}
Coconut oil	1.00	10.00 (18.43)^{d}	15.33 (23.04)^{d}	21.00 (27.26)^{d}	11.00 (3.39)^{d}	22.33 (4.78)^{d}	61.67 (7.88)^{e}
Groundnut oil	1.00	19.67 (26.31)^{f}	24.33 (29.55)^{e}	31.33 (34.03)^{e}	21.00 (4.64)^{e}	41.33 (6.47)^{e}	81.67 (9.06)^{f}
Neem oil	1.00	3.33 (10.52)^{b}	6.00 (14.17)^{b}	10.67 (19.05)^{b}	5.00 (2.35)^{c}	17.67 (4.26)^{c}	31.67 (5.73)^{c}
Untreated control	-	72.67 (58.46)^{j}	78.67 (62.47)^{i}	79.33 (62.94)^{i}	215.00 (14.68)^{h}	411.67 (20.30)^{h}	586.33 (24.22)^{i}
S.Em. ±	-	0.45	0.58	0.58	0.07	0.08	0.06
C.D. (0.01)	-	1.82	2.33	2.32	0.30	0.31	0.23

DAT= Days after treatment
*Figures in parentheses are arcsine transformed values **Figures in parentheses are “x+0.5 transformed values
Means followed by the same letter in a column are not significantly different (p=0.01) by DMRT

Plant powders

The protectant ability of sweet flag rhizome powder @ 5 g kg^{-1} seeds is highly remarkable. The observations of Sibi (2003) and Adhe *et al*. (2018) are in perfect agreement with the results of present study. The toxic and sterilizing effects of sweet flag can be owed to its active ingredient, b-asarone (Schmidt and Streloke, 1994). The reduced oviposition observed in the treated seeds could be as a result of high initial mortality of *C. chinensis* as well as the oviposition deterrent activity of this product. Reduction in adult emergence can also be attributed to high larval mortality or reduction in the hatching of the eggs. However, other botanical powders exhibited only intermediate to low effectiveness against bruchids in storage.

Plant oils

All the plant oils especially neem and coconut oils were found effective in suppressing *C. chinensis*. The observations are in harmony with the observations of Ali *et al*. (1983) and Das (1986). Don-Pedro (1990) reported that the ovicidal action of plant oils may be as a result of physical properties of the oils. He proposed that the oils exert lethal action slowly by blockage of respiratory pores or by direct toxicity of the active ingredients that possibly penetrate the eggs. Similarly, Credland (1992) observed that occlusion of the space enclosed between the bruchid egg and the testa of the seed to which it is attached is responsible for the ovicidal and larvicidal effects of oils. A considerable interference in locomotion, mating behaviour and egg laying is observed in the present investigation which corroborates the reports of Adedire *et al*. (2011) and Ileke and Oni (2011).

Inert materials

Among the inert materials tested, cow dung ash @ 200 g kg^{-1} seeds did exhibit its usefulness by inducing cent per cent mortality as early as 4 DAT. The results are in confirmation with those of Sibi (2003), Shaheen and Khaliq (2005) and Sharma and Devi (2016). As the free movements of the adults for oviposition is interfered by ash, egg laying and larval development of the beetles are hampered and they also forced to deposit their whole stock of eggs on relatively few seeds (Adane and Abraham, 1996). Adugna *et al*. (2003) also reported that the ash dust reduces the relative humidity of the storage conditions and keeps the grain surface dry, thus hampering egg lying and larval development of the beetles. Hence, being a very and cheap and easily available material, it is highly remarkable as an effective surface protectant for cowpea seeds.

CONCLUSION

It was concluded that the sweet flag rhizome powder @ 5 g kg^{-1} seeds, cow dung ash @ 200 g kg^{-1} and neem oil @ 10 ml kg^{-1} seeds possessed remarkable protectant ability against *C. chinensis*. The adult mortality in these was cent per cent as against zero in the control at 4 days after treatment (DAT). They were also found to have considerable persistence as evident from the superior adult mortality at 60 and 90 DAT. Coconut oil @ 10 ml kg^{-1} seeds and groundnut oil @ 10 ml kg^{-1} seed also exhibited their usefulness by inducing more than 50.00 per cent mortality of *C. chinensis* at 4 DAT. However, red soil dust @ 50 g kg^{-1} seeds and turmeric rhizome powder @ 5 g kg^{-1} seeds failed to achieve cent per cent mortality even at 8 DAT indicating their inefficiency as grain protectants.

REFERENCES

Adane, K. and Abraham, T., 1996, Comparison of some insecticides for effectiveness against the maize weevil, *Sitophilus zeamaize* Motsch (Curculinidae) on stored sorghum. *Proceedings of the third Annual Conference of Crop Protection Society of Ethiopia*, Addis Ababa, Ethiopia, pp. 113-119.

Adedire, C. O., Obembe, O. M., Akinkurolere, R. O., and Oduleye, S. O., Response of *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae) to extracts of cashew kernels. *Journal of Plant Disease and Protection,* **118**: 75-79.

Adhe, F. R., Rathod, P. K., Rathod, L., Bhalkare, S. K., Murumkar, R. P., Borkar, A. and Mate, V. N., 2018, Effects of botanicals on mortality of pulse beetle, *Callosobruchus* spp. in stored pigeon pea. *International Journal of Current Microbiology and Applied Science*, **6**: 2554-2560.

Adugna, H., Dagnew, G. and Biniam, Z., 2003, On-farm storage studies on sorghum and chickpea in Eritrea. *African Journal of Biotechnology*, **5**: 1537-1544.

Ali, S. I., Singh, O. P. and Misra, U. S., 1983, Effectiveness of plant oils against pulse beetle *Callosobruchus chinensis* Linn. *Indian Journal of Entomology*, **45**: 6-9.

Balikai, R.A. and Neenu Augustine, 2018, Biology, varietal screening and management of pulse beetles in storage. *Journal of Eco-friendly Agriculture*, **13**: 52-59.

Credland, P. F., 1992, The structure of bruchid eggs may explain the ovicidal effect of oils. *Journal of Stored Product Research*, **28**: 1-9.

Das, G. P., 1986, Effect of different concentrations of neem oil on the adult mortality and oviposition of *Callosobruchus chinensis* Linn. (Bruchidae: Coleoptera). *Indian Journal of Agricultural Sciences,* **56**: 743-744.

Deshpande, V. K., Makanur, B., Deshpande, S. K., Adiger, S. and Salimath, P. M., 2011, Quantitative and qualitative losses caused by *Callosobruchus maculatus* in cowpea during seed storage. *Plant Archives*, **11**: 723-731.

Don-Pedro, K. N., 1990, Insecticidal activity of fatty acid constituents of fixed vegetable oils against *Callosobruchus maculatus* (F.) on cowpea. *Pest Management Science*, **30**: 295-302.

Hill, D. S., 1993, Pests of stored products and their control. Belhaven Press, London, p. 242.

Ileke, K. D. and Oni, M. O., 2011, Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (Motschulsky) [Coleoptera: Curculiondae] on stored wheat grains (*Triticum aestivum*). *African Journal of Agricultural Research*, **6**: 3043-3048.

Schmidt, G. H. and Streloke, M., 1994, Effect of *Acorus calamus* (L.) (Araceae) oil and its main compound â-asarone on *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). *Journal of Stored Product Research*, **30**: 227-235.

Shaheen, F. A. and Khaliq, A., 2005, Management of pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) in stored chickpea using ashes, red soil powder and turpentine oil. *Pakistan Entomologist*, **27**: 19-24.

Sharma, R. and Devi. R., 2016, Evaluation of certain inert materials against pulse beetle, *Callosobruchus chinensis* (L.) infesting stored chickpea, *Cicer arietinum* (L.). *International Journal of Agricultural and Allied Sciences,* **2**: 12-21.

Sibi, V. G., 2003, Comparative biology and management of *Callosobruchus* spp. infesting soybean and other pulses with special reference to *Callosobruchus analis.* (Fabricius). *M. Sc. (Agri.) Thesis*, University of. Agricultural Sciences, Dharwad, Karnataka (India).

Southgate, B. J., 1979, Biology of Bruchidae. *Annual Review of Entomology*, **24**: 449-473.

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Biology and management of mealy bug, *Phenococcus solenopses* Tinsley in FCV Tobacco

K China Chenchaiah

ICAR-CTRI Regional Station, Kandukur - 523 101, Andhra Pradesh, India
E-mail: kcchenchaiah@gmail.com

ABSTRACT

Mealy bug, *Phenococcus solenopses* Tinsley, a serious pest of many agricultureal crops and weeds, espceially cotton, was found infesting FCV tobacco, as a minor pest, in some tobacco growing areas of Andhra Pradesh in recent years. Its biology studied on FCV tobacco indicated that on an average 133.8 crawlers emerged from each egg sack. Eggs hatched in 4.6 days. The nymphal life passed through three instars of 5.8, 6.6 and 7.4 days duration, respectively. It took 24.4 days from egg to adult. Adult male survived for 2.0 days while female lived for 54.2 days. Total life span of a female is of 78.60 days. Clothianidin, imidacloprid and thiamethoxam at higher dose gave 100 per cent control of mealy bugs. However, they were at par with acephate in controlling the insect. At normal dose, clothianidin and acephate were at par (97.5%) followed by thiamethoxam. At lower dose, clothianidin managed 87.5 per cent mealy bugs followed by acephate, thiamethoxam and imidacloprid. The study concluded that clothianidin and acephate at normal dose, controlled mealy bugs in FCV tobacco. The pesticides tested are in the order of Clothianidin ≥ Acephate ≥ Thiamethoxam ≥ Imidacloprid ≥ Chlorpyriphos ≥ Acetamiprid in controlling the mealy bug.

Key words: Mealy bug, FCV tobacco, biology, control.

Tobacco is one of the most important commercial crops in Southern Light Soils of Andhra Pradesh grown under rain fed conditions. During 2013-14, it was grown in about 58,000 ha, with a production of 55.00 million kg of cured leaf (Anonymous, 2015). The tax revenue generated in India during 2016-17 by Tobacco and tobacco products is to a tune of Rs. 34000 crores and the tobacco industry provide a livelihood to 45.7 million farmers and farm labourers (Anonymous, 2018). According to a study, about 19.35 per cent cured leaf is lost by sucking and caterpillar insect pests (Anonymous, 2004). Pest magnitude is changing from time to time due to changes in environment and other man made causes. The changing nature will be continued till the ecosystem gets equilibrium. The Mealy bug, *Phenococcus solenopses* Tinsley, not known to damage FCV Tobacco, was first recorded on FCV Tobacco during 2007-08 at Kandukur and adjoining villages (Chenchaiah *et al*, 2008 a, b) as a minor pest in tobacco nurseries and later continued to damage the transplanted crop. Changes in climate, cropping pattern and crop intensity led to infestation of mealy bug in some tobacco growing areas in recent years.

The mealy bug feed on young seedlings by sucking the spa of young tobacco leaf and cause leaf curl and crinkling symptoms. It prefers to feed from the ventral side of the leaf near veins (Plate-1 & 2). In main field, it feeds on lower leaves of the plant causing injury to leaf by draining the sap. The leaves turn yellow and reach maturity at an early date. The affected plants look stunted and overall growth of the plant was retorted (Plate-3 & 4). It slowly climbs to upper leaves.

In the process of periodical harvesting of leaf for curing, the insect population is reduced on plant or might fall down to soil. The occurrence of this mealy bug has also been noticed on few weed hosts namely, *Achyranthus aspera, Abutilon indicum, Acalypha sp., Cida sp., Parthenium sp.* growing around the fields. It is also noticed on some ornamental plants like *Tagitus erecta, Chrysanthemum sp.* and *Hybiscus rosasinensis*. In view of the potential threat to FCV tobacco, the study on its biology on FCV tobacco and to find suitable control measures to fight the menace in case of severity of the damage was initiated.

MATERIAL AND METHODS

Field observations were made primarily on damage symptoms both in nursery and main crop. Alternate hosts of mealy bug were recorded from the bunds around the nursery beds and main fields. For studying the biology, five egg sacs were collected from the infested tobacco fields and kept under observation in a BOD incubator at 25 ± 2^{o} C. The crawlers or nymphs emerging from egg sacs were used for this study. Twenty five nymphs were allowed to feed on young tobacco seedlings kept in plastic petri dishes (15 cm x 40 mm dia) whose trimmed root system was wrapped with moist cotton swab. The tobacco seedlings were replaced with fresh seedlings after every two days interval. Observations were recorded on number of crawlers or nymphs hatched, time taken by an egg to hatch, time taken for development of nymphs, no of nymphal instars and survival of adult. From the above data, period of each development stage was calculated.

In another study, ten 3rd instar nymphs were released on each potted tobacco plant, sprayed with required concentration of test insecticides 4 hours before the release. The insecticides and their concentration used were imidacloprid (17.8% SL) @ 11.25, 22.5 and 45 g ai ha^{-1} spray; thiamethoxam (25% WG) @ 12.5, 25 and 50 g ai ha^{-1} spray; acephate (75% SP) @ 187.5, 375 and 750 g ai ha^{-1} spray; clothianidin (50% WDG) @ 37.5, 75 and 150 g ai ha^{-1} spray; chlorpyriphos (20% EC) @ 125, 250 and 500 g ai ha^{-1} spray; acetamiprid (20% SP) @ 15, 30 and 60g ai ha^{-1} spray and distilled water. After release of insects, the tobacco leaf was enclosed in a perforated polythene cover. There were four replications for each treatment. Observation on mortality of mealy bug was recorded daily for four days. The experiment was conducted for two years during 2011 and 2012 crop season and the data thus recorded was analysed statistically (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Biology of mealy bug on FCV tobacco

Data revealed that egg hatched in 4.6 days (range 3-8 days). The nymphs, passing through three instars with life periods of 5.8, 6.6 and 7.4 days, respectively, completed development in 19.8 days (range 17-23 days). Kamariya (2009) reported the biology of mealy bug on cotton with the nymphal periods of 4.82, 5.64 and 6.42 days, respectively. The nymphal developmental period of 19.8 days on FCV Tobacco in the present study is close to the Kamariya (2009) findings (16.88 days). Adult male survived for 2.0 days (2-3 days range) while, female lived for 54.2 days (44-75 days range). It took 24.4 days (19-37 range) from egg to adult. An average of 133.8 ±5.23 nymphs (120-147 range) latched from each egg sack. Total life span of a female is 78.6 days (range 63-112 days). Similar results were reported by Jun Huang et al, (2012) on tomato. The mealy bug completed the development in 16.3 days for male with 1.8 days longevity and 15.4 and 42.6 days for female, respectively. The fecundity was 134.6 nymphs. Total nymphal period, adult longevity and fecundity of female mealy bug in the current study are

Table 1. Duration of developmental stages of mealy bug, *Phenacoccous solenopsis* on FCV tobacco

Insect developmental stage/Item	Egg Period (days)	Nymphal period (days)			Total Nymphal Period (days)	Adult survival (days)	
		Ist instar	IInd instar	IIIrd instar		Male	Female
Mean Period	4.6 ± 0.93	5.8 ± 0.37	6.6 ± 0.4	7.4 ± 0.45	19.8± 1.13	2.0 ± 0.32	54.2 ± 5.6
Range	3-8	5-7	6-8	6-8	17-23	2-3	44-75

Table 2. Control of Mealy bug, *Phenacoccous solenopsis* in FCV Tobacco

Treatments	**Per cent mealy bugs controlled***			
	Lower dose	**Normal dose**	**Higher dose**	**Mean**
Imidacloprid 17.8% SL (confidor) 11.25, **22.5**, 45 g ai/ ha	77.5	77.5	100.0	85.0
	(61.7)	(61.5)	(90.0)	(67.2)
Thiamethoxam 25% WG (actara) 12.5,.**25**, 50 ai/ ha	82.5	92.5	100.0	91.6
	(65.3)	(74.1)	(90.0)	(73.2)
Acephate 75% SP (starthene) 187.5, **375,** 750 g ai/ ha	82.5	97.5	97.5	92.4
	(65.3)	(80.9)	(80.9)	(74.0)
Clothianidin 50% WDG (dantotsu) 37.5, **75**, 150 g ai/ ha	87.5	97.5	100.0	94.9
	(69.3)	(80.9)	(90.0)	(76.9)
Chlorpyriphos 20% EC (chloroban) 125, **250**, 500 g ai/ ha	67.5	75.0	92.5	78.3
	(55.4)	(60.0)	(74.1)	(62.2)
Acetamiprid 20% SP (scuba) 15,**30**,60 g ai/ ha	55.0	65.0	77.5	65.8
	(47.9)	(53.7)	(61.7)	(54.2)
Water ©	10.0	10.0	10.0	10.0
	(18.4)	(18.4)	(18.4)	(18.4)
	Treatment	**Dose**	**Interaction**	
S.Em ±	1.69	1.11	2.92	
CD at 5%	4.68	NS	8.11	
CV %	3.41	7.89	6.39	

*Figures in the parenthesis indicate angular transformed values very near to the findings of Jun Huang et al, 2012. Moreover, the developmental period of insects depends much on the nutrition quality of the food and the host species on which it is developing (Panda, 2004).

During the course of study, one hymenopterous parasite *Aenasius bambawalei* Hayat was recorded controlling the insect population (identification was confirmed by Div. Entomology, IARI, New Delhi).

Management of mealy bug

The results conducted under laboratory conditions on potted plants for two years to showed that the mortality of mealy bugs ranged between 10.0 in water spray to 100.0 per cent under clothianidin treatment (Table 2). Clothianidin at high dose (150 g ai ha^{-1} spray) gave 100.0 per cent control of mealy bugs. However, imidacloprid, and thiamethoxam were at par followed by acephate and chlorpyriphos. At normal dose, the clothianidin and acephate were at par in controlling mealy bugs (97.5%) followed by thiamethoxam (92.5%). At lower dose, Clothianidin controlled 87.5 per cent mealy bugs while acephate and thiamethoxam were at par (82.5%) followed by imidacloprid (77.5%). The mean of the treatments indicate that the efficacy of the treatments is in the order of Clothianidin e" Acephate e" Thiamethoxam e" Imidacloprid e" Chlorpyriphos e" Acetamiprid. Bhatt *et al*. (2009) reported that methomyl effectively controlled the mealy bug in Bidi tobacco. Several chemicals have been reported to effectively control the mealy bug population on cotton. There are chlorpyrifos and carbofuran (Larrain, 2002); methomyl, profenofos and chlorpyrifos (Shafqat *et al*. 2007); imidacloprid, spirotetramat (Anonymous, 2008); methyl parathion (Kamariya, 2009); profenophos, acephate, thiodicarb, chlorpyrifos, quinolphos and carbaryl (Singh and Dhawan, 2009), sulfoxaflor (Lysandrou *et al*, 2012). According to Jun Huang, 2012 imidacloprid provids good control of mealy bug on tomato.

It was concluded that clothianidin @ 75 g ai ha^{-1} spray or alternatively thiamethoxam @ 25 g ai ha^{-1} or Acephate 187.5 g ai ha^{-1} spray can be recommended for the management of mealy bug infestation in FCV tobacco in case of emergency.

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REFERENCES

Anonymous 2004. Annual Report, Central Tobacco Research Institute, Rajahmundry. p.84.

Anonymous 2008. Annual Report, All India Coordinated Cotton Improvement Project, ICAR. p.157.

Anonymous 2015. FCV Tobacco Leaf Exhibition, Tobacco Board, Guntur. 23p.

Anonymous 2018. Sustainable Tobacco farming in India. *TII Tobacco News*, **9**: 3-6.

Bhatt, N.A., Jayani, D.B. and Patel, A.D. 2009. Mealy bug, *Phenacoccous solenopsis* Tinsley an emerging pest of bidi tobacco in Gujarat. **In:** *Proceedings of the National Symposium on IPM. Strategies to Combat Emerging Pests in the Current Scenario of Climate Change*, held at CAU, Pasighat (Arunachal Pradesh), January **28**, p.38.

Chenchaiah, K.C., Jagadish Chandra, I., Panda, A.R. and Sreenivasulu, R. 2008 a. Mealy Bug: An emerging pest on FCV Tobacco, *Agrobios Newsletter*, **7**: 30-31.

Chenchaiah, K.C., Jagadish Chandra, I., Panda, A.R. and Sreenivasulu, R. 2008 b. Vergenia Pogaku Sedyamlo ponchivunna muppu-Pindipurugu. *Agrigold Swarna Sedyam*, **11**: 20-21.

Gomez, K.A. and Gomez, A. A. 1984. *Statistical Procedures for Agriculture Research*. John Willey & Sons, New York. 680p.

Jun Huang, Juan Zhang, Yong-Ming Yu, Yao-Bin Lu, and Jun-Bo Luan, 2012. Biological Characteristics and Chemical Control of the Invasive Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on Tomato in the Laboratory. *Journal of the Kansas Entomological Society*, **85**:179-185.

Kamariya. N.M. 2009. *Biology and control of mealy bug, Phenacoccous solenopsis Tinsley infesting cotton*. M.S.c. Thesis submitted to JAU, Junagadh. 157p.

Larrain, S.P. 2002. Insect and mite pest incidence on sweet pepinos (*Solanum muricatum* Ait.) cultivated in the IV Region, Chile. *Agriculture Tecnica*, **62**: 15-26.

Lysandrou, M., Ahmad, M. and Longhurst, C. 2012. Management of mealybug, Phenacoccus solenopsis Tinsley in cotton with a new sap feeding insecticide "sulfoxaflor". *Journal of Agricultural Research*, **50**: 493-507.

Panda, N. 2004. Host plant resistance and insect pest management. In: *Proceedings of the National Symposium on Frontier Areas of Entomological Research* (Eds. B. Subramanyam, V.V. Ramamurthy, and V.S. Singh) IARI, New Delhi, from Nov. 5-7, 2003. p.377-394.

Shafqat, S., Munir Ahmad, Mustaq Ahmad and Yong Jung, K. 2007. Insecticidal control of the mealy bug, *Phenacoccous solenopsis* Tinsley (Hemiptera: Pseudococcidae), a new pest of cotton in Pakistan. *Entomological Research*, **37**: 76-80.

Singh, R and Dhawan, K. 2009. Evaluation of different insecticides against *Phenacoccous solenopsis*, Tinsley on transgenic cotton. *Journal of Insect Science*, **22**: 95-97.

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Preference of potato tuber moth *Phthorimaea operculella* (Lepidoptera: Gelechiidae) and their level of infestation among three potato varieties

Tufail Ahmad[1*], Simret Zemuy[2], Hanna Afeworki[2], Segen Weldu[2] and Mogos Tesfamariam[2]

Department of Plant Protection, Hamelmalo Agricultural College, State of Eritrea
*[*1]Associate Professor and author for corresponding, [2]Senior Research Project Students*
E-mail: tufailrm@gmail.com

ABSTRACT

The experiment, conducted in the state of Eritrea to study the preference and the level of infestation of potato tuber moth (*Athorimaea operculela*) on three potato varieties i.e. Condor, Ajiba and Picasso, grown in the highland of Eritrea, particularly in Zoba Maekel and Debub, revealed maximum number of adults emerging from Condor variety against the minimum from Ajiba showing high preference. The infested potato varieties kept separately in different plastic container and observed for the adult emergence there from showed that the condor variety followed by Picasso and ajiba registered maximan amergence *i.e.* 8.33, 11.00 and 2.00, respectively. The present research was concluded with finding of the presence of potato tuber moth in three selected potato varieties which was not reported so far from state of Eritrea.

Key words: Potato tuber moth, *Phthorimaea operculella* Condor, Picasso, Ajiba

Potato (*Solanum tuberosum* L.) is the fourth important food crop in the world following rice, corn and wheat (Horton, 1987). According to the quantity of production and consumption worldwide, potato is the most important vegetable crop. In 2007 the total volume of world potato production was more than 325.3 million tons that was harvested from a total area of 19.33 million hectare. In the same year in Africa, potato production was 16.71 million tons from 1.54 million hectares (Horton, 1987). It is a healthy and nutritious crop providing no fat, no cholesterol and no sodium while providing more potassium and less calories than many other crops (Haytowitz *et al*., 2011). It is used for the preparation of a large grained starch, by the food, paper and textile industries and as flour, it can be used in baking industry. Potato can be eaten boiled, baked, roasted, or fried and also used to make granules. Eritrea has a long history of growing potato crop. It is one of the most economically important and widely grown vegetable crops in Eritrea concentrated in the high lands, mainly Debub (77%) and Maekel (16%) and the rest (7%) in Anseba and Northern Red sea zones. The bulk of production occurs in the central highlands (Zoba Maekel and Zoba Debub) with a limited amount coming from Zoba Anseba and Zoba Semenawi Keyh Bahri (Bereketsahay, 2000). The crop contributes to food security directly as a food source and also as a cash crop (Biniam, 2017). The total area under potato production had reached 6400 ha and the production was estimated to be more than 3200 tons in the year 2010. Data from the Ministry of Agriculture [MOA] of the year 2011 estimated that the total land under potato cultivation was 2,357 ha with an average yield of 11 ton ha^{-1}.

Potato is attacked by various insect pests and diseases causing direct and indirect damages to its quality and quantity. The potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) is a serious and the major pest of potatoes in the field and the store under traditional storage systems in Africa (Roux *et al*. 1992). Some farmers cultivate their own seed, which they store for a few months until planting commences (Kroschel and Koch 1994). Careless planting, late and slow harvesting and poor markets with the consequent holding back of the crop, would bring about such conditions. It can be introduced easily from one locality to another since tubers provide enough food for its multiplication and sustenance. Tuber moth causes serious damage to potato leaves and larvae make tunnel by feeding inside tubers, which later leads to infestation by secondary pathogens. The infested tubers become unsuitable for human consumption and also for the seed. Keeping in view the importance of the crop, the preference and the level of infestation of potato tuber moth in three most commonly available varieties, namely Ajiba, Condor and Picasso was assessed.

MATERIALS AND METHODS

The study was conducted at Hamelmalo Agricultural College located along the bank of Anseba River, 12 Km northeast of Keren. The geographical location of Hamelmalo agricultural college is 15º54.16"N north and 38º27.38"E south with an altitude of 1286 m.a.s.l. It has semiarid climate with annual mean rainfall of 438 mm. Temperature varies with maximum monthly mean of 35.1ºC.

Infested potatoes collected from the market were kept in the container until adults emerged. Newly emerged tuber moths were collected from the container and transferred to fresh potato tubers for further development. The process was carried out for about five months. The female and male tuber moths could be differentiated on the basis of color pattern on the forewings and the shape of the abdomen. The male ends inside the tuft of scales, while in females, the tip of the abdomen is without any side tufts. Freshly emerged females have a dark black patch in the middle of forewing. But sometimes after emergence these black spots fades away due to shedding of scales.

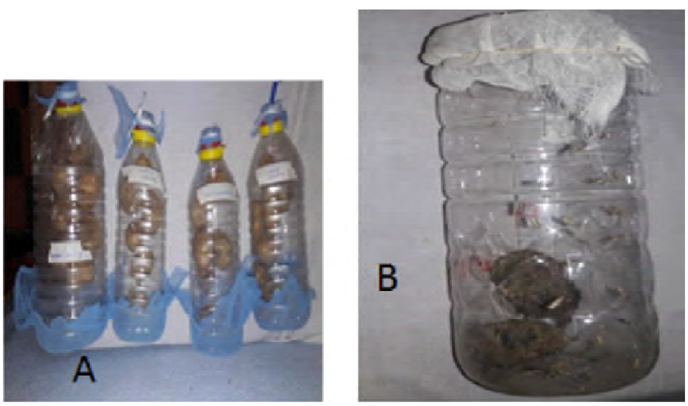

Fig. 1. (A) Infested tubers for rearing PTM (B) Adult PTM from infested tubers

The potato samples of each cultivar were procured from research center NARI starting from January to March. For female PTM preference and population dynamics studies,

Figure 2 Potato varieties

the experimental potato varieties were collected from market randomly during January to April.

The resistance of tested potato cultivars for egg laying was conducted by choice test inside plastic cages having four openings, three being small sized (4.5 lit sabah oil) each connected to small plastic (1.5 lit) container. Potato varieties (Condor, Picasso, and Ajiba) were inserted inside each small container. The larger outlet was used as passage for the inlet of adults to the central section of the plastic cage. Five pairs of males and females with were introduced into the cage over three days. The adults were expected to take their preferred paths to the small plastic containers and lay eggs. After 6-7 days the potato varieties were isolated in new containers and waited for emergence of adult with this procedure was replicated three times in each month.


Fig. 3: Plastic cages used for the experiment for host preference

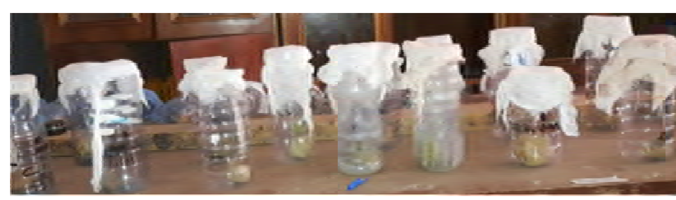
Fig. 4: Plastic containers used for study

The data on the number of potato tuber moth adults emerging out of plastic containers with three different varieties were statistically analyzed using GENESTAT software at 5 per cent level of significance and SPSS.

RESULTS AND DISCUSSION

The data indicated that there was a high significant difference ($P<0.001$) among the three potato cultivars, whereas, there was significant difference ($P<0.05$) between Picasso and Condor. The tested potato varieties could be classified into three categories according to their resistance for PTM (Table 1). The cultivar Condor that encouraged female to deposit the largest number of eggs was found highly susceptible. The average number of adults emerged were 12, 13 and 15 potato^{-1} in January, February and March, respectively.

The variety, Picasso, having significantly less infestation, was moderately susceptible than the Condor

(P<0.05) recording average number of 7.67, 8.33 and 11 adults potato^{-1} in January, February and March, respectively. The Ajiba where the average number of adults emerged was 1.00, 1.33 and 2.00 in January, February and March, respectively was slightly susceptible with highly significant difference at (P<0.01). From the above results, it was concluded that Condor was the most preferred cultivar for oviposition by PTM; while Ajiba was the least suitable of all tested varieties. These observations may be related to biochemical protection factor as was noticed by Mumford (1931). In this respect, Fenemore (1980) confirmed the importance of the surface texture of potato cultivar in determining the ovipositional preference. He further reported that full fecundity of PTM was achieved only in the presence of suitable substrate that leads the future population of potato tuber moth. Meisner *et al.* (1974) reported that oviposition is stimulated by ethanolic extracts of potato peel and suggested that I-glutamic acid might be an important component in this respect.

Table 1: Mean no. of adults emergence from different potato the varieties

	Mean no. of adults emerge at three months		
Variety	January	February	March
Condor	12.00 ^{a}	13.00^{a}	15.00^{a}
Picasso	7.67^{b}	8.33^{b}	11.00^{b}
Ajiba	1.00^{c}	1.33^{c}	2.00^{c}
LSD @5%	2.903	1.489	2.307
CV %	21.1	9.9	12.4

Means in vertical columns with the same letters are not significantly different (P>0.05).

The data on level of infestation during four-months observation revealed that the PTM population increased from January to April in all three varieties (Fig. 5).

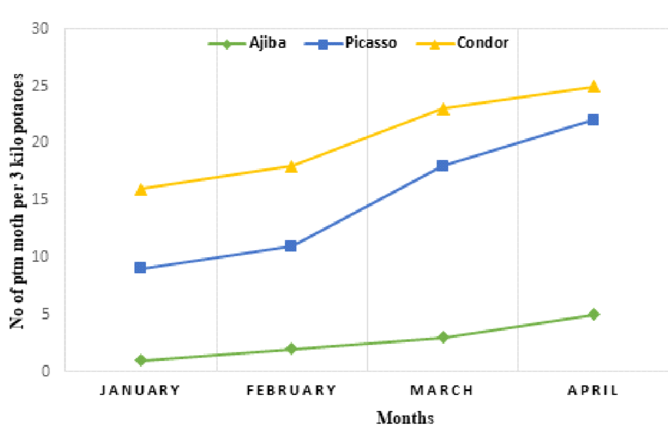

Fig. 5: Population dynamics of PTM on three varieties

Condor was highly susceptible at 1 per cent level of significance than Ajiba. While significant differences at 5 per cent level of significance between Condor and Picasso during January and February was observed. The differences between Condor and Picasso in March and April were not significant.

Table 2: Population dynamics of PTM in three varieties

Variety	Mean no .of adults emerged			
	JAN	FEB	MAR	APR
Condor	5.33^{a}	6^{a}	7.67^{a}	8.33^{a}
Picasso	3^{b}	3.67^{b}	6^{a}	7.33^{a}
Ajiba	0.33^{c}	0.67^{c}	1^{b}	1.67^{b}
LSD 5%	1.489	1.489	2.106	1.153
CV %	25.80%	21.60%	21.60%	10%

Means in vertical columns with the same letters are not significantly different (P>0.05).

Minimum temperature was significantly and positively correlated with Ajiba, Picasso and Condor (r=0.972, 0.957, 0.967), respectively, whereas maximum temperature was highly correlated with Ajiba, Picasso and Condor (r=0.84,0.835,0.863), respectively. Humidity was negatively correlated with Ajiba, Picasso and Condor (r=-0.23, -0.259, -0.312), respectively.

Table 3: Correlation of PTM population with metrological data

Varieties/ Metrological Parameter	**Max Temperature**	**Min Temperature**	**Humidity**
Ajiba	0.84	0.972*	-0.23
Picasso	0.835	0.957*	-0.259
Condor	0.863	0.967*	-0.312

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed).

CONCLUSION

The study concluded that PTM infests all the three varieties in Eritrea. Among these, the Condor was most susceptible, Picasso moderately susceptible and Ajiba was least susceptible.

REFERENCES

Biniam, M.G. (2017). Characterization of potato *Solanum tuberrosum L.* Cultivars grown in Eritrea using morphological, molecular and nutritional descriptor. A PhD thesis published Lambert Publication Germany.

Horton, D. (1987). Potatoes Production, marketing and program for developing countries. International technology publication, London, England, Pp 27.

Bereketsahay, T. (2000). Potato production in Eritrea: Prospects for future development. In *Proceedings of the Fifth Triennial*

Congress of African Potato Association. Kampala, Uganda: African Potato Association. Congress. Pp. 544.

Fenemore, P.G. (1980). Oviposition of potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae); identification of hostplant factors influencing oviposition response. *New Zealand Journal of Zoology*. **7**: 435-439.

Haytowitz, D.B., Lemar, L.E., Pehrsson, P.R., Exler, J., Patterson, K.K., Thomas, R.G. and Holden, J.M. (2011). USDA national nutrient database for standard reference, Release 24 September 28pp.

Kroschel, J. and Koch, W. (1994). Studies on the population dynamics of the potato tuber moth in the Republic of Yemen. *Journal of Applied Entomology*, **118**: 327-341.

Meisner, J., Ascher, K.R.S. and Lavie, D. (1974). Factors influencing the attraction of the potato tuber moth, *Gnorimoschema aperculella*. *Z. Angew. Ent. N*, 179-189.

MoA, (2012). Potato production. Head office Asmara, Eritrea.

Mumford, E.P. (1931). Strategies in certain factors affecting the resistance of plants to insect pests. *Science*. **13**: 49-50.

Roux, O., Von Arx, R. and Baumgartner, 1. (1992). Estimating potato tuberworm (Lepidoptera: Gelechiidae) damage in stored potatoes in Tunisia. *Journal of Economic Entomology*, **85**: 2246-2250.

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Evaluation of botanicals and bio-pesticides against major insect pests of potato during *kharif* season

Prashant K. Natikar and R. A. Balikai

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

ABSTRACT

Field experiment undertaken at AICRP on Potato, MARs, Dharwad during *Kharif* 2016 and 2017 to find out the effective botanical and bio-pesticide for managing insect pests of potato showed highest per cent protection over control against major insect pests of potato *viz.*, potato shoot borer, aphids, leafhoppers, whitefly, thrips, mites and *Spodoptera litura* (52.77, 74.88, 68.04, 70.36, 73.94, 57.71 and 66.70 per cent, respectively) with the standard check, chlorpyriphos 20 EC @ 2.50 ml^{-1} across two *kharif* seasons. This was followed by NSKE @ 5 per cent (42.36 and 66.19 per cent), azadirachtin 3000 ppm @ 3.00 ml^{-1} (42.43 and 62.16 per cent) and neem oil @ 2 per cent (35.52 and 48.39 per cent) with respect to shoot borer and aphids. However in case of leafhopper, neem oil @ 2 per cent proved to be the next best treatment (62.92%), the second highest protection of 65.95 and 71.25 per cent, respectively was observed in *Verticillium lecanii* 2×10^8 cfu^{-1} @ 2 g^{-1} with respect to whitefly and thrips. The treatment, azadirachtin 3000 ppm @ 3.00 ml^{-1} recorded highest per cent protection over control in case of mites (44.49%) and defoliator, *S. litura* (52.04%).

Key words: Potato, insect pests, *kharif*, botanicals, bio-pesticides.

Potato is being increasingly grown in the plateau region of India that covers vast area of central and peninsular India spread over parts of Tamil Nadu, Karnataka, Gujarat, Andhra Pradesh, Maharashtra, Madhya Pradesh, Bihar and even Orissa. Considering the world scenario, it is being grown in more than 100 countries. China holds the credit of first rank followed by Russia and India. More than 62 per cent of the global food production is shared by China, India, USA, Ukraine, Germany and Poland. The potato crop is grown under diverse agro-climatic conditions over an area of 20.85 lakh ha with production of 480.96 lakh metric tonnes and productivity of 23.07 t/ha (Anon., 2016). The major potato growing districts in Karnataka are Hassan, Kolar, Dharwad, Chikmagalur, Belagavi and Benngaluru (Rural). There is a great diversity of insect pests on potato in different agro-climatic zones, feeding on leaves, stems and tubers and ultimately resulting in the yield decline. The potato crop is known to be infested by 101 arthropod pests. The sucking pests *viz.*, aphids, leafhoppers, whiteflies and thrips are considered as a major group because of their role as the vectors of viral diseases. Among them, *Myzus persicae* (Sulzer) and *Aphis gossypii* Glov. are extremely important as the vectors of potato virus. The tobacco caterpillar, *Spodoptera litura* Fabricius is a serious pest on potato in Karnataka and causes severe defoliation. It occurs during monsoon season (June-September) on 40 to 60 days old crop. The shoot borer, *Leucinodes orbonalis* (Guenee) has become the most destructive and ubiquitous pest in the recent years causing heavy yield losses in potato crop. The aim of the present study was therefore to identify the insecticidal molecule that is effective in managing major insect pests of potato.

MATERIALS AND METHODS

A field experiment was conducted in a randomized block design at AICRP on Potato, MARS, Dharwad during *kharif* 2016 and 2017. The experiment consisted of ten treatments including an untreated check (Table 1) and replicated thrice. The test variety Kufri Pukhraj was raised in a plot size of 3 × 4 m with a spacing of 60 × 20 cm. All agronomic practices were followed as per the recommended package of practices of the University of Agricultural Sciences, Dharwad to raise the crop except the plant protection measures. The treatments were imposed by using knapsack sprayer with 500 liters of spray solution per hectare. The crop received two sprays, the first being given at 30 days after sowing and another at 15 days later based on economic threshold level of the pests. The observations made at fifteen days after first spray was considered as pre-treatment count for second spray.

The sucking pests *viz.*, aphids, leaf hoppers, thrips and whiteflies were counted on three compound leaves from upper, middle and lower portion of the crop canopy of the tagged plants (Dharpure, 2002; Konar and Mohasin, 2003). Observations were recorded from ten plants on bottom, middle and top compound leaf at one day before and 5, 10 and 15 days after treatments. Hand lens (10X) was used for sampling the sucking pests. Mites count was taken at one day before and 5, 10 and 15 days after spray on two compound leaves selected from top and middle canopy of three randomly selected plants (Rani, 2001).

The number of infested shoots and total number of shoot per plant at one day before and 5, 10 and 15 days after spray (DAS) was recorded from five randomly selected plants from each treatment for recording shoot borer, *L. orbonalis* infestation. The per cent shoot damage was worked out and converted to angular values and the data were subjected to statistical analysis. The initial larval counts of defoliator, *S. litura* were recorded by selecting ten plants at random. The insect counts were taken at one day before and 5, 10 and 15 days after imposition of treatments (Basavaraju *et al*., 2010). The yield per plot was converted to quintals per ha. All the data were subjected to statistical analysis. Finally, the cost of economics of each treatment was computed.

RESULTS AND DISCUSSION

Aphid, *Myzus persicae*

The pooled data over two seasons revealed that, a day before imposition of first spray the aphid population ranged from 6.98 to 7.88 per compound leaf among various treatments and did not differ significantly indicating uniformity in the pest population. At 15 DAFS significantly least population was recorded in chlorpyriphos 20 EC @ 2.00 ml^{-1} (1.63 aphids/compound leaf) which was followed by azadirachtin 3000 ppm @ 3 ml^{-1} (2.73 aphids/compound leaf) and NSKE @ 5 per cent (2.70 aphids/compound leaf) whereas, significantly higher incidence (8.21 aphids compound leaf^{-1}) was recorded in control. Similar trend was followed at 15 DASS and the incidence ranged between 2.14 aphids compound leaf $^{-1}$ (chlorpyriphos 20 EC @ 2.00 ml^{-1}) to 8.51 aphids compound leaf^{-1} (Untreated check) (Table 1). Dharpure (2002) reported that the application of phorate @ 1 kg a.i. ha^{-1} followed by ethofenprox @ 0.02 per cent, NSKE @ 10 per cent and neem oil @ 0.5 per cent were most efficient in decreasing aphid population in potato which is in close agreement with the present investigations with respect to biopesticides.

Leafhoppers (*Empoasca* sp., *Empoascanara indica* and *Amrasca biguttula biguttula*)

The pooled data indicated that, the leafhopper populations in all the treatments were statistically uniform at one day before imposition of treatments as indicated by the non-significant differences among the treatments (Table 1). Significantly lower incidence of 1.85 leafhoppers per compound leaf was recorded in chlorpyriphos 20 EC @ 2.00 ml^{-1} at 15 DAFS which was statistically on par with neem oil @ 2 per cent (2.04 leafhoppers compound leaf^{-1}). The pest population ranged between 1.65 and 5.15 leafhoppers per compound leaf during 15 DASS and significantly lower pest population was recorded in chlorpyriphos 20 EC @ 2.00 ml^{-1} (1.65 leafhoppers compound leaf^{-1}) whereas, the remaining treatments neem oil @ 2 per cent (1.91 leafhoppers compound leaf^{-1}), azadirachtin 3000 ppm @ 3 ml^{-1} (2.37 leafhoppers compound leaf^{-1}) and NSKE @ 5 per cent (2.44 leafhoppers compound leaf^{-1}) were on par with each other and the untreated control recorded highest leafhopper population (5.15 leafhoppers compound leaf^{-1}). The work done on the management of potato leafhopper using botanicals and biopesticides is very scanty.

Whitefly (*Bemisia tabaci*)

The results on pooled analysis revealed that there was no significant difference with respect to whitefly population among the treatments at one day before spray. However, at 15 DAFS all the treatments tested were found significantly superior over untreated check except *Nomuraea rileyi* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} and *Beauveria bassiana* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1}. The lowest whitefly population of 1.84 whiteflies per compound leaf was recorded by chlorpyriphos 20 EC @ 2.00 ml^{-1}, which was statistically on par with *Verticillium lecanii* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} (2.13 whiteflies compound leaf^{-1}). The next best treatments were neem oil @ 2 per cent (2.73 whiteflies compound leaf^{-1}) and NSKE @ 5 per cent (2.80 whiteflies compound leaf^{-1}) which were on par with azadirachtin 3000 ppm @ 3 ml^{-1} (3.00 whiteflies compound leaf^{-1}) and *Vitex negundo* @ 5 per cent (3.53 whiteflies compound leaf^{-1}). The highest population was recorded with the untreated check (4.81 whiteflies compound leaf^{-1}). A similar trend was noticed during 15 DASS as evidenced from Table 1. NSKE 5 per cent @ 5 g a.i. ha^{-1} proved to be the best treatment in managing the whitefly population throughout the crop period of brinjal as it supported 3.50 mean whitefly population per leaf as reported by Mandal *et al*. (2010), which is in agreement with the present findings.

Thrips (*Scirtothrips dorsalis*, *Thrips palmi* and *Bathrips melanicornis*)

The pooled data revealed that, the pre count observations made on population of thrips was found to be non-significant. At 15 DAFS, lowest population of 1.67 and 1.88 thrips per compound leaf was observed in treatments treated with chlorpyriphos 20 EC @ 2.00 ml^{-1} and *Verticillium lecanii* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1}, which were statistically on par with each other. Significantly higher count of thrips (5.08 thrips compound leaf^{-1}) was noticed in untreated check (Table 1). At 15 DASS, similar trend was noticed wherein chlorpyriphos 20 EC @ 2.00 ml^{-1} (1.42 thrips compound leaf^{-1}) and *Verticillium lecanii* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} (1.57 thrips compound leaf^{-1}) recorded least population of thrips. The

Table 1: Efficacy of botanicals and biopesticides against aphids, leafhoppers, whiteflies and thrips in potato during *kharif* 2016 and 2017 (Pooled)

Treatments	Aphids compound leaf^{-1}			Leaf hoppers compound leaf^{-1}			Whiteflies compound leaf^{-1}			Thrips compound leaf^{-1}		
	1 DBFS	15 DAFS	15 DASS	1 DBFS	15 DAFS	15 DASS	1 DBFS	15 DAFS	15 DASS	1 DBFS	15 DAFS	15 DASS
T_1	6.98 (2.73)^{a}	2.73 (1.80)^{bc}	3.22 (1.93)^{b}	2.70 (1.79)^{a}	2.77 (1.80)^{b}	2.37 (1.69)^{b}	2.56 (1.75)^{a}	3.00 (1.87)^{cd}	3.00 (1.87)^{cd}	2.92 (1.85)^{a}	2.86 (1.83)^{b}	2.58 (1.75)^{cde}
T_2	7.88 (2.89)^{a}	7.19 (2.77)^{dh}	8.19 (2.95)^{fg}	3.15 (1.91)^{a}	4.50 (2.23)^{cd}	4.88 (2.32)^{de}	3.22 (1.92)^{a}	4.39 (2.21)^{ef}	4.06 (2.13)^{d}	2.85 (1.83)^{a}	4.68 (2.27)^{de}	4.85 (2.31)^{g}
T_3	7.69 (2.86)^{a}	6.83 (2.70)^{gh}	7.87 (2.89)^{fg}	2.89 (1.84)^{a}	4.54 (2.24)^{cd}	4.72 (2.28)^{de}	3.07 (1.89)^{a}	4.24 (2.17)^{ef}	4.21 (2.16)^{d}	3.33 (1.96)^{a}	4.43 (2.22)^{cde}	4.50 (2.23)^{fg}
T_4	7.43 (2.81)^{a}	4.39 (2.21)^{de}	5.20 (2.38)^{cd}	2.86 (1.83)^{a}	3.79 (2.07)^{c}	3.63 (2.03)^{c}	2.73 (1.79)^{a}	2.13 (1.62)^{ab}	1.85 (1.53)^{ab}	3.14 (1.91)^{a}	1.88 (1.54)^{a}	1.57 (1.44)^{ab}
T_5	7.57 (2.84)^{a}	3.76 (2.06)^{cd}	4.39 (2.21)^{c}	2.53 (1.74)^{a}	2.04 (1.59)^{a}	1.91 (1.55)^{ab}	2.60 (1.75)^{a}	2.73 (1.80)^{bc}	2.52 (1.74)^{bc}	3.07 (1.89)^{a}	2.73 (1.79)^{b}	2.38 (1.69)^{bcd}
T_6	7.46 (2.82)^{a}	5.86 (2.52)^{fg}	6.92 (2.72)^{ef}	3.15 (1.91)^{a}	4.09 (2.14)^{cd}	4.03 (2.12)^{cd}	3.23 (1.93)^{a}	3.53 (2.01)^{cde}	3.32 (1.95)^{cd}	3.41 (1.97)^{a}	3.82 (2.08)^{cd}	3.33 (1.95)^{de}
T_7	7.29 (2.79)^{a}	2.70 (1.78)^{b}	2.88 (1.83)^{ab}	2.50 (1.73)^{a}	2.81 (1.82)^{b}	2.44 (1.71)^{b}	3.01 (1.87)^{a}	2.80 (1.82)^{bc}	2.60 (1.76)^{bc}	3.10 (1.89)^{a}	2.51 (1.73)^{b}	2.07 (1.60)^{abc}
T_8	7.67 (2.86)^{a}	5.33 (2.41)^{ef}	6.29 (2.60)^{de}	2.69 (1.78)^{a}	3.61 (2.03)^{c}	3.40 (1.97)^{c}	3.12 (1.89)^{a}	3.77 (2.06)^{de}	3.57 (2.00)^{cd}	3.53 (2.01)^{a}	3.69 (2.05)^{c}	3.42 (1.98)^{ef}
T_9	7.51 (2.83)^{a}	1.63 (1.46)^{a}	2.14 (1.62)^{a}	2.67 (1.78)^{a}	1.85 (1.52)^{a}	1.65 (1.45)^{a}	3.11 (1.90)^{a}	1.84 (1.53)^{a}	1.61 (1.45)^{a}	3.36 (1.96)^{a}	1.67 (1.47)^{a}	1.42 (1.38)^{a}
T_{10}	7.61 (2.85)^{a}	8.21 (2.95)^{h}	8.51 (3.00)^{g}	3.33 (1.96)^{a}	4.80 (2.30)^{d}	5.15 (2.37)^{e}	2.93 (1.84)^{a}	4.81 (2.30)^{f}	5.44 (2.43)^{e}	3.19 (1.87)^{a}	5.08 (2.36)^{e}	5.44 (2.43)^{g}
S.Em.±	0.06	0.09	0.08	0.07	0.07	0.07	0.10	0.07	0.09	0.11	0.06	0.09
C.D. (0.05)	NS	0.27	0.24	NS	0.20	0.22	NS	0.21	0.28	NS	0.19	0.27

T_1: Azadirachtin 3000 ppm @ 3 ml/l T_2: *Nomuraea rileyi* 2 × 10^8 cfu/g @ 2 g/l T_3: *Beauveria bassiana* 2 × 10^8 cfu/g @ 2 g/l
T_4: *Verticillium lecanii* 2 × 10^8 cfu/g @ 2 g/l; T_5: Neem oil @ 2 % T_6: *Vitex negundo* @ 5 %;
T_7: NSKE @ 5 %; T_8: Pongamia oil @ 2 %; T_9: Chlorpyriphos 20 EC @ 2 ml/l (Standard check) T_{10}: Untreated check
DBFS: Day before first spray, DAFS: Days after first spray, DASS: Days after second spray,
Figures in parentheses are “x+0.5 transformed values
Means followed by the same letter in a column are not significantly different (P=0.05) by DMRT

untreated check recorded significantly higher thrips population 5.44 thrips per compound leaf, which was being on par with *Nomuraea rileyi* 2 × 10^8 cfu g^{-1} @ 2 g^{-1} (4.85 thrips compound leaf^{-1}) and *Beauveria bassiana* 2 × 10^8 cfu g^{-1} @ 2 g^{-1} (4.50 thrips compound leaf^{-1}) (Table 1). The literature is scanty to support the present findings in respect of thrips management using botanicals and biopesticides on potato. However, Bhatnagar (2009) reported that the treatment which comprised first spray of imidacloprid 0.02 per cent followed by second spray of neem product proved superior by recording (0.0 to 2.45 thrips plant^{-1}) and (1.0 to 2.10 thrips plant^{-1}) in potato which is in close agreement with the present study.

Shoot borer (*Leucinodes orbonalis)*

The pooled data revealed that the shoot infestation in all the treatments was uniform a day before imposition of treatments as indicated by the non-significant differences among the various treatments. At 15 days after first spray (DAFS), chlorpyriphos 20 EC @ 2.00 ml^{-1} recorded least incidence of shoot infestation (11.65%) which was on par with azadirachtin 3000 ppm @ 3 ml^{-1} (13.63%) and NSKE @ 5 per cent (13.94%), whereas untreated check recorded the higher incidence of shoot infestation (21.38%). At 15 DASS, the treatments chlorpyriphos 20 EC @ 2.00 ml^{-1}, azadirachtin 3000 ppm @ 3 ml^{-1}, NSKE @ 5 per cent and neem oil @ 2 per cent were found to be significantly superior by recording 11.47, 13.98, 13.99 and 15.65 per cent, respectively which were on par with each other. However, untreated check differed with these treatments by recording 24.28 per cent shoot infestation (Table 2). These findings are in agreement with Hanapur and Nandihalli (2004) wherein they reported that, among botanicals neemgold @ 0.5 per cent and NSKE @ 5 per cent proved to be effective by recording lowest shoot infestation in potato. Murugesan and Murugesh (2009) evaluated the efficacy of botanicals against *L. orbonalis* in brinjal and revealed that, neem oil @ 2.0 per cent was superior in reducing the pest infestation by 60.20 per cent. The next best treatments were nimbecidine @ 2 ml^{-1} (57.42%), neem cake extract @ 5.0 per cent (51.97%) and *Calotropis gigantean*

(L.) leaf extract @ 5.0 per cent (51.34%).

Defoliator (*Spodoptera litura*)

The defoliator population recorded a day before imposition of first spray ranged from 2.48 to 3.49 larvae per plant among various treatments and did not differ significantly indicating uniformity in pest population. At 15 DAFS, the least population of 3.03, 3.49, 3.91, 4.13 and 4.34 larvae per plant was noticed in treatments chlorpyriphos 20 EC @ 2.00 ml^{-1}, NSKE @ 5 per cent, *Nomuraea rileyi* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1}, azadirachtin 3000 ppm @ 3 ml^{-1} and neem oil @ 2 per cent respectively, which were statistically on par with each other. Significantly higher incidence of 7.43 larvae per plant was observed in untreated check and was on par with *Beauveria bassiana* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} (6.68 larvae plant^{-1}) and *Verticillium lecanii* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} (6.89 larvae plant^{-1}). At 15 DASS, least population of defoliator was observed in chlorpyriphos 20 EC @ 2.00 ml^{-1} (2.73 larvae plant^{-1}), NSKE @ 5 per cent (3.24 larvae plant^{-1}) and *Nomuraea rileyi* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} (3.77 larvae plant^{-1}), which were statistically on par with each other. However on the contrary, significantly higher incidence (8.18 larvae plant^{-1}) was noticed in untreated check (Table 2).

Mite (*Polyphagotarsonemus latus*)

The pooled data indicated that, the leafhopper populations in all the treatments were statistically uniform at one day before imposition of treatments as indicated by the non-significant differences among the treatments (Table 2). At 15 DAFS during *kharif* 2016, the treatments chlorpyriphos 20 EC @ 2.00 ml^{-1} and azadirachtin 3000 ppm @ 3 ml^{-1} registered 5.85 and 7.89 mites per compound leaf, respectively and were statistically on par with each other, whereas, the highest population was recorded with untreated check (13.23 mites compound leaf^{-1}). Further at 15 DASS, similar trend was observed wherein chlorpyriphos 20 EC @ 2.00 ml^{-1} (5.87 mites compound leaf^{-1}) recorded lowest pest incidence followed by azadirachtin 3000 ppm @ 3 ml^{-1} (7.71 mites compound leaf^{-1}), NSKE @ 5 per cent (8.45 mites compound leaf^{-1}) and neem oil @ 2 per cent (8.90 mites

Table 2: Efficacy of botanicals and biopesticides against shoot borer, defoliator and mites in potato during *kharif* 2016 and 2017 (Pooled)

Treatments	*Shoot infestation (%)			#Number of larvae plant^{-1}			#Mites compound leaf^{-1}		
	1 DBFS	15 DAFS	15 DASS	1 DBFS	15 DAFS	15 DASS	1 DBFS	15 DAFS	15 DASS
T_1	13.86 (21.85)^{a}	13.63 (21.66)^{ab}	13.98 (21.94)^{ab}	2.99 (1.86)^{a}	4.13 (2.15)^{ab}	3.93 (2.10)^{bc}	8.03 (2.92)^{a}	7.89 (2.89)^{ab}	7.71 (2.86)^{ab}
T_2	13.93 (21.90)^{a}	18.26 (25.29)^{cde}	19.49 (26.15)$^{c-f}$	3.15 (1.91)^{a}	3.91 (2.10)^{ab}	3.77 (2.06)^{ab}	8.13 (2.94)^{a}	12.53 (3.60)^{e}	13.70 (3.77)^{ef}
T_3	14.21 (22.13)^{a}	19.32 (26.08)^{de}	21.40 (27.43)^{def}	3.31 (1.93)^{a}	6.68 (2.67)^{cd}	7.59 (2.84)^{e}	8.63 (3.02)^{a}	12.00 (3.53)^{e}	13.01 (3.67)^{ef}
T_4	15.22 (22.95)^{a}	19.94 (26.49)^{de}	22.31 (28.12)^{ef}	3.15 (1.90)^{a}	6.89 (2.72)^{d}	7.61 (2.85)^{e}	8.23 (2.95)^{a}	11.52 (3.47)^{de}	12.49 (3.59)^{ef}
T_5	14.76 (22.57)^{a}	15.69 (23.31)^{bc}	15.65 (23.29)^{abc}	3.29 (1.95)^{a}	4.34 (2.20)^{ab}	3.94 (2.10)^{bc}	8.35 (2.97)^{a}	8.88 (3.06)^{bcd}	8.90 (3.06)^{bcd}
T_6	14.71 (22.55)^{a}	18.11 (25.17)^{cde}	19.03 (25.86)^{cde}	2.75 (1.80)^{a}	5.17 (2.38)^{bc}	5.13 (2.36)^{cd}	8.19 (2.95)^{a}	10.97 (3.38)^{cde}	11.45 (3.46)^{def}
T_7	13.81 (21.80)^{a}	13.94 (21.91)^{ab}	13.99 (21.96)^{ab}	3.49 (1.99)^{a}	3.49 (2.00)^{a}	3.24 (1.93)^{ab}	8.96 (3.07)^{a}	8.35 (2.97)^{bc}	8.45 (2.99)^{bc}
T_8	15.30 (23.01)^{a}	16.67 (24.06)^{bcd}	17.08 (24.40)^{bcd}	2.48 (1.72)^{a}	5.30 (2.41)^{bc}	5.58 (2.46)^{d}	8.68 (3.03)^{a}	10.41 (3.29)$^{b-e}$	10.70 (3.34)^{cde}
T_9	14.76 (22.55)^{a}	11.65 (19.95)^{a}	11.47 (19.75)^{a}	3.46 (1.99)^{a}	3.03 (1.88)^{a}	2.73 (1.79)^{a}	8.35 (2.97)^{a}	5.85 (2.51)^{a}	5.87 (2.51)^{a}
T_{10}	15.51 (23.19)^{a}	21.38 (27.47)^{e}	24.28 (29.51)^{f}	3.09 (1.89)^{a}	7.43 (2.80)^{d}	8.18 (2.94)^{e}	8.54 (3.00)^{a}	13.23 (3.70)^{e}	13.89 (3.79)^{f}
S.Em.±	0.65	0.79	1.12	0.08	0.10	0.10	0.09	0.14	0.14
C.D. (0.05)	NS	2.36	3.35	NS	0.30	0.28	NS	0.42	0.41

T_1 : Azadirachtin 3000 ppm @ 3 ml^{-1} l T_2 : *Nomuraea rileyi* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} l T_3 : *Beauveria bassiana* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} l
T_4 : *Verticillium lecanii* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} l; T_5 : Neem oil @ 2 per cent T_6 : *Vitex negundo* @ 5 per cent;
T_7 : NSKE @ 5 per cent; T_8 : Pongamia oil @ 2 per cent; T_9 : Chlorpyriphos 20 EC @ 2 ml^{-1} l (Standard check)
T_{10} : Untreated check DBFS: Day before first spray, DAFS: Days after first spray, DASS: Days after second spray,
#Figures in parentheses are “x+0.5 transformed values *Figures in parentheses are arcsine transformed values
Means followed by the same letter in a column are not significantly different (P=0.05) by DMRT

Table 3: Per cent protection over control in botanicals and biopesticides against major insect pests of potato during *kharif* 2016 and 2017 (Pooled)

Tr. No.	Treatments	Dosage	Per cent protection against						
			Shoot borer	Aphids	Leaf hoppers	Whiteflies	Thrips	Mites	*S. litura*
T_1	Azadirachtin 3000 ppm	3 ml l^{-1}	42.43	62.16	53.96	44.92	52.54	44.49	52.04
T_2	*Nomuraea rileyi* 2×10^8 cfu g^{-1}	2 g l^{-1}	19.72	3.80	5.27	25.41	10.84	1.36	53.97
T_3	*Beauveria bassiana* 2×10^8 cfu g^{-1}	2 g l^{-1}	11.87	7.56	8.48	22.69	17.33	6.34	7.23
T_4	*Verticillium lecanii* 2×10^8 cfu g^{-1}	2 g l^{-1}	8.10	38.88	29.57	65.95	71.25	10.05	7.03
T_5	Neem oil	2 per cent	35.52	48.39	62.92	53.70	56.25	35.92	51.83
T_6	*Vitex negundo*	5 per cent	21.62	18.70	21.87	39.10	38.79	17.57	37.37
T_7	NSKE	5 per cent	42.36	66.19	52.70	52.17	61.94	39.17	60.39
T_8	Pongamia oil	2 per cent	29.66	26.12	34.03	34.48	37.23	22.97	31.77
T_9	Chlorpyriphos 20 EC (Standard check)	2 ml l^{-1}	52.77	74.88	68.04	70.36	73.94	57.71	66.70
T_{10}	Untreated check	-	-	-	-	-	-	-	-

compound leaf^{-1}). Since the literature pertaining to efficacy of these botanicals and biopesticides on potato is lacking, the present findings are compared with the reports on other crops. George and Giraddi (2007) studied the efficacy of different organic amendments on the incidence of chilli mite, *P. latus* and revealed that the crop which received vermicompost (2.5 t ha^{-1}) or neem cake (0.5 t ha^{-1}) followed by four sprays of NSKE @ 5 per cent and neemazal 10,000 ppm at 2, 5, 7 and 11 weeks after transplanting alternatively, recorded significantly less population of mites, which is in close agreement with the present findings.

Per cent protection over control in botanicals and biopesticides against major insect pests of potato during *kharif* 2016-17 and 2017-18 (Pooled)

Among the various botanicals and biopesticides, the highest per cent protection over control against major insect pests of potato *viz.*, potato shoot borer, aphids, leafhoppers, whitefly, thrips, mites and *S. litura* (52.77, 74.88, 68.04, 70.36, 73.94, 57.71 and 66.70 per cent, respectively) was registered in the standard check, chlorpyriphos 20 EC @ 2.50 ml^{-1} across two *kharif* seasons. This was followed by NSKE @ 5 per cent (42.36 and 66.19 per cent), azadirachtin 3000 ppm @ 3.00 ml^{-1} (42.43 and 62.16 per cent) and neem oil @ 2 per cent (35.52 and 48.39 per cent) with respect to shoot borer and aphids. However in case of leafhopper, neem oil @ 2 per cent proved to be the next best treatment followed by azadirachtin 3000 ppm @ 3.00 ml^{-1} which recorded 62.92 and 53.96 per cent protection over control, respectively. The second highest protection of 65.95 and 71.25 per cent respectively was observed in *Verticillium lecanii* 2×10^8 cfu g^{-1} @ 2 g^{-1} with respect to whitefly and thrips. The treatments azadirachtin 3000 ppm @ 3.00 ml^{-1} and NSKE @ 5 per cent offered the second highest per cent protection over control in case of mites (44.49 and 39.17%, respectively) and defoliator, *S. litura* (52.04 and 60.39%, respectively). Whereas, the least per cent protection over control with respect to majority of pests (aphids, leafhopper, thrips and mites) was recorded in *Nomuraea rileyi* 2×10^8 cfu g^{-1} @ 2 g^{-1} treated plot (Table 3).

Effect of botanicals and biopesticides on yield and cost economics

The different botanicals and biopesticides evaluated against major insect pests of potato during *kharif* 2016 revealed that, all the treatments differed significantly in terms of yield (Table 4). Among the treatments, significantly highest yield of 220.33 q ha^{-1} was recorded in chlorpyriphos 20 EC @ 2.00 ml^{-1} with highest net returns (₹ 2,68,167.67 ha^{-1}) and B:C ratio of 7.65 followed by NSKE @ 5 per cent (194.14 q ha^{-1}) with net returns (₹ 2,24,294.44 ha^{-1}) and B:C ratio of 5.72, azadirachtin 3000 ppm @ 3 ml^{-1} (175.39 q ha^{-1}) with net returns (₹ 1,99,244.44 ha^{-1}) and B:C ratio of 5.30 and neem oil @ 2 per cent (169.97 q ha^{-1}) with net returns (₹ 1,93,404.11 ha^{-1}) and B:C ratio of 5.34. The untreated control recorded least yield (79.31 q ha^{-1}) which was significantly inferior to all other treatments except *Beauveria bassiana* 2×10^8 cfu g^{-1} @ 2 g^{-1} (86.61 q ha^{-1}) and *Nomuraea rileyi* 2×10^8 cfu g^{-1} @ 2 g^{-1} (95.08 q ha^{-1}). Similarly during *kharif* 2017, maximum yield of 208.67 q ha^{-1} was recorded in chlorpyriphos 20 EC @ 2.00 ml^{-1} with net profit of ₹ 2,51,834.33 ha^{-1} and B:C ratio of 7.25 followed by NSKE @ 5 per cent which recorded yield of 202.25 q ha^{-1} with net returns of ₹ 2,35,650.00 ha^{-1} and B:C ratio of 5.96, azadirachtin 3000 ppm @ 3 ml^{-1} (182.83 q ha^{-1}) with net returns (₹ 2,09,666.67 ha^{-1}) and B:C ratio of 5.53 and lowest yield was recorded in untreated check (90.36 q ha^{-1}) with B:C ratio of 3.16. The pooled data on tuber yield over two seasons.

CONCLUSION

It was conducted that the chlorpyriphos 20 EC @ 2.00 ml^{-1}, besides providing maximum reduction in different pests infestation levels, registered significantly higher yield and cost benefit ratio of 214.50 q ha^{-1} and 7.45, respectively, followed by NSKE @ 5 per cent (198.19 q ha^{-1} and 5.84) and azadirachtin 3000 ppm @ 3 ml^{-1} (179.11 q ha^{-1} and 5.42).

Table 4: Economics of botanicals and biopesticides against major insect pests of potato during *kharif* 2016 and 2017

Tr. No.	Tuber yield (q ha^{-1})			Gross returns (₹ ha^{-1})			Cost of cultivation (₹ ha^{-1})			Net returns (₹ ha^{-1})			Net gain over control (₹ ha^{-1})			BCR		
	Kharif 2016	*Kharif* 2017	Mean	*Kharif* 2016	*Kharif* 2017	Mean	*Kharif* 2016	*Kharif* 2017	Mean	*Kharif* 2016	*Kharif* 2017	Mean	*Kharif* 2016	*Kharif* 2017	Mean	*Kharif* 2016	*Kharif* 2017	Mean
T_1	175.39^{bc}	182.83^{ab}	179.11^{b}	245544.44	255966.67	250755.6	46300.0	46300.0	46300.0	199244.44	209666.67	204455.6	128216.67	123161.11	125688.9	5.30	5.53	5.42
T_2	95.08^{def}	94.83^{d}	94.95^{de}	133116.67	132766.67	132941.7	40250.0	40250.0	40250.0	92866.67	92516.67	92691.67	21838.89	6011.11	13925	3.31	3.30	3.31
T_3	86.61^{ef}	99.92^{d}	93.26^{de}	121255.56	139883.33	130569.4	40250.0	40250.0	40250.0	81005.56	99633.33	90319.45	9977.78	13127.78	11552.78	3.01	3.48	3.25
T_4	135.75^{cd}	135.94^{bcd}	135.84^{c}	190050.00	190322.22	190186.1	40250.0	40250.0	40250.0	149800.00	150072.22	149936.1	78772.22	63566.67	71169.45	4.72	4.73	4.73
T_5	169.97^{bc}	169.78^{abc}	169.87^{b}	237961.11	237688.89	237825	44560.0	44560.0	44560.0	193401.11	193128.89	193265	122373.33	106623.33	114498.3	5.34	5.33	5.34
T_6	124.92^{de}	118.47^{cd}	121.54^{cd}	174883.33	165861.11	170372.2	40250.0	40250.0	40250.0	134633.33	125611.11	130122.2	63605.56	39105.56	51355.56	4.34	4.12	4.23
T_7	194.14^{ab}	202.25^{a}	198.19^{ab}	271794.44	283150.00	277472.2	47500.0	47500.0	47500.0	224294.44	235650.00	229972.2	153266.67	149144.44	151205.6	5.72	5.96	5.84
T_8	126.53^{de}	142.00^{bcd}	134.26^{c}	177138.89	198800.00	187969.4	44400.0	44400.0	44400.0	132738.89	154400.00	143569.4	61711.11	67894.44	64802.78	3.99	4.48	4.24
T_9	220.33^{a}	208.67^{a}	214.50^{a}	308466.67	292133.33	300300	40299.0	40299.0	40299.0	268167.67	251834.33	260001.0	197139.89	165328.78	181234.3	7.65	7.25	7.45
T_{10}	79.31^{f}	90.36^{d}	84.83^{e}	111027.78	126505.56	118766.7	40000.0	40000.0	40000.0	71027.78	86505.56	78766.67	-	-	-	2.78	3.16	2.97
S.Em.±	1.63	2.02	1.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C.D. (0.05)	4.86	6.00	3.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

T_1 : Azadirachtin 3000 ppm @ 3 ml^{-1} l T_2 : *Nomuraea rileyi* 2 × 10^{8} cfu^{-1} g @ 2 g^{-1} l T_3 : *Beauveria bassiana* 2x10^{8} cfu^{-1} g @ 2 g^{-1} l
T_4 : *Verticillium lecanii* 2 × 10^{8} cfu^{-1} g @ 2 g^{-1} l; T_5 : Neem oil @ 2 per cent T_6 : *Vitex negundo* @ 5 per cet; T_7 : NSKE @ 5 per cent;
T_8 : Pongamia oil @ 2 per cent; T_9 : Chlorpyriphos 20 EC @ 2 ml^{-1} l (Standard check) T_{10} : Untreated check
Means followed by the same letter in a column are not significantly different (P=0.05) by DMRT
*Cost of cultivation- ₹ 40000 ha^{-1} Price of potato ₹ 1400 q^{-1}

Whereas, *Beauveria bassiana* 2 × 10^{8} cfu g^{-1} @ 2 g^{-1} recorded lower yield of 93.26 q ha^{-1} and 3.25 benefit cost ratio. The effectiveness of NSKE @ 5 per cent or neem based products on yield and BC ratio was proved by Sangappa (1999), Hanapur and Nandihalli (2004) and Gautam *et al*. (2008).

REFERENCES

Anonymous, 2016, *Annual Report (2015-16)*. National Horticultural Research and Development Foundation, Nasik. p. 80.

Basavaraju, B. S., Shashank, P. R., Doddabasappa, B., Vijayakumar, L. and Chakravarthy, A. K., 2010, Efficacy of poison baits and bio-pesticides against *Spodoptera litura* (Lepidoptera: Noctuidae) in potato. *Pest Management in Horticultural Ecosystems*, **16**: 64-68.

Bhatnagar, A., 2009, Efficacy and economics of insecticides and bio-pesticides against thrips on Potato. *Annals of Plant Protection Sciences*, **17**: 501-503.

Dharpure, S. R., 2002, Effectiveness of botanicals and ethofenprox with phorate against *Myzus persicae* in seed potato production. *Journal of Indian Potato Association*, **29**: 55-59.

Gautam, G. P. N., Verma, R. A., Gautam, R. D. and Khan, A. M. D., 2008, Comparative efficacy of insecticides, bio-pesticides and botanicals against *Leucinodes orbonalis* Guenee infesting brinjal. *Annals of Plant Protection Sciences*, **16**: 309-311.

George, S. and Giraddi, R. S., 2007, Management of chilli (*Capsicum annuum* L.) thrips and mites using organics. *Karnataka Journal of Agricultural Sciences*, **20**: 537-540.

Hanapur, R. H. and Nandihalli, B. S., 2004, Bioefficacy of certain insecticides and botanical against the potato shoot borer, *Leucinodes orbonalis* Guenee. *Karnataka Journal of Agricultural Sciences*, **17**: 602-603.

Konar, A. and Mohasin, M. D., 2003, Incidence of cutworm on potato in different locations West Bengal. *Journal of Indian Potato Association*, **30**: 329-330.

Mandal, S., Singh, N. J. and Konar, A., 2010, Efficacy of synthetic and botanical insecticide against whitefly (*Bemisia tabaci*) and shoot and fruit borer (*Leucinodes orbonalis*) on brinjal. *Journal of Crop and Weed*, **6**: 49-51.

Murugesan, N. and Murugesh, T., 2009, Bioefficacy of some plant products against brinjal fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). *Journal of Biopesticides*, **2**: 60-63.

Rani, H. R., 2001, Bio-ecology and control of yellow mite, *Polyphagotarsonemus latus* (Banks) infesting potato (*Solanum tuberosum* L.) and chilli (*Capsicum annum* L.). *M. Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bengaluru, Karnataka (India).

Sangappa, N., 1999, Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. *M. Sc. (Agri.) Thesis,* University of Agricultural Sciences, Dharwad, Karnataka (India).

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Yield loss estimation in safflower due to aphid, *Uroleucon compositae* (Theobald)

M. B. Gurunath and R. A. Balikai

Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: rabalikai@gmail.com

ABSTRACT

The field experiment, conducted with five safflower varieties during rabi 2015-16 under protected and unprotected conditions, revealed that the variety A-1, showing greater degree of tolerance/ resistance to aphids, recording the least number of aphids per plant (83.20 aphids 5 cm apical twig^{-1}) followed by A-300 (86.35 aphids 5 cm apical twig^{-1}) and A-2 (92.20 aphids 5 cm apical twig^{-1}), recorded the highest yield of 10.8 q ha^{-1}, 10.41 q ha^{-1}, 9.33 q ha^{-1}, respectively). Whereas, PBNS-12 and non-spiny Nari-6, the most susceptible ones, recording maximum number of aphids (103.45 and 119.50 aphids 5 cm apical twig^{-1}, respectively). yielded the lowest of 8.81 q ha^{-1} and 8.52 q ha^{-1}, respectively under protected condition. The yield under unprotected condition was highest in A-1 (7.73 q ha^{-1}) followed by A-300 (7.14 q ha^{-1}) and A-2 (6.96 q ha^{-1}), lowest in PBNS-12 (6.56 q ha^{-1}) and Nari-6 (6.224 q ha^{-1}). Per cent losses in unprotected over protected condition were highest in variety A-300 (45.80%) followed by A-1 (39.72%), Nari-6 (36.54%), PBNS-12 (34.30%) and A-2 (34.05%). The loss in yield due to safflower aphid alone ranged from 34.05 to 45.80 per cent across varieties.

Key words: Aphid, Loss estimation, Safflower, Seed yield

Safflower (*Carthamus tinctorius* L.) is an ancient crop of the family Compositae or Asteraceae, originated in the near east and has been grown for centuries in China, India and North Africa. It is a multi-purpose species with many traditional uses. In India, safflower cultivation is being done for centuries for its orange red and yellow dye (Carthamine) extracted from the florets were once used to colour food and clothing and for its oil, rich in poly unsaturated fatty acids which are considered to reduce blood cholesterol and good for heart patients. Among are several causes for its low productivity in Karnataka, biotic factors play key role.

The safflower aphid, *Uroleucon compositae* (Theobald) is one of the most destructive pests (Akashe *et al*, 1999). It alone causes 35-72 per cent yield loss during heavy infestation period (Anon., 2007). Balikai (1999) recorded 46.2 per cent yield loss of safflower in Karnataka. Seed and oil content losses due to this pest, reported from different parts of the country, ranges from 20 to 80 per cent, (Singh *et al*, 2000). The aphids not only reduce yields of seed and oil content but also attack the petals lowering the quality of the value added product of this plant part (Sastry, 1997). Therefore, the study on determination of yield losses in safflower due to aphid infestation was attempted.

MATERIALS AND METHODS

Assessment of loss of safflower crop in the form of yield reduction due to the infestation of the aphid was made by raising the crop during *rabi* 2015-16. Five varieties of safflower were sown during the second week of October under protected and unprotected conditions. Two replications of five treatments under protected condition and two replications of five treatments under unprotected condition following factorial design. In the protected plot only one spray of dimethoate 30 EC @ 1.70 ml l^{-1} was taken up when the aphid population crossed ETL (after 50 DAS). Under unprotected condition, no spraying was taken up. The varieties used for sowing under protected and unprotected conditions were A-1, A-2, A-300, Nari-6 and PBNS-12.

The observations on number of aphids (2 tender twigs of 5 cm plant^{-1}) were recorded three times at 10 days interval starting from initial infestation (55 DAS) on five randomly selected plants from each net plot. Finally, 100 seed weight and seed yield per plot was recorded and subjected to statistical analysis. The per cent losses over unprotected condition were calculated using following formula.

$$A = \frac{T - C}{C} \times 100$$

Where,

A = Per cent loss in yield over unprotected condition

T = Yield in treated plot

C = Yield in Untreated plot

RESULTS AND DISCUSSION

Results pertaining to the assessment of loss in the form of yield reduction due to the infestation of aphid under protected and unprotected condition using five different varieties are presented in Table 1.

Fifty five days after sowing

The data pertaining to aphid population at 55, 65 and 75 days after sowing recorded on 5 cm apical twig as influenced by different varieties under protected and unprotected condition are furnished in Table 1. Significant differences were observed between the protection levels, varieties and their interaction.

The results revealed that there was a significant difference between protected and unprotected plot with respect to aphids population on 5 cm apical twig (30.74 and72.86 aphids on 5 cm apical twig, respectively). Under protected condition the variety A-1 recorded least number of aphids (25.4 aphids on 5 cm apical twig) which was followed by A-2 (27.6 aphids on 5 cm apical twig), PBNS-12 (28.7 aphids on 5 cm apical twig) and A-300 (29 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (43.0 aphids on 5 cm apical twig) which is susceptible to aphids showed highest number of aphids on 5 cm apical twig. Under unprotected condition the variety A-1 recorded least number of aphids (66.4 aphids on 5 cm apical twig) which was followed by A-300 (69.2 aphids on 5 cm apical twig), A-2 (71.1 aphids on 5 cm apical twig) and PBNS-12 (76.2 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (81.4 aphids on 5 cm apical twig) which is susceptible to aphids showed highest number of aphids on 5 cm apical twig. However, number of aphids on 5 cm apical twig in all the five varieties differed significantly from each other. The interaction effect with respect to aphid population on 5 cm apical twig also varied significantly.

Sixty five days after sowing

Significant differences were observed between protection levels, varieties and their interaction. The mean number of aphid population on 5 cm apical twig under protected and unprotected plot was 37.48 and 77.60 aphid on 5 cm apical twig, respectively which differed significantly from each other. Under protected condition variety A-1 recorded least number of aphid populations (32.00 aphids on 5 cm apical twig) and it was followed by A-2 (33.3 aphids on 5 cm apical twig), A-300 (34.3 aphids on 5 cm apical twig) and PBNS-12 (36.01 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (51.07 aphids on 5 cm apical twig) which is susceptible to aphids showed highest number of aphids on 5 cm apical twig. Under unprotected condition the variety A-1 recorded least number of aphids (73.1 aphids on 5 cm apical twig) which was followed by A-300 (73.7 aphids on 5 cm apical twig), A-2 (75.4 aphids on 5 cm apical twig) and PBNS-12 (82.00 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (83.8 aphids on 5 cm apical twig) which is susceptible to aphids showed highest number of aphids on 5 cm apical

Table 1: Crop loss estimation of safflower due to aphid under protected and unprotected condition

Treatments	No. of aphids on 5 cm apical twig per plant								
	55 DAS		Mean	65 DAS		Mean	75 DAS		Mean
	Protected	Unprotected		Protected	Unprotected		Protected	Unprotected	
NARI-6	43.0 (6.59)^{c}	81.4 (9.05)^{f}	62.2 (7.82)^{c}	51.7 (7.22)^{c}	83.8 (9.17)^{e}	67.75 (8.20)^{c}	55.7 (7.49)^{d}	104.5 (10.25)^{i}	80.10 (8.87)^{d}
A-2	27.6 (5.30)^{ab}	71.1 (8.70)^{e}	49.35 (7.00)^{ab}	33.3 (5.81)^{ab}	75.4 (8.71)^{d}	54.35 (7.26)^{ab}	37.8 (6.19)^{b}	90 (9.51)^{g}	63.90 (7.85)^{b}
A300	29.0 (5.48)^{b}	69.2 (8.35)^{d}	49.1 (6.92)^{ab}	34.3 (5.90)^{ab}	73.7 (8.61)^{d}	54.00 (7.24)^{ab}	37.4 (6.13)^{b}	87.4 (9.38)^{f}	62.41 (7.75)^{ab}
PBNS12	28.7 (5.39)^{b}	76.2 (8.76)^{e}	52.45 (7.07)^{b}	36.1 (6.05)^{b}	82.0 (9.08)^{e}	59.05 (7.57)^{b}	39.42 (6.32)^{c}	94.8 (9.76)^{h}	67.10 (8.04)^{c}
A-1	25.4 (5.08)^{a}	66.4 (8.18)^{d}	45.90 (6.63)^{a}	32 (5.70)^{a}	73.1 (8.58)^{d}	52.55 (7.16)^{a}	35.9 (6.03)^{a}	84.9 (9.24)^{e}	60.40 (7.64)^{a}
Mean	30.74 (5.57)^{a}	72.86 (8.61)^{b}	-	37.48 (6.14)^{a}	77.60 (8.83)^{b}	-	41.24 (6.43)^{a}	92.32 (9.63)^{b}	-
For comparing means of	S.Em. ±	C.D. at 5 %		S.Em. ±	C.D. at 5 %		S.Em. ±	C.D. at 5 %	
Varieties (V)	0.03	0.09	-	0.03	0.10	-	0.01	0.04	-
Protection (P)	0.05	0.15	-	0.05	0.15	-	0.02	0.06	-
Interaction (V×P)	0.07	0.21	-	0.07	0.22	-	0.03	0.08	-

Figures in the parentheses are $\sqrt{x+0.5}$ transformed values, DAS -Days after sowing

Means followed by the same lower case letter/s in a column do not differ significantly by DMRT (P = 0.05) twig. However, aphid population in all the five varieties differed significantly from each other. The interaction effect with respect to aphid population on 5 cm apical twig also varied significantly.

Seventy five days after sowing

Significant differences were observed between protection levels, varieties and their interaction. The mean number of aphid population on 5 cm apical twig under protected and unprotected plot was 60.40 and 80.10 aphids on 5 cm apical twig, respectively which differed significantly from each other. The variety A-1 recorded minimum number of aphid population (35.9 aphids on 5 cm apical twig) it was followed by A-300 (37.4 aphids on 5 cm apical twig), A-2 (37.8 aphids on 5 cm apical twig) and PBNS-12 (39.42 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (55.7 aphids on 5 cm apical twig) which is susceptible to aphid recorded highest number of aphids on 5 cm apical twig. Under unprotected condition variety A-1 recorded minimum number of aphid population (84.9 aphids on 5 cm apical twig) it was followed by A-300 (87.4 aphids on 5 cm apical twig), A-2 (90.00 aphids on 5 cm apical twig) and PBNS-12 (94.8 aphids on 5 cm apical twig). Whereas, the non-spiny variety Nari-6 (104.5 aphids on 5 cm apical twig) which is susceptible to aphid recorded highest number of aphids on 5 cm apical twig. However, aphid population in all the five varieties differed significantly from each other. The interaction effect with respect to aphid population on 5 cm apical twig also varied significantly.

Seed weight and yield

The data recorded with respect to 100 seed weight and seed yield as influenced by different varieties under protected and unprotected condition are furnished in Table 2. Significant differences were observed between protection levels, varieties and their interaction.

The results revealed that there was significant difference between protected and unprotected plot with respect to seed yield (5.05 and 3.97 g). Under protected condition variety A-1 recorded highest 100 seed weight of 5.05 g which was on par with A-300 (5.34 g) and followed by A-2 (5.20 g). Whereas, the variety PBNS-12 (4.66 g) and Nari-6 (4.62 g) non spiny variety which is susceptible to aphids recorded lowest 100 seed weight. Under unprotected condition variety A-1 recorded highest 100 seed weight of 4.34 g which was on par with A-300 (4.26 g) and A-2 (4.14 g). Whereas, the variety PBNS-12 (3.63 g) and Nari-6 (3.52 g) non spiny variety which is susceptible to aphids recorded lowest 100 seed weight. However, 100 seed weight in all the five varieties differed significantly from each other

The results revealed significant differences between protected and unprotected plot with respect to seed yield (9.57 and 6.92 q ha^{-1}, respectively). Under protected condition variety A-1 recorded highest seed yield of 10.8 q ha^{-1} which was on par with A-300 (10.41 q ha^{-1}), A-2 (9.33 q ha^{-1}) and PBNS-12 (8.81 q ha^{-1}). Whereas, the non-spiny variety Nari-6 (8.52 q ha^{-1}), which is susceptible to aphids, recorded the lowest seed yield. Under unprotected condition variety, A-1 recorded highest seed yield of 7.73 q ha^{-1} which was on par with A-300 (7.14 q ha^{-1}) and A-2 (6.96 q ha^{-1}). The variety PBNS-12 (6.56 q ha^{-1}) and non-spiny variety Nari-6 (6.24 q ha^{-1}), which were susceptible to aphids, recorded the lowest seed yield. However, seed yield in all the five varieties differed significantly from each other.

Per cent yield losses over protected condition were least in the variety A-2 (34.05%) and PBNS-12 (34.30%). The varieties having highest per cent yield losses over protected condition in descending orders were A-300 (45.80%), A-1 (39.72%) and Nari-6 (36.52%).

For loss estimation, the yield loss assessment data are the primary tools to design a module for insect pest

Table 2: Crop loss estimation of safflower due to aphid under protected and unprotected condition

Varieties	100 Seed weight (g)		Mean	Seed yield (q ha^{-1})		Mean	Per cent yield loss over protected condition
	Protected	Unprotected		Protected	Unprotected		
NARI-6	4.62^{c}	3.52^{b}	4.07^{b}	8.52^{b}	6.24^{e}	7.38^{c}	36.54
A-2	5.20^{b}	4.14^{a}	4.67^{a}	9.33^{a}	6.96^{cd}	8.14^{b}	34.05
A300	5.34^{ab}	4.26^{a}	4.8^{a}	10.41^{a}	7.14^{c}	8.77^{a}	45.80
PBNS12	4.66^{c}	3.63^{b}	4.13^{b}	8.81^{a}	6.56^{de}	7.68^{bc}	34.30
A-1	5.46^{a}	4.34^{a}	4.90^{a}	10.8^{a}	7.73^{c}	9.26^{a}	39.72
Mean	5.05^{a}	3.97^{b}	-	9.57^{a}	6.92^{b}	-	-
For comparing means of	S.Em. ±	C.D. at 5 %	-	S.Em. ±	C.D. at 5 %	-	-
Varieties (V)	0.04	0.12	-	0.05	0.16	-	-
Protection (P)	0.06	0.18	-	0.09	0.26	-	-
Interaction (V×P)	0.09	0.26	-	0.12	0.36	-	-

Means followed by the same lower case letter/s in a column/ row do not differ significantly by DMRT (P = 0.05) management. These data are very important and considered for determining the status of the pest. Even few attempts have been made in the major safflower growing areas. Bindra and Vaishampayan (1965) and Bhumannavar (1976) estimated the safflower yield loss due to the aphid and loss was found to be 35.0 and 36.05 per cent respectively. However, the technique adopted to estimate the loss due to the aphid was by comparing the yield of insecticide treated plot and with untreated plots

Per cent losses over protected condition were highest in variety A-300 (45.80 %), in descending orders A-1 (39.72 %), Nari -6 (36.54 %), PBNS-12 (34.30 %) and A-2 (34.05 %). Thus, the loss in yield due to safflower aphid alone ranged from 34.05 to 45.80 per cent across varieties. This work is comparable with Shetgar *et al.* (1992) who conducted the field studies in Maharashtra, India, during the *rabi* seasons to determine the effect of infestations of *U. carthami* on yield loss of safflower. The highest yields were obtained from plots treated with dimethoate 30 EC @ 0.05 % (which represented 24.20 per cent increase in yield compared to untreated control). Balikai (1999) recorded 46.2 per cent yield loss of safflower in Karnataka. Further, he also reported that, three entries *viz.*, PI- 306934, PI-199932 and SSF-16 recorded higher productivity levels with respect to seed and oil yield under unprotected condition indicating their high degree of tolerance to aphids.

The results are similar with that of Painkara *et al*. (2003), who reported that yield of fully protected plot, treated with oxydemeton-methyl @ 0.03 per cent, was comparable with the yield of untreated plot. The aphid number in fully protected plot ranged from 8.00 to 13.00 on per 5 cm terminal shoot length, while it was 9.2 to 137.00 in protected plots. The yield obtained in the fully protected plot was 1,597 kg ha^{-1} as compared to 800 kg ha^{-1} in the unprotected plot.

REFERENCES

Akashe, V. B., Pisal, A. A., Mehtre, S. P. and Sawant, P. H., 1999, Insect pest scenario of safflower in drought prone areas of Maharashtra (India). *Journal of Maharashtra Agricultural Universities,* **14:** 103-108.

Anonymous, 2007, *AICRP (Safflower) Annual Report 2007*, Directorate of Oilseeds Research. (DOR), Hyderabad, p. 165.

Balikai, R. A., 1999, Evaluation of some aphid tolerant safflower germplasm lines for their productivity levels. *Agricultural Science Digest*, **19**: 119-121.

Bindra, O. S. and Vaishampayana, S.M., 1965, Studies on the chemical control of safflower aphid (*Dactynotus compositae* Theobald). *Indian Oilseeds Journal*, **9**: 113-118.

Bhumannavar, B. S., 1976, Studies on the bionomics of the safflower aphid, *Dactynotus compositae* (Theobald), its role in safflower crop loss and its control. *M. Sc. (Agri.) Thesis,* University of Agricultural Sciences, Bengaluru, Karnataka (India)

Painkara, G. P., Yadu, Y. K. and Dubey, V. K., 2003, Losses to safflower yield caused by the aphid *(Dactynotus carthami)*. *Insect Environment*, **9**: 88-89.

Sastry, K., 1997, Managing pests of safflower: New Paradigm. *The Proceedings of IV International Safflower Conference*, Bari (Italy), 2-7th June, 1997, pp. 285-291.

Shetgar, S. S., Bilapate, G. G., Puri, S. N., Patil, V. M. and Londhe, G. M., 1992, Assessment of yield loss in safflower due to aphids. *Journal of Maharashtra Agricultural Universities,* **17**: 303-304.

Singh, V., Shing, H., Hegde, D. M., Ghorpade, S. A. and Men, U. B., 2000, Insect pests of safflower and their management. *Journal of Applied Zoological Research*, **2:** 196-213.

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Management of garlic bulb rot disease through consortium of *Trichoderma* spp.

Geetika and Mushtaq Ahmed

Department of Environmental Sciences, School of Earth and Environmental Sciences, Central University of Himachal Pradesh, TAB Shahpur-176206, Kangra (HP), India.
E.mail: Mushtaq.cuhp@gmail.com, Mobile number: +91-98-165-30171

ABSTRACT

Garlic (*Allium sativum* L.), the most valuable gift of nature to mankind, grown domestically and commercially throughout the world, is used as food ingredient and medicine. However, recently bulb rot disease, caused by pathogenic fungus, *Fusarium proliferatum,* has been reported affecting its clove growth and the yield adversely all over the globe. Chemical fungicides such as benomyl, which are hazardous to the ecosystem, are currently under use to combat this disease. Therefore, role of consortium of *Trichoderma* spp., as a safer alternative to the chemicals, was evaluated. It was found that the consortium of *Trichoderma* spp. besides being very effective in controlling the disease were also effective in increasing the garlic yield.

Key words: *Trichoderma* spp, *Fusarium proliferatum,* garlic yield.

Cultivation of *Allium* plants such as leeks, onion and garlic is as old as human civilization itself. This shows the importance of these plants both as food ingredient and as medicinal herb (Bayan *et al.,* 2014). Garlic (*Allium sativum* L.) is a member of the family Liliaceae that is a perennial herb consisting of many cloves (Bayan *et al.,* 2014). Growth of garlic depends upon a number of external factors including temperature, photoperiod, soil moisture and soil pH (Griffiths *et al.,* 2002). Though sensitive, garlic is the strongest flavored *Allium* which is full of antioxidants (Lanzotti, 2006). Garlic is rich in calcium and riboflavin and also contains iron, phosphorus, potassium, sodium, iodine, zinc, copper, manganese, selenium, vtamin C, thiamin, niacin, pantothenic acid, folate, vitamin E, vitamin K and pyruvic acid (Lanzotti, 2006). The presence of large number of these compounds and elements makes garlic a very important food additive with beneficial health properties (Nicastro *et al.,* 2015). Garlic is used to cure a number of illnesses including fever, cough, liver disorders, diabetes and high blood pressure (Nicastro *et al.,* 2015). Garlic has the ability to improve immunity in human beings and has been reported to be effective in cancer prevention, cold and flu, heart diseases, allergies and inflammations (Nicastro *et al.,* 2015). Allicin present in the garlic helps in lowering the blood cholesterol level (Nicastro *et al.,* 2015). Recently bulb rot disease caused by the pathogenic fungus *F. proliferatum* has been reported to adversely affect the clove growth in garlic throughout the world (Dugan *et al.,* 2003; Fuentes *et al.,* 2013). The infected garlic cloves have water soaked like appearance and drooping off of leaves leading to considerable reduction in plant yield (Dugan *et al.,* 2003; Fuentes *et al.,* 2013). The pathogen namely, *F. proliferatum* that causes the bulb rots in garlic, has been reported to easily adapt to different geographical and climatic conditions and hence it is necessary to control it to prevent the damage caused to the crop plants including garlic (Palmero *et al.,* 2012). The chemical fungicides such as benomyl, mancozeb and carbendazim are commonly used in modern agricultural practices to control the disease (Benítez *et al.,* 2004). However, prolonged use of these chemicals in agriculture is not eco friendly and moreover; the pathogen evolves into new strains over a period of time that are resistant to the chemicals (Benítez *et al.,* 2004). A sustainable and eco friendly alternative to the chemicals are the plant growth promoting soil microbes including the species of *Pseudomonas* and *Trichoderma* that can be used to combat the pathogen and also enhance the crop yield (Rai *et al.,* 2016). In the present study we used consortium of *Trichoderma* spp. to manage the bulb rot of garlic and found that the results are encouraging. The consortium of *T. viride*, *T. asperellum* and *T. harzianum* was found to exhibit antagonistic activity against the pathogen and also improved the yield of garlic (Schuster and Schmoll, 2010; Rai *et al.,* 2016).

MATERIALS AND METHODS

Soil samples were collected from the agricultural fields at Varanasi and dumping sites of Dharamshala region of Himachal Pradesh. The samples were brought to Environmental Science laboratory at the Central University of Himachal Pradesh, Dharamshala. Soil fungi were isolated using pour plate method (Warcup, 1950). For this, 0.15 gram of air dried soil sample was added to each of the five sterile

Petri plates under aseptic conditions. Then 20 ml of melted and cooled Potato Dextrose Agar was added to each Petri plate separately. This medium was supplemented with rose bengal (0.0084 gram/L). Soil particles were dispersed throughout the medium by gentle rotation of Petri plates in clockwise and anticlockwise direction. The medium in the Petri plates was then allowed to solidify for few minutes. After solidification of the medium, the Petri plates were incubated at 25 ± 2°C for seven days. The plates were checked regularly for appearance of the fungal colonies. After seven days, fungal colonies appeared in the Petri plates that were sub cultured to obtain the pure culture of each isolate. The isolated fungal isolates were stored at 4°C in PDA slants for future use. Each isolate was identified through direct sequencing of 18s rRNA. The identified fungal isolates included *Trichoderma harzianum/ H. lixii* (MF661969.1), *Trichoderma viride* (MF663724.1), *Trichoderma asperellum* (MF661885.1) and *Fusarium proliferatum* (MF661933.1). These species of fungi are well known bio control agents for sustainable agriculture. *Fusarium proliferatum* is a pathogenic fungus that causes bulb rot of garlic. Mass culture of each isolate was prepared on barley grains following standard protocol (Shivanna *et al.,* 1994). The mass culture of each isolate was sterilized at 121°C for 1-2 hour and then cooled down at room temperature. When the temperature of the mass culture was appropriate, it was inoculated with the fresh culture of all the fungi separately in different conical flasks under aseptic conditions. The flasks were tightly closed with the help of aluminum foil and parafilm. The cultures were incubated at 25°C± 2°C and were shaken once or twice daily for quick and homogenous growth of the fungus. The effect of these mass cultures was evaluated for the management of bulb rot of garlic.

The garlic cloves were collected from the local farmers in Shahpur region of Dharamshala, Himachal Pradesh and brought to the Environmental Science Lab. The viability of each garlic clove was checked by subjecting it to the moisture conditions by spraying a small amount of distilled water on it in a Petri plate. After few days, the viable cloves germinated on the petri plates. These viable garlic seedlings were then transferred into clay pots filled with finely ground sterilized (by autoclaving for 1-2 hour at 121°C) soil. A total of two hundred fifty two pots were prepared. Each pot was supplemented with 5 per cent farm yard manure. The pots were divided into nine sets, each in triplicate, as control set (twenty eight replicates) without any treatment, with mass culture of *F. proliferatum* (1% w/w), *T. harzianum/H. lixii* (1% w/w), *F. proliferatum* (1% w/w) with the fungicide (1% w/w), *T. harzianum/H. lixii* (1% w/w) with, carbendazim (1% w/w), *T. harzianum/H. lixii* (1% w/w) and *F. proliferatum* (1% w/w) with carbendazim (1% w/w), *T. harzianum/H. lixii* (1% w/w) and *F. proliferatum* (1% w/w), consortium of *T. harzianum/H. lixii*, *Trichoderma viride*, *Trichoderma asperellum* (1% w/w) and *T. harzianum/H. lixii*, *Trichoderma viride*, *Trichoderma asperellum* (1% w/w) and *F. proliferatum* (1% w/w) added to the soil and mixed properly.

Each experimental pots was also supplemented with 5 per cent farm yard manure. This was autoclaved prior to its addition to the pots. The pots were moistened using distilled water in small quantity and were set aside at room temperature for seven days for proper colonization of fungi with the soil particles. After seven days the garlic seedlings grown in the petri plates were transferred into the clay pots (two seedlings in each pot) precisely under the same growing environment. The pots were then shifted from lab into open sunlight under natural conditions and were watered regularly. The seedlings growth in the pots was observed for length of shoot (LDS), fresh weight of plant (FWP), dry weight of plant (DWP), weight bulb (WOS), diameter bulb (DOB), number of cloves (NOC) and the yield at intervals of 10, 30, 50, 70, 90, 110, 130, 150, 170, 190 and 210 days after sowing (Table 1 to 9). Diameter of bulb was calculated by measuring the circumference of each and every single bulb with the help of a thread using the formula given below:

$$\text{Circumference} = 2\pi r$$

The percentage increase in the yield was calculated by using the below given formula.

$$= \frac{\text{Control} - \text{Treatment}}{\text{Control}} \times 100$$

Statistical analysis was performed in Sigma Plot ver.11.0 software by comparing the means using one-way ANOVA and found to be significant with $p \leq 0.001$ levels.

RESULTS AND DISCUSSION

Soil pH and texture

Garlic being a pH sensitive plant its growth is known to be greatly affected by pH and texture of the surrounding soil (Griffiths *et al,* 2002). The pH 6 to 6.8 is considered optimum for cultivation of *Allium* plants (Griffiths *et al,* 2002). Moreover, soil having less percentage of clay particles is considered suitable for proper bulb formation in *Allium* plants (Griffiths *et al,* 2002). Hence, the soil used in the experiments, was firstly analyzed for its pH and texture. It was found that soil pH was around 6 and the soil consisted 44 per cent sand particles, 43 per cent silt particles and 13 per cent clay particles. Thus this experimental soil did not require any special treatment for maintaining the pH and hence was used as such in the experiments after sterilizing.

Strain selection

The selection of potent strain was done on the basis of effect of pH and fungicide on colony diameter of the isolate. A comparative study on the effect of pH and fungicide on colony diameter of all the strains was done under *in vitro* conditions. Among all the isolates used in the present study, *Trichoderma harzianum/H. lixii* was found to be the most potent strain in terms of its tolerance to pH variations (Figure 1) and varying concentrations of the fungicide (Figure 2) under *in vitro* conditions.

Effect of pathogen on garlic clove

Garlic cloves sown in pots containing pathogen (*F. proliferatum*) inoculated soil failed to grow beyond seedling stage (Figure 8). It was observed that seedling growth was seized in presence of the pathogen. Though viable at the time of sowing, these cloves developed into a fleshy mass that had water soaked like appearance over a short period of time (Figure 8 (e). The fleshy mass of cloves started losing the water and finally dried up (Figure 8 (f) at about fifteen days after sowing (DAS). The experiment was repeated again and we could make the similar observation. This led to conclude that the cloves got infected by the pathogen colonizing the soil leading to the development of bulb rot disease resulting in death of the garlic seedlings. Our observations are in consonance with earlier reports. Dugan *et al*. (2003) have reported that *F. proliferatum* infected garlic cloves displayed water soaked appearance and white mycelium near the bulb

Table 1: Control (Evaluation of the growth and yield of garlic at different intervals of time)

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	2.94±0.04*	1.09018±0.07	0.51780±0.04	-	-	-
30th	6.04±0.04	2.64784±0.02	1.11368±0.01	-	-	-
50th	10.96±0.02	2.99314±0.01	1.25712±0.01	-	-	-
70th	21.70±0.08	3.45870±0.11	1.45260±0.04	-	-	-
90th	28.42±0.10	5.77010±0.03	2.40430±0.01	-	-	-
110th	32.48±0.02	6.13146±0.03	4.57518±0.01	1.70542±0.05	1.02±0.02	-
130th	38.04±0.02	7.88784±0.06	7.38848±0.11	3.61376±0.14	1.56±0.02	-
150th	42.92±0.02	9.89150±0.07	9.55018±0.03	5.87088±0.04	1.94±0.02	-
170th	54.92±0.02	12.74744±0.13	11.86320±0.06	7.53054±0.09	2.08±0.02	-
190th	64.72±0.02	17.39276±0.12	13.00006±0.06	8.53314±0.13	2.44±0.02	-
210th	67.88±0.07	19.79128±0.11	16.06012±0.05	10.88582±0.08	2.56±0.02	7.0±0.2

*Mean with standard error

Table 2: Effect of *F. proliferatum* (pathogen) on the growth of garlic seedling

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
1st	2.94±0.04	-	-	-	-	-
5th	2.94±0.04	-	-	-	-	-
10th	1.76±0.02	-	-	-	-	-
15th	1.76±0.02	-	-	-	-	-
20th	1.76±0.02	-	-	-	-	-

Table 3: Effect of treatment of *T. harzianum/H. lixii* alone on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	2.94±0.04	1.02886±0.01	0.43080±0.01	-	-	-
30th	6.06±0.02	3.15886±0.06	1.07212±0.01	-	-	-
50th	10.68±0.07	2.87600±0.06	1.20788±0.02	-	-	-
70th	24.58±0.01	3.19138±0.01	1.34240±0.01	-	-	-
90th	30.18±0.07	6.40730±0.06	2.68980±0.02	-	-	-
110th	33.54±0.12	17.00644±0.01	9.94244±0.01	2.20328±0.02	2.06±0.02	-
130th	40.64±0.22	35.87976±0.13	19.72552±0.08	4.94132±0.04	3.06±0.02	-
150th	50.28±0.44	48.18128±0.34	26.52008±0.21	7.06588±0.04	3.76±0.02	-
170th	58.76±0.15	54.72902±0.27	30.13604±0.16	14.42046±0.12	4.26±0.02	-
190th	68.80±0.12	61.90406±0.32	34.07218±0.19	21.75166±0.10	4.66±0.02	-
210th	75.72±0.17	66.72604±0.26	36.70742±0.15	26.55792±0.10	4.66±0.02	12.00±0. 2

axis. *F. proliferatum* can also have harmful effect during the early stages of crop growth in the field (Palmero *et al*., 2012). Moreover it has also been reported that *F. proliferatum* infected plants show reduction in emergence and yellow and/or browning of leaves at tips (Dugan *et al*., 2003; Fuentes *et al*., 2013; Ravi Sankar, 2012; Stankovic *et al*., 2007). Similar results were obtained in the present study, when garlic seedlings were grown in *F. proliferatum* inoculated soil (figure.9). The exact mechanism by which *F. proliferatum* causes bulb rot disease in garlic is not yet known. However, it is believed that during incubation period, the pathogen on colonizing the soil particles, might be producing certain toxins/ secondary metabolites such as trichothecene, zearalenone and fumonisins that result in the development of the disease thereby, inhibiting the seedling growth of garlic (Ma *et al*., 2013). Moreover, *F. proliferatum* is also considered as the main source of fumonisins in foodstuffs (Jurado *et al*., 2010; Bacon and Nelson, 1994). Besides fumonisins other compounds

Table 4: Effect of combined treatment of fungicide and *F. proliferatum* (pathogen) on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	2.94±0.04	1.03190±0.01	0.42854±0.01	-	-	-
30th	6.10±0.06	2.82302±0.03	1.20554±0.01	-	-	-
50th	11.34±0.10	3.07218±0.01	1.27802±0.01	-	-	-
70th	25.52±0.14	3.97590±0.06	1.66188±0.03	-	-	-
90th	30.54±0.12	6.74154±0.09	2.83142±0.04	-	-	-
110th	32.68±0.17	7.02230±0.01	3.36332±0.01	1.21236±0.01	1.06±0.02	-
130th	38.72±0.17	8.33224±0.06	7.76344±0.18	3.67344±0.07	2.06±0.02	-
150th	43.64±0.22	9.96710±0.06	10.8008±0.01	5.89352±0.04	2.86±0.02	-
170th	55.80±0.12	12.79824±0.10	13.09358±0.08	8.03210±0.03	3.26±0.02	-
190th	65.84±0.10	18.17422±0.10	14.50710±0.18	9.88860±0.09	3.46±0.02	-
210th	71.80±0.12	20.91916±0.36	16.44112±0.07	11.95474±0.03	3.46±0.02	8.00±0.2

Table 5: Effect of combined treatment of fungicide and *T. harzianum/H. lixii* on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	3.10±0.08	1.04232±0.01	0.44536±0.01	-	-	-
30th	5.90±0.06	3.62578±0.05	1.49098±0.01	-	-	-
50th	7.76±0.15	5.24304±0.03	2.08080±0.04	-	-	-
70th	12.64±0.04	5.91798±0.05	2.44142±0.06	-	-	-
90th	25.96±0.12	6.98094±0.01	2.94148±0.01	-	-	-
110th	31.08±0.44	7.93358±0.05	3.28504±0.03	1.15858±0.01	1.06±0.02	-
130th	33.4±0.10	10.67396±0.18	5.33028±0.06	3.67248±0.07	2.06±0.02	-
150th	38.68±0.20	19.84728±0.10	9.92362±0.05	5.75258±0.07	2.78±0.02	-
170th	45.64±0.22	23.72078±0.15	13.86190±0.08	9.33924±0.10	3.26±0.02	-
190th	56.72±0.17	28.98228±0.09	19.49114±0.04	16.65026±0.05	3.46±0.02	-
210th	71.88±0.07	31.58166±0.23	25.80682±0.11	19.63306±0.05	3.46±0.02	8.00±0.2

Table 6: Effect of combined treatment of fungicide, *T. harzianum/H. lixii* and *F. proliferatum* (pathogen) on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	2.94±0.04	1.02502±0.01	0.42052±0.01	-	-	-
30th	7.06±0.02	3.31724±0.02	1.39318±0.01	-	-	-
50th	11.50±0.18	4.81798±0.05	2.09346±0.01	-	-	-
70th	25.34±0.38	5.80652±0.02	2.44696±0.01	-	-	-
90th	30.52±0.44	6.93072±0.06	2.90076±0.03	-	-	-
110th	33.32±0.05	7.74200±0.01	3.25156±0.01	1.10284±0.01	1.06±0.02	-
130th	40.34±0.17	19.82256±0.08	7.70754±0.16	3.58898±0.09	2.06±0.02	-
150th	48.84±0.10	27.88476±0.15	10.92300±0.04	5.81628±0.06	2.86±0.02	-
170th	57.76±0.15	32.04364±0.07	14.79324±0.07	9.64592±0.08	3.26±0.02	-
190th	67.30±0.12	39.86418±0.10	21.35596±0.10	17.30682±0.07	3.86±0.02	-
210th	72.68±0.20	43.69200±0.21	27.75308±0.10	21.58812±0.11	3.86±0.02	9.00±0.2

such as moniliformin and beauvericin (Marasas *et al.*, 1984) are also reported as toxins that if consumed, have adverse effect on human and animals. Some of these mycotoxins also proliferate cancer in humans (Bacon and Nelson, 1994).

Effect of different treatments on growth and yield of garlic plants

Analysis of the results revealed that the *Trichoderma* spp. in presence or absence of the pathogen had remarkably increased the yield of the garlic plant and also suppressed the pathogen (Table.1 to 9 and Figure.3 to 11). Among all the treatments, the consortium of *Trichoderma asperellum*, *Trichoderma harzianum/ Hypocrea lixii* and *Trichoderma viride* was found to be most effective in suppressing the pathogen and enhancing the yield of garlic plants at 70th days after sowing (DAS) as compared to control (p d™ 0.001,Table.1). The pathogen suppression was utmost in case of consortium treatment (Table.9 and Figure. 9-10) followed by *T. harzianum/ H. lixii* (Table.7 and Figure.9-10), fungicide + *T. harzianum/ H. lixii* (Table.6 and Figure.9-10) and the fungicide treatment

Table 7: Effect of combined treatment of *T. harzianum/H. lixii* and *F.proliferatum* (pathogen) on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	3.34±0.10	1.04726±0.01	0.43980±0.01	-	-	-
30th	8.32±0.12	3.61914±0.10	1.52000±0.04	-	-	-
50th	13.90±0.08	5.58190±0.11	2.34436±0.04	-	-	-
70th	26.80±0.14	6.62268±0.06	2.75876±0.02	-	-	-
90th	32.34±0.10	8.04406±0.01	4.37848±0.01	-	-	-
110th	34.50±0.18	19.11660±0.03	10.82892±0.02	1.10474±0.01	1.06±0.02	-
130th	41.44±0.34	32.64142±0.23	18.27194±0.13	6.67276±0.14	3.06±0.02	-
150th	52.60±0.24	50.95598±0.11	28.52824±0.09	9.91744±0.06	3.86±0.02	-
170th	61.72±0.17	57.82290±0.21	32.38268±0.12	17.31670±0.11	4.36±0.02	-
190th	70.72±0.17	65.33744±0.18	36.78612±0.12	25.94576±0.04	4.76±0.02	-
210th	77.68±0.20	69.68508±0.22	39.06004±0.14	29.64638±0.14	4.86±0.02	13.00±0.2

Table 8: Effect of treatment of consortium *of Trichoderma* strains on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	3.18±0.02	1.04210±0.01	0.43442±0.01	-	-	-
30th	8.88±0.02	3.48842±0.03	1.46508±0.01	-	-	-
50th	14.16±0.04	5.50472±0.03	2.28716±0.02	-	-	-
70th	26.82±0.08	7.24762±0.04	3.04398±0.02	-	-	-
90th	36.44±0.06	15.90168±0.04	9.73868±0.02	-	-	-
110th	38.40±0.10	28.89692±0.02	16.15664±0.01	2.83384±0.08	1.06±0.02	-
130th	42.30±0.12	37.98878±0.09	22.03218±0.05	4.44726±0.05	1.56±0.02	-
150th	53.96±0.02	52.78156±0.17	30.61328±0.10	10.37348±0.10	3.96±0.02	-
170th	65.96±0.02	62.67570±0.16	36.35184±0.09	20.42520±0.10	4.56±0.02	-
190th	71.68±0.20	69.69938±0.22	40.45604±0.13	27.53000±0.13	4.96±0.02	-
210th	80.64±0.22	74.03380±0.41	42.96094±0.33	31.60080±0.12	5.04±0.03	14.00±0.2

Table 9: Effect of combined treatment of consortium *of Trichoderma* strains in presence of the pathogen on the growth and yield of garlic at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
10th	3.54±0.04	1.08388±0.01	0.47290±0.01	-	-	-
30th	9.54±0.04	3.69432±0.04	1.61094±0.04	-	-	-
50th	14.62±0.08	5.48092±0.09	2.35530±0.04	-	-	-
70th	29.40±0.06	7.39466±0.01	3.10564±0.01	-	-	-
90th	39.52±0.21	9.18992±0.04	3.80364±0.17	-	-	-
110th	42.08±0.02	20.20606±0.20	11.40252±0.20	1.88904±0.05	1.56±0.02	-
130th	50.80±0.12	41.71816±0.15	24.60268±0.10	3.92432±0.08	2.56±0.02	-
150th	65.84±0.10	55.71382±0.14	32.89714±0.11	11.73556±0.14	4.06±0.02	-
170th	71.28±0.44	68.70048±0.21	40.58410±0.12	24.72606±0.14	4.86±0.02	-
190th	79.92±0.05	73.74632±0.10	43.69244±0.02	29.73304±0.15	5.36±0.02	-
210th	84.60±0.24	77.55974±0.17	45.76022±0.10	35.63108±0.12	5.46±0.02	19.00±0.2

(Table.4 and Figure.9-10).

Length of shoot of garlic plants was also found to be remarkably higher in all treatments as compared to control (p d™ 0.001, Table 1) at 210th DAS and it was observed that the shoot length was maximum in consortium treatment (Table 8 and 9, Figure 9 and 10) followed by *T. harzianum/H. lixii* treatment (Table 3 and 7, Figure 9 and 10), fungicide + *T. harzianum/H. lixii* treatment (Table 5 and 6, Figure 9 and 10), and fungicide + pathogen treatment (Table 4, Figure 9 and 10).

In case of fresh weight and dry weight of the plants, all treatments showed higher values as compared to control (p d™ 0.001, Table.1) at 210th DAS. In case of both above mentioned treatments the consortium + pathogen treatment (Table.9, Figure.9and10) also resulted in the maximum increase in fresh as well as dry weight of the plant followed by consortium treatment (Table.8, Figure.9and10), *T. harzianum/H. lixii* + pathogen treatment (Table.7, Figure. 9and10), *T. harzianum/H. lixii* treatment (Table.3, Figure.9and10), fungicide + *T. harzianum/H. lixii* + pathogen treatment (Table.6, Figure.9and10), fungicide + *T. harzianum/ H. lixii* treatment (Table.5, Figure.9and10) and fungicide + pathogen treatment (Table.4, Figure.9and10).

Similarly, when weight and diameter of the bulb was measured, it was found that treatments showed better results as compared to control (p d™ 0.001, Table.1) at 210th DAS and it was observed that again the consortium + pathogen treatment (Table.9, Figure.9and10) showed maximum increase in the weight and the diameter of the bulb followed by treatment with consortium (Table.8, Figure.9and10), *T. harzianum/H. lixii* + pathogen (Table.7, Figure. 9and10), *T. harzianum/H. lixii* (Table.3, Figure.9and10), fungicide + *T. harzianum/H. lixii* + pathogen (Table.6, Figure.9and10), fungicide + *T. harzianum/H. lixii* (Table.5, Figure.9and10) and fungicide + pathogen (Table.4, Figure.9and10).

Number of cloves per bulb increased with each treatment in that order which was higher as compared to control (p d™ 0.001, Table.1) at 210th DAS.

The consortium of *T. asperellum*, *T. harzianum/H. lixii* and *T. viride* in presence of the pathogen was found to be most effective in terms of increasing the growth and yield parameters of the garlic plant at 210th DAS (Table.9 and 10). There was about 2 to 300 per cent increase in all yield parameters of the garlic plant viz., length of shoot, fresh weight of plant, dry weight of plant, weight of bulb, diameter of bulb and number of cloves as compared to control (p d™

Table 10: Comparison of percent increase in the yield parameters of garlic after the treatments

Treatment	Percentage (%) increase in growth and yield parameters					
	LOS	FWP	DWP	WOB	DOB	NOC
Control	0*	0	0	0	0	0
Pathogen	-**	-	-	-	-	-
T. harzianum/H. lixii	11.50*	237.10	128.51	144.02	82.03	71.43
fungicide + pathogen	5.80	5.70	2.36	9.83	35.16	14.29
fungicide + *T. harzianum/H. lixii*	5.90	59.60	60.64	80.42	35.16	14.29
Fungicide+ *T. harzianum/H. lixii* + pathogen	7.1	120.80	72.78	98.38	50.78	28.57
***T. harzianum/H. lixii* + pathogen**	14.40	252.10	143.21	172.42	89.84	85.71
consortium	18.80	274.00	167.49	190.44	96.88	100.00
Consortium + pathogen	24.6	291.90	184.90	227.50	113.30	171.47

*Value according to the formula of the percent yield as mentioned in materials and methods. **Not recorded

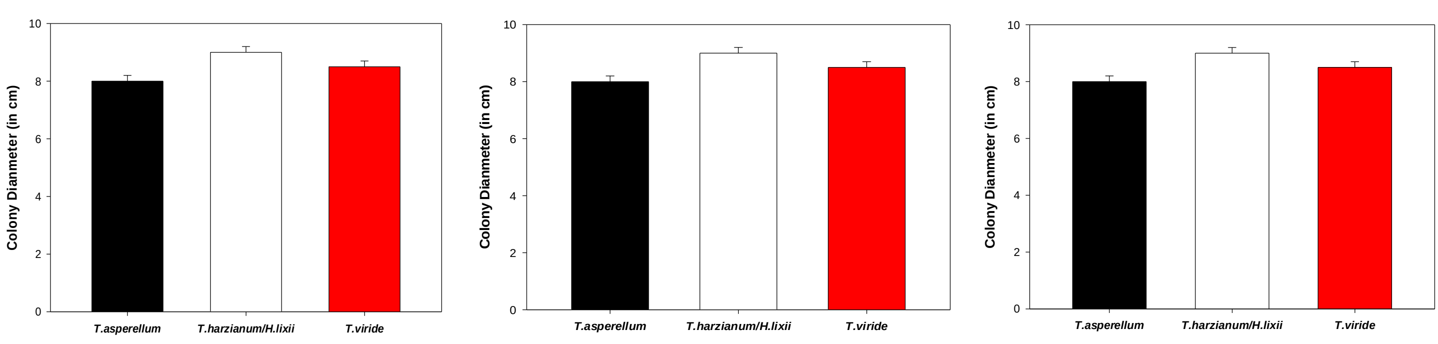

Fig. 1: Effect of pH on the colony diameter of *Trichoderma* spp.

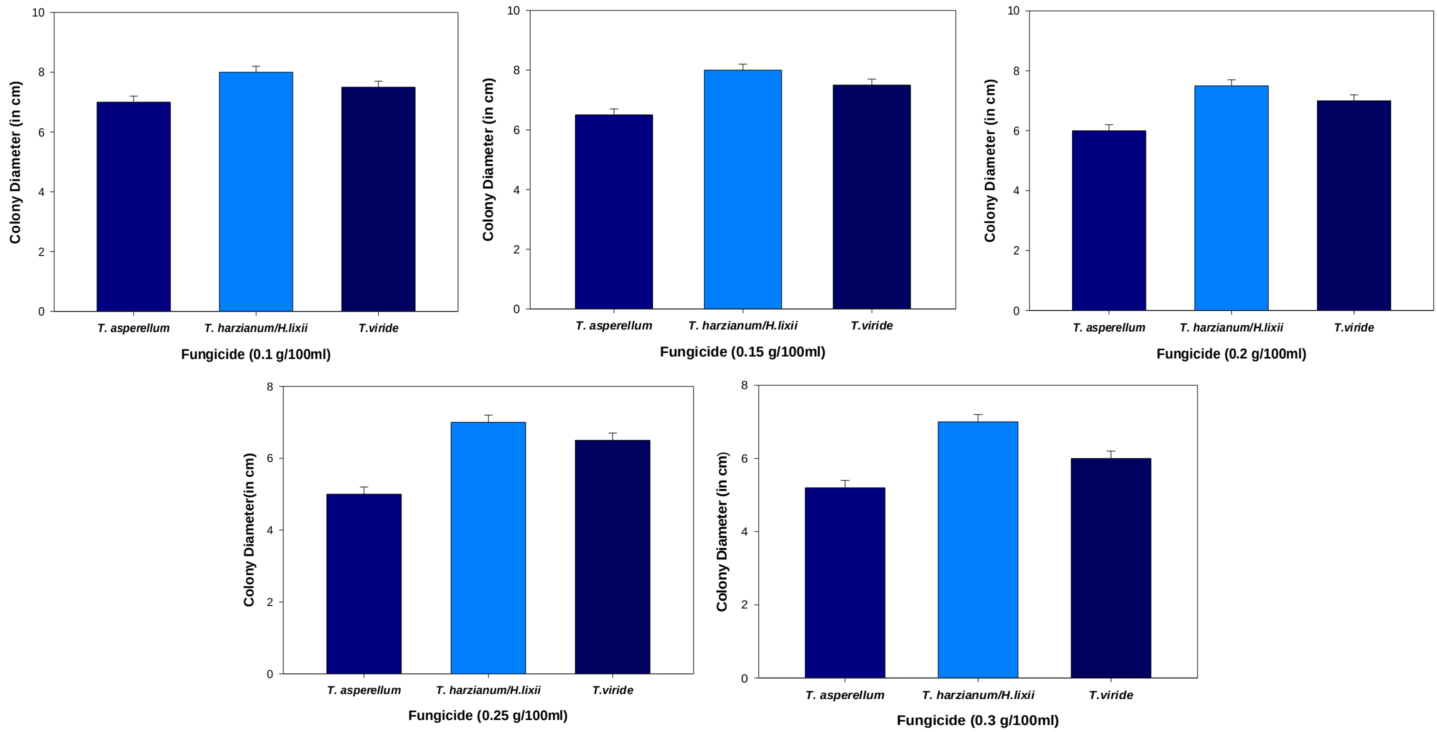

Fig. 2: Effect of fungicide (carbendazim) on the colony diameter of *Trichoderma* spp.

0.001, Table.10) at 210th DAS. During these studies, it was noted that the treatments involving fungicide (carbendazim), although comparatively increased the yield parameters of the garlic plants as compared to the control, it was not as effective as the consortium treatment at 210th DAS (Table 10). These results are in conformity with earlier reports (Ahmed and Upadhyay, 2011). Moreover, the pathogen had adverse effect on the growth of the seedlings and eventually

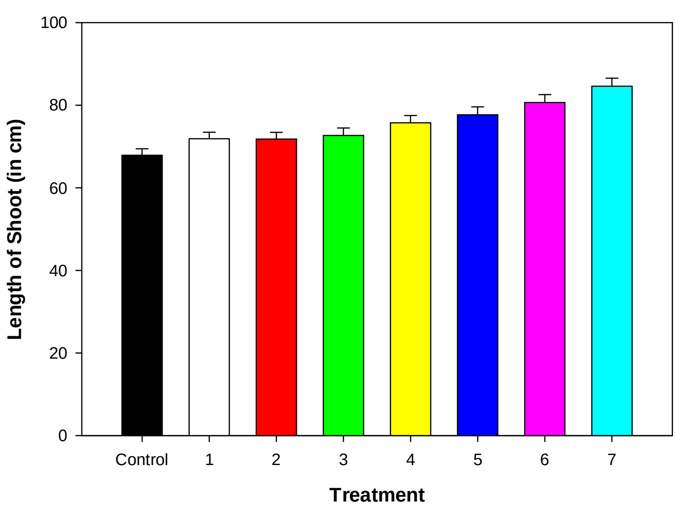

Fig. 3. Comparison of length of shoot between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/ H.lixii* and pathogen **(4)** *T. harzianum H.lixii* **(5)** *T. harzianum /H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

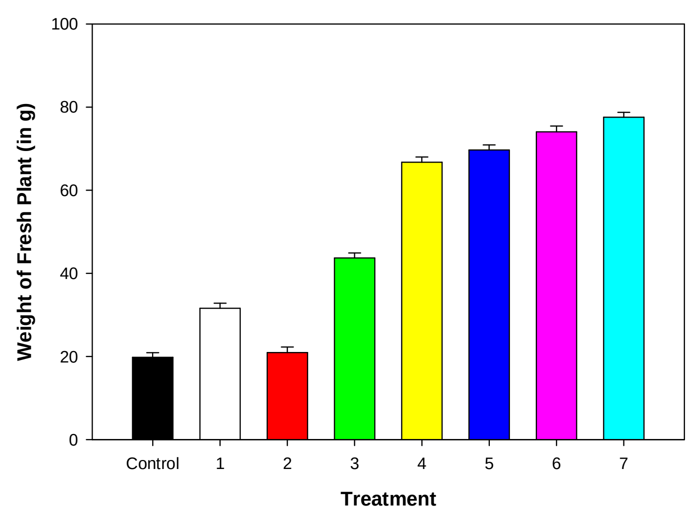

Fig. 4. Comparison of weight of fresh plant between control and treatments; **(1)** Fungicide and *T. harzianum/ H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

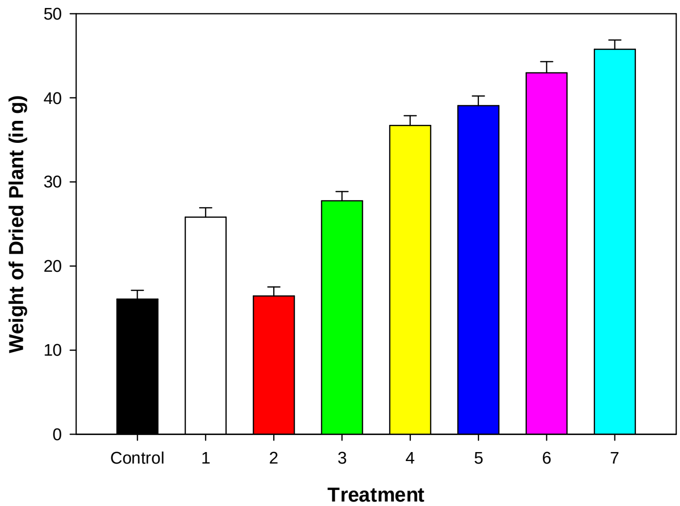

Fig. 5. Comparison of weight of dried plant between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

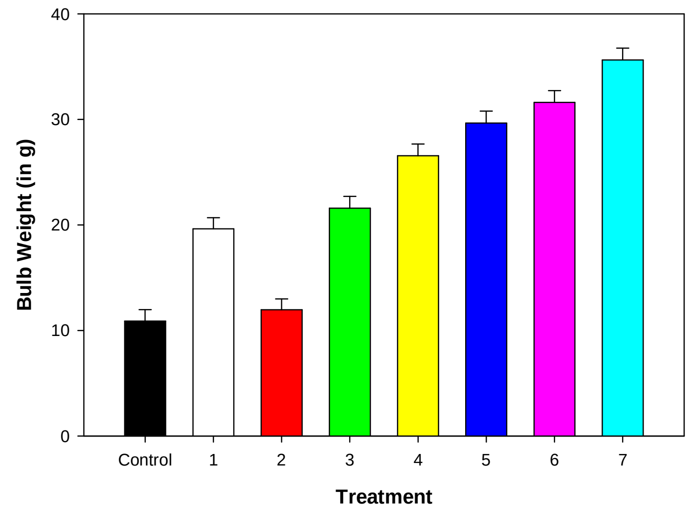

Fig. 6. Comparison of weight of bulb between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

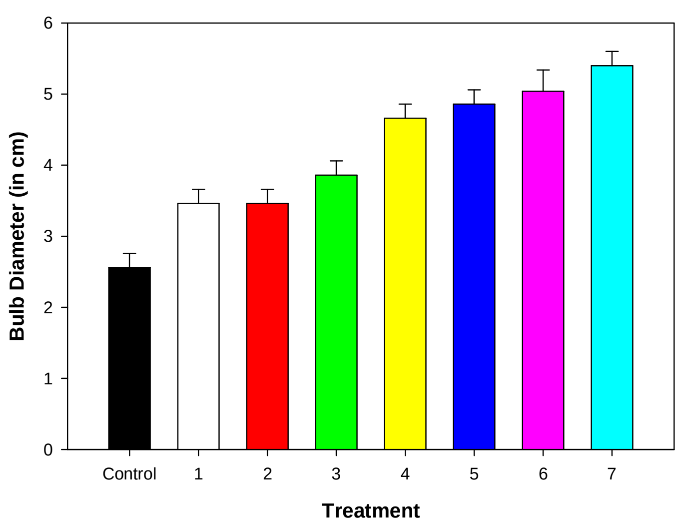

Fig. 7. Comparison of diameter of bulb between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

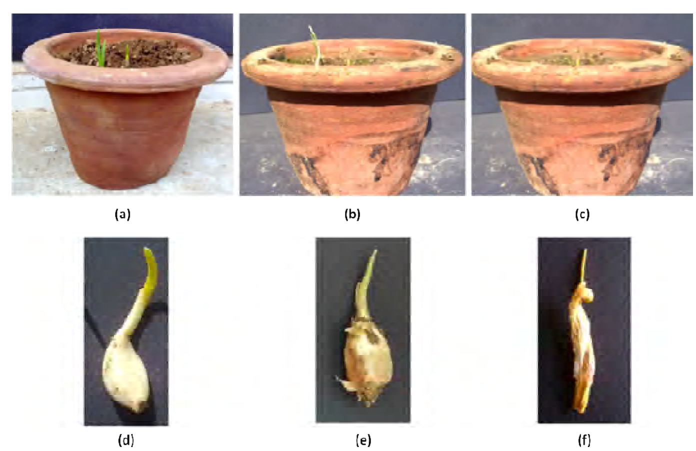

Fig. 8. Effect of pathogen on garlic cloves **(a)&(d)** First day of plantation **(b) & (e)** After 10th day of plantation **(c) & (f)** After 20th day of plantation.

killed them. *F. proliferatum* has been reported to have harmful effect on the early stage of plant growth (Palmero *et al*., 2012) and hence no yield parameters were recorded in this treatment (Table.2). *Trichoderma* spp. have been already reported to increase the plant yield in absence of the pathogen (Chang *et al*., 1986; Harris, 1999; Shivanna *et al*., 1996; Windham *et al*., 1986). In presence of the pathogen, several metabolites such as alamethicin, auxin analogues, harzianolides and harzianic acid produced by *Trichoderma* spp. are involved in the induction of plant resistance and overall improvement in the plant health (Vinale *et al*., 2014; Nieto Jacobo *et al*., 2017). *Trichoderma* spp. are reported to be susceptible to some fungicides such as benomyl, carbendazim, mencozeb and dicloran (Kredics *et al*., 2003). It has also been found that *Trichoderma* spp. are able to grow in presence of the above mentioned fungicides if the concentration of these fungicides present in the soil is

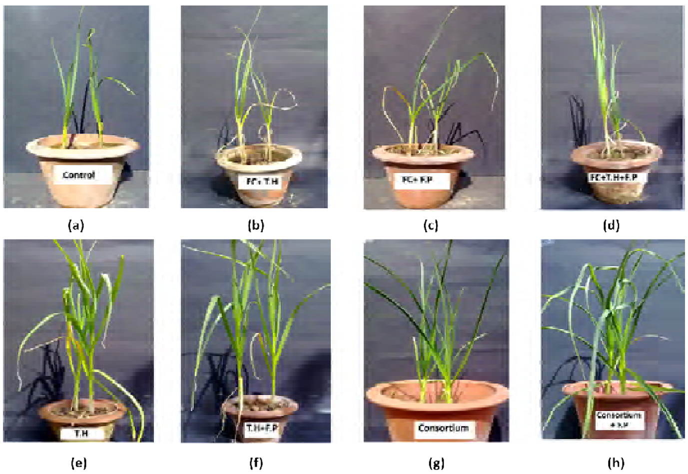

Fig. 9. Comparison of treatments in experimental pots; **(a)** Control **(b)** Fungicide and *T. harzianum/H.lixii* **(c)** Fungicide and pathogen **(d)** Fungicide, *T. harzianum/H.lixii* and pathogen **(e)** *T. harzianum/H.lixii* **(f)** *T. harzianum/H.lixii* and pathogen **(g)** Consortium **(h)** Consortium and pathogen.

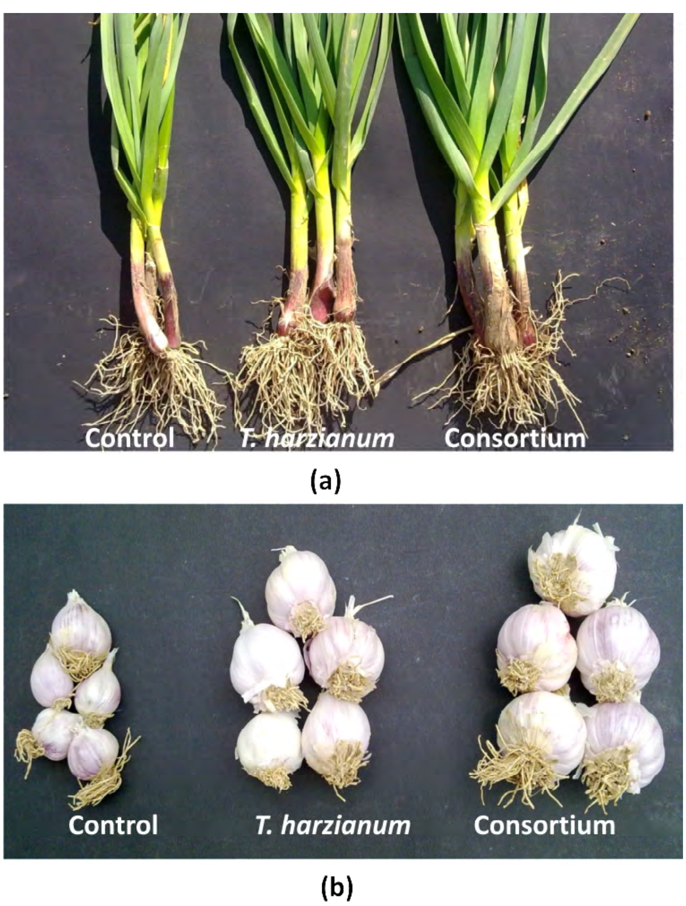

Figure 11. Garlic bulb Comparison on **(a)** 90th day and **(b)** 210th day

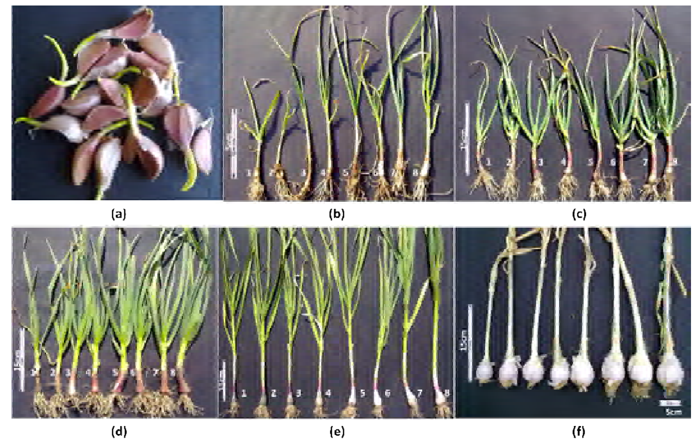

Fig.10. (a) Garlic cloves and Freshly uprooted plants at different intervals of time **(b)** 30th day **(c)** 90th day **(d)** 130th day **(e)** 170th day **(f)** 210th day, having order of treatments; **(1)** Control **(2)** Fungicide and *T. harzianum/H.lixii* **(3)** Fungicide and pathogen **(4)** Fungicide, *T. harzianum/H.lixii* and pathogen **(5)** *T. harzianum/H.lixii* **(6)** *T. harzianum/H.lixii* and pathogen **(7)** Consortium **(8)** Consortium and pathogen.

optimum for *Trichoderma* spp. or the existing strains of fungicide are resistant (Kredics *et al.*, 2003). *Trichoderma* spp. have been reported to increase the plant growth particularly at the root level by triggering auxin dependent mechanisms (Contreras- Cornejo *et al.*, 2009; Nieto Jacobo *et al.*, 2017). *Trichoderma* spp. are also reported to change the microbial composition in roots, enhancement of nutrient uptake and solubilization of soil nutrients in plants along with enhancement of deep root penetration (Harman, 2006; Benítez *et al.*, 2004; Ahmed and Upadhyay, 2010; Nieto Jacobo *et al.*, 2017). *Trichoderma* spp. are highly resistant to a wide range of mycotoxins which are produced by various pathogens (Harman *et al.*, 2004). Some *Trichoderma* secondary metabolites may act as elicitors of plant defense mechanisms against the pathogens such as reduction of disease symptoms in tomato and canola seedlings by treatment with 1-6- pentyl-a-pyrone (Vinale *et al.*, 2014; Ahmed and Upadhyay, 2009). In the present study the concentration of secondary metabolites produced by the fungal strains might have increased about three fold since the consortium consisted of three strains of *Trichoderma* spp. viz., *T. asperellum*, *T. harzianum/H. lixii* and *T. viride* and these metabolites might have helped in increasing the growth and the yield parameters of the garlic plant.

CONCLUSION

It was concluded that the treatment of the garlic plant with consortium of *Trichoderma* isolates not only suppressed the growth of the pathogen, it also increased the crop productivity. Therefore, the consortium of *Trichoderma* spp. instead of individual strains, can be used in combating the bulb rot pathogens and enhancing the garlic yield. However, further studies are needed to understand the mechanism of consortium effectivity.

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REFERENCES

Ahmed, M., Upadhyay, R. S. 2011. Role of soil amendment with *Trichoderma viride* and carbendazim in presence of the wilt pathogen on growth and yield of tomato. *Journal of Eco-friendly Agriculture*, **6**: 194-197.

Ahmed, M., Upadhyay, R. S. 2009. Rhizosphere fungi of tomato: their effect on seed germination, seedling growth and the causal agent of wilt of tomato. *Journal of Mycopathological Research,* **47**: 99-110.

Ahmed, M., Upadhyay, R. S. 2010. Effect of soil amendment with plant growth promoting fungi on growth and yield of tomato. *Journal of Mycopathological Research,* **48**: 35-43.

Bacon, C. W., Nelson, P. E .1994.Fumonisin production in corn by toxigenic strains of *Fusarium moniliforme* and *Fusarium proliferatum*. *Journal of Food Protection,* **57**: 514-521.

Bayan, L., Koulivand, P. H., Gorji, A. 2014. Garlic: a review of potential therapeutic effects. *Avicenna Journal of Phytomedicine,* **4:** 1-14.

Benítez, T., Rincón, A. M., Limón, M. C., Codón, A. C. 2004. Biocontrol mechanisms of *Trichoderma* strains. *International Microbiology,* **7:** 249-260.

Chang, Y., Baker, R., Kleifeld, O., Chet, I. 1986. Increased growth of plants in the presence of the biological control agent *Trichoderma harzianum*. *Plant Disease*, **70**:145-148.

Contreras-Cornejo, H.A., Macías-Rodríguez, L., Cortés-Penagos, C., López-Bucio, J. 2009. *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in *Arabidopsis*. *Plant physiology*, **149**:1579-1592.

Dugan, F. M., Hellier, B. C., Lupien, S. L. 2003. First report of *Fusarium proliferatum* causing rot of garlic bulbs in North America. *Plant Pathology,* **52:** 426-426.

Fuentes, Y. M. O., Ortiz, J. C. D., Chávez, E. C., Castillo, F. D. H., Olivas, A. F., Morales, G., Martinez, O. V., Guerra, R.R. 2013. The first report of *Fusarium proliferatum* causing garlic bulb rots in Mexico. *African Journal of Agricultural Research,* **8:** 570-573.

Griffiths, G., Trueman, L., Crowther, T., Thomas, B., Smith, B. 2002. Onions—a global benefit to health. *Phytotherapy Research,* **16:** 603-615.

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., Lorito, M. 2004. *Trichoderma* species—opportunistic, avirulent plant symbionts. *Nature Reviews of Microbiology*, **2**: 43-56.

Harman, G.E. 2006. Overview of mechanism and uses of *Trichoderma* spp. *Phytopathology*, **96**: 190-194.

Harris, A.R., 1999. Plant growth promotion by binucleate *Rhizoctonia* and bacterial isolates in monoxenic cultures. *Microbiological research*, **154**: 71-74.

Jurado, M., Martín, P., Callejas, C., Moretti, A., Vázquez, C., González- Jaén, M.T. 2010. Genetic variability and fumonisin production by *Fusarium proliferatum*. *Food Microbiology*, **27**: 50-57.

Kredics, L., Antal, Z., Manczinger, L., Szekeres, A., Kevei, F. , Nagy, E., 2003. Influence of environmental parameters on *Trichoderma* strains with biocontrol potential. *Food Technology and Biotechnology*, **41**: 37-42.

Lanzotti, V. 2006. The analysis of onion and garlic. *Journal of Chromatography A,* **1112:** 3-22.

Ma, L. J., Geiser, D. M., Proctor, R. H., Rooney, A.P., O'Donnell, K., Trail, F.,Gardiner, D.M., Manner, J.M., Kazan, K. 2013. *Fusarium* pathogenomics. *Annual Review of Microbiology,* **67**: 399-416.

Marasas, W. F. O., Thiel, P.G, Rabie, C.J, Nelson, P.E., Toussoun, T.A. 1984. Moniliformin production in *Fusarium* section *Liseola*. *Mycologia*, **78**: 242-247.

Nieto Jacobo, M.F., Salazar Badillo, F.B., Rostás, M., Jiménez Bremont, J.F., Stewart, A. and Mendoza, A.M. 2017. Environmental growth conditions of Trichoderma spp. affects indole acetic acid derivatives, volatile organic compounds, and plant growth promotion. *Frontiers in Plant Science,* **8**: 102.

Nicastro, H. L., Ross, S. A., Milner, J. A. 2015. Garlic and onions: their cancer prevention properties. *Cancer Prevention Research*, **8**: 181-189.

Palmero, D. , De Cara, M., Nosir, W., GálvEz, L., Cruz, A., Woodward, S., González-Jaén, M.T., Tello, J.C. 2012. *Fusarium proliferatum* isolated from garlic in Spain: Identification, toxigenic potential and pathogenicity on related Allium species. *Phytopathologia Mediterranea*, **51**: 207-218.

Rai, S., Kashyap, P. L, Kumar, S., Srivastava, A.K., Ramteke, P.W. 2016. Identification, characterization and phylogenetic analysis of antifungal *Trichoderma* from tomato rhizosphere. *Springer Plus,* **5:** 1939.

Ravi Sankar, N. 2012. First report of *Fusarium proliferatum* causing rot of garlic bulbs (*Allium sativum*) in India. *Plant Disease*, **96**: 290.

Schuster, A., Schmoll, M. 2010. Biology and biotechnology of *Trichoderma*. *Applied Microbiology and Biotechnology,* **87:** 787-799.

Shivanna, M.B., Meera, M.S. and Hyakumachi, M., 1996. Role of root colonization ability of plant growth promoting fungi in the suppression of take-all and common root rot of wheat. *Crop protection*, **15:** 497-504.

Shivanna, M. B., Meera, M. S., Hyakumachi, M. 1994. Sterile fungi from zoysiagrass rhizosphere as plant growth promoters in spring wheat. *Canadian Journal of Microbiology,* **40:** 637-644.

Stankovic, S., Levic, J., Petrovic, T., Logrieco, A., Moretti, A. 2007. Pathogenicity and mycotoxin production by *Fusarium proliferatum* isolated from onion and garlic in Serbia. *European Journal of Plant Patholology,* **118**:165-172.

Vinale, F., Sivasithamparam, K., Ghisalberti, E.L., Woo, S.L., Nigro, M., Marra, R., Lombardi, N., Pascale, A., Ruocco, M., Lanzuise, S., Manganiello, G. 2014. *Trichoderma* secondary metabolites active on plants and fungal pathogens. *The Open Mycology Journal*, **8**: 127-139.

Warcup, J.H. 1950. The soil-plate method for isolation of fungi from soil. *Nature,***166**:117-118.

Windham, M.T., Elad, Y., Baker, R. 1986. A mechanism for increased plant growth induced by *Trichoderma* spp. *Phytopathology*, **76:** 518-521.

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Improving yield parameters in onion through antagonistic activity of *Trichoderma* spp. against *Fusarium* bulb rots disease

Geetika and Mushtaq Ahmed

Department of Environmental Sciences, School of Earth and Environmental Sciences, Central University of Himachal Pradesh, TAB Shahpur- 176206, Kangra (HP), India
E-mail: Mushtaq.cuhp@gmail.com, Mobile number: +91-98-165-30171

ABSTRACT

Onion, a leading vegetable crops among the species of *Allium* all over the globe by virtue of its having medicinal properties, is well known for its economicae importance throughout the world. However, recently many workers have reported that a pathogenic fungus, *Fusarium proliferatum*, known to infect a wide range of crop and ornamental plants, is causing bulb rots disease in onion. The current study reveals that this pathogenic fungus has lethal effect on onion plantlets. Chemicals are used to combate this disease, but these being unfriendly to non-target organisms, the bio control agents namely, *Trichoderma harzianum/Hypocrea lixii*, *Trichoderma viride* and *Trichoderma asperellum* were evaluated. The results revealed that *T. harzianum/H. lixii, T. viride* and *T. asperellum* used in combination restrained the infection and enhanced the onion yield.

Key words: *Trichoderma* spp; bulb rot pathogen; onion yield.

Onion (*Allium cepa* L.), a member of Liliaceae family, is a biennial plant cultivated all around the world for its food, therapeutic and medicinal values (Wang *et al*., 2012). Onion is a rich source of vitamin C, folic acid, biotin, calcium, B6, potassium, chromium, quercitin and dietary fibers (Othman *et al*., 2011). Various sulphur containing compounds present in onion provide a number of health benefits like detoxification of body, heart disease prevention, cancer prevention and blood sugar lowering action (Nicastro *et al*., 2015). Although onions are associated with a number of benefits but these plants are very sensitive to climate and soil conditions (Griffiths *et al.,* 2002). Usually onions do not grow in the soil with high percentage of clay and high salinity (Griffiths *et al.,* 2002). They are vulnerable to a number of diseases like downy mildew, onion smut, onion smudge, white rot, neck rot, soft rot, aster yellow and onion thrips caused by fungi, bacteria, viruses and insects (Akhtar and Javaid 2018). Recently a new disease, namely bulb rots of *Allium* has been reported by many workers from different countries over the globe (Palmero *et al*., 2012; Fuentes *et al*., 2013). The pathogen namely, *Fusarium proliferatum* causes the disease (Fuentes *et al.,* 2013). On infection with the pathogen, the onion plants show water soaked like appearance of their bulbs leading to drooping off of leaves resulting in huge yield losses (Haapalainen *et al.,* 2016). Besides, onion, the pathogen is also reported to infect a wide variety of crop and ornamental plants (Ichikawa and Takayuki 2000). The pathogen is reported to easily get acclimatized to different geographical and climate conditions (Ferrigo *et al*., 2016). As mentioned above, the pathogen is highly notorious resulting in huge yield losses and hence its management is indispensable. Chemical pesticides are routinely used to combat the pathogen but the chemicals not being safe for the ecosystem, their use needs to be discouraged (Benítez *et al*., 2004). Moreover, the use of chemicals results in the evolution of chemical resistant strains of the pathogen over a period of time (Benítez *et al*., 2004). A safe alternative to such hazardous chemicals are the bio control agents such as *Trichoderma* spp. that naturally exist in the crop rhizosphere and are beneficial to them (Mushtaq and Upadhyay, 2010). *Trichoderma* spp. have been reported for their bio control activity against a number of pathogenic fungi (Schuster and Schmoll 2010; Rai *et al*., 2016). These bio control agents not only prevent diseases in plant but also enhance the crop productivity (Rai *et al*., 2016). In the present work, the effect of different combination of *Trichoderma* spp. on the pathogen *in vitro* was studied.

MATERIALS AND METHODS

Soil samples for isolation of the fungi were collected from dumping sites in Dharamshala area of Himachal Pradesh and the agricultural fields at Varanasi, Uttra Pradesh. All of the samples were collected in sterile polyethene bags and brought to Environmental Sciences laboratory at the Central University of Himachal Pradesh, Dharamshala for further studies. The soil fungi were isolated using the standard methodology (Warcup, 1950). Identification of the fungal isolates was established through direct sequencing of 18s rRNA gene. The isolates included *Trichoderma asperellum* (MF661885.1), *Trichoderma harzianum/ H. lixii* (MF661969.1), *Trichoderma viride* (MF663724.1) and *Fusarium proliferatum* (MF661933.1). These three isolates of *Trichoderma* are well known for their antagonistic activity against a number of plant pathogens and hence are of immense significance for agricultural practices. The fourth isolate namely, *Fusarium proliferatum* is reported to be pathogenic causing a number of diseases in crop plants such as wilts and rots. Mass culture of each isolate was separately prepared using standard protocol (Shivanna *et al.,* 1994).

The onion seeds were taken from the local farmers in Shahpur area of Dharamshala, Himachal Pradesh and brought to the laboratory. Previously autoclaved and finely ground soil was taken in few cardboard boxes. 35-40 onion seeds were sown per cardboard box. These cardboard boxes were watered properly and covered with thick jute cloth in order to maintain moisture and darkness for proper germination of the seeds. Water was sprinkled regularly 2-3 times per day upon the cloth to provide the adequate moisture to the seeds. Seeds were also checked for their growth regularly. After seven days onion seeds were found to be germinated with cent percent survival rates. After three days of seed germination the cover cloth was removed and seedlings were allowed to grow upto few centimeters height. When the seedlings attained the height upto 6.0-6.5 cm, the plantlets were lifted carefully and subjected to different treatments in already prepared different experimental pots. Only healthy plantlets were used for further experiments.

The onion plantlets were subjected to nine different treatments comprising of the control with no treatment given to the onion plantlets, the pot soil mixed with the mass culture of the pathogen *F. proliferatum, T. harzianum/H. lixii, F. proliferatum* with the fungicide carbandazim (1% w/w), *T. harzianum/H. lixii* (1% w/w) with carbendazim, *T. harzianum/ H. lixii* and *F. proliferatum* carbendazim, *T. harzianum/H. lixii* and *F. proliferatum,* and consortium of *T. harzianum/H. lixii* , *Trichoderma viride*, *Trichoderma asperellum* and consortium of *T. harzianum/H. lixii* , *Trichoderma viride*, *Trichoderma asperellum* and *F. proliferatum*.

Each and every treatments tested in 28 replications was supplemented with 5 per cent pre-autoclaved farm yard manure that was slightly moistened with distilled water. These experimental pots were incubated at room temperature for seven days for proper colonization of the fungi with the soil. After interval of seven days two onion plantlets were planted into the each pots. The pots were kept in sunlight under natural conditions for proper growth of the plantlets and were regularly watered. The growth of the onion plantlets for each treatment was observed by evaluating each of the yield parameter after a fixed time interval at 10^{th}, 30^{th}, 50^{th}, 70^{th}, 90^{th}, 110^{th}, 130^{th}, 150^{th}, 170^{th}, 190^{th}, and 210^{th} days after sowing (Table 3 to 11). Five parameters, namely the length of shoot (LDS), fresh weight of plant (FWP, dry weight of plant (DWP), weight of bulb (WDB) and diameter of bulb were used to analyze the growth and yield of the onion plants.

The diameter and the circumference of the onion bulb was measured with the help of a thread using the following formula:

$$\text{Circumference} = 2\pi r$$

Percentage increase in the yield parameters was computed by using the formula given below.

$$= \frac{\text{Control-Treatment}}{\text{Control}} \times 100$$

Statistical analysis was performed in Sigma Plot ver.11.0 software. These analyses were done by comparing the means using one-way ANOVA test and found to be significant with p d≤ 0.001 levels.

RESULTS AND DISCUSSION

pH and texture of analyzed soil

The soil consisted of 13, 44 and 43 per cent clay, sand and silt, respectively with pH of approximately 6. Hence, this was found most suitable for proper growth of the onion plants. Moreover, the clay content was also less in the soil and therefore, the soil texture was also appropriate for proper growth of onion plants.

Strain selection among *Trichoderma* isolates

T. harzianum/H. lixii showed comparatively better colony growth in presence of different values of pH (5.5, 6.0 and 6.5) and different concentrations (0.10, 0.15, 0.20, 0.25 and 0.30 g/100 ml) of the fungicide i.e. carbendazim (Table 1 and 2) under *in vitro* conditions. This was therefore, selected as the most potent strain among the three isolates of *Trichoderma* spp., the other two being *Trichoderma viride* and *Trichoderma asperellum.*

Table 1: Effect of pH on *Trichoderma* spp. under *in vitro* conditions

pH	Colony Diameter (in cm)		
	T.asperellum	*T.harzianum/H.lixii*	*T.viride*
5.5	8.0±0.01	9.0±0.01	8.5±0.01
6.0	8.0±0.01	9.0±0.01	8.5±0.01
6.5	8.0±0.01	9.0±0.01	8.5±0.01

Table 2 : Effect of fungicide on *Trichoderma* spp. under *in vitro* conditions

Fungicide (g/100ml)	Colony Diameter (in cm)		
	T.asperellum	*T.harzianum/H.lixii*	*T.viride*
0.1	7.0±0.01	8.0±0.01	7.5±0.01
0.15	6.5±0.01	8.0±0.01	7.5±0.01
0.20	6.0±0.01	7.5±0.01	7.0±0.01
0.25	5.5±0.01	7.0±0.01	6.5±0.01
0.30	5.2±0.01	7.0±0.01	6.0±0.01

Effect of pathogen on onion plant

The pathogen namely, *F. proliferatum* was found to have lethal effect on the onion plantlets. The plantlets, planted in the pots inoculated with the pathogen only, were not able to survive and died within five days. The experiment was repeated and same result was obtained again and again (Figure 9). The lethality of the pathogen might be due to the production of various toxins that interfered with the growth

Table 3: Assessment of the growth and yield parameters of onion at different time intervals under control conditions

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	8.02±0.03	0.17858±0.01	0.02322±0.01	-	-
30th	11.02±0.03	0.29462±0.01	0.02696±0.01	-	-
50th	15.26±0.07	0.31474±0.01	0.04088±0.01	-	-
70th	17.46±0.10	0.57060±0.01	0.07410±0.01	-	-
90th	20.12±0.03	1.87826±0.01	0.24414±0.01	0.03110±0.01	0.304±0.01
110th	26.88±0.04	2.51986±0.03	0.32758±0.01	0.08240±0.01	0.660±0.02
130th	29.62±0.17	4.70150±0.01	2.35182±0.01	1.06310±0.02	1.040±0.02
150th	32.64±0.02	11.75208±0.09	5.40436±0.15	3.01538±0.03	1.560±0.02
170th	37.94±0.02	17.72618±0.08	9.69818±0.13	5.92830±0.04	1.980±0.04
190th	42.70±0.12	25.51926±0.19	15.89150±0.05	9.97074±0.14	2.420±0.04
210th	50.70±0.12	33.49218±0.22	19.97716±0.04	16.58900±0.18	2.460±0.02

Table 4: Effect of pathogen (*F. proliferatum*) on the growth and yield of onion plantlets

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)	NOC
1st	8.04±0.04	-	-	-	-	-
5th	8.04±0.04	-	-	-	-	-

Table 5: Effect of *T. harzianum/H. lixii* on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	10.06±0.09	0.19444±0.01	0.02526±0.01	-	-
30th	13.02±0.01	0.32894±0.01	0.04276±0.01	-	-
50th	16.02±0.01	0.45640±0.01	0.05930±0.01	-	-
70th	19.56±0.05	0.58950±0.01	0.07656±0.01	-	-
90th	21.06±0.02	1.87356±0.01	0.23962±0.01	0.02924±0.01	0.302±0.01
110th	26.84±0.15	2.52090±0.01	0.32770±0.01	0.08336±0.01	0.702±0.01
130th	29.12±0.09	5.82000±0.03	1.43802±0.01	0.09224±0.01	0.904±0.01
150th	31.64±0.03	15.13250±0.07	7.40752±0.04	4.63716±0.07	2.020±0.01
170th	43.60±0.09	20.81276±0.19	11.72264±0.10	7.57758±0.08	3.420±0.01
190th	49.60±0.09	28.60542±0.55	17.39864±0.30	14.78896±0.01	4.820±0.01
210th	53.92±0.01	41.38718±0.15	27.20172±0.04	23.43132±0.03	6.020±0.01

Table 6: Synergetic effect of fungicide and *F. proliferatum* (pathogen) on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	10.10±0.03	0.13528±0.01	0.01754±0.01	-	-
30th	13.28±0.07	0.37432±0.01	0.04856±0.01	-	-
50th	16.74±0.14	0.49708±0.01	0.06460±0.01	-	-
70th	19.64±0.10	0.60916±0.02	0.07918±0.01	-	-
90th	23.88±0.05	1.92350±0.02	0.25004±0.01	0.04516±0.01	0.352±0.01
110th	27.18±0.11	2.60122±0.02	0.36812±0.01	0.08346±0.01	0.704±0.01
130th	29.02±0.02	5.93910±0.01	1.50082±0.01	1.01036±0.01	1.020±0.02
150th	34.44±0.04	12.21052±0.11	5.70514±0.07	2.77406±0.04	2.020±0.02
170th	37.52±0.02	18.59476±0.03	11.80172±0.07	5.75250±0.02	2.820±0.02
190th	41.22±0.02	25.57190±0.03	14.83262±0.03	9.77696±0.06	4.020±0.02
210th	48.52±0.02	34.97110±0.02	19.70344±0.08	16.32804±0.13	4.620±0.02

Table 7: Synergetic effect of fungicide and *T. harzianum/H. lixii* on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	11.06±0.03	0.18444±0.01	0.02360±0.01	-	-
30th	14.12±0.01	0.50030±0.01	0.06496±0.01	-	-
50th	17.42±0.01	0.70080±0.01	0.09200±0.01	-	-
70th	20.22±0.05	0.77994±0.01	0.10134±0.01	-	-
90th	23.56±0.03	1.95548±0.01	0.25428±0.01	0.04150±0.01	0.352±0.01
110th	30.30±0.09	3.13672±0.02	0.40772±0.01	0.08402±0.01	0.702±0.01
130th	32.56±0.03	7.38672±0.07	2.14788±0.02	1.34108±0.01	1.020±0.01
150th	34.42±0.01	15.27806±0.10	7.56926±0.10	2.77700±0.04	2.020±0.01
170th	39.22±0.01	19.46850±0.09	15.42582±0.08	5.83368±0.03	2.920±0.01
190th	48.62±0.01	26.35660±0.10	19.37060±0.07	10.84336±0.05	4.120±0.01
210th	51.88±0.07	35.34524±0.21	22.29574±0.22	18.74750±0.09	4.820±0.01

Table 8: Synergetic effect of fungicide, *T. harzianum/H. lixii* and *F. proliferatum* (pathogen) on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	10.16±0.03	0.11774±0.01	0.01524±0.01	-	-
30th	14.02±0.01	0.46560±0.01	0.05878±0.01	-	-
50th	17.20±0.03	0.61226±0.02	0.07954±0.01	-	-
70th	20.30±0.06	0.62650±0.01	0.08144±0.01	-	-
90th	24.02±0.01	1.94674±0.01	0.25382±0.01	0.04204±0.01	0.352±0.01
110th	28.16±0.11	3.04776±0.01	0.39618±0.01	0.08674±0.01	0.702±0.01
130th	30.52±0.02	10.79910±0.14	4.50140±0.13	1.92398±0.01	1.040±0.03
150th	34.02±0.02	16.48760±0.11	8.70736±0.06	3.94776±0.03	2.020±0.02
170th	40.26±0.06	19.10090±0.13	10.80836±0.24	6.85746±0.02	3.220±0.02
190th	48.10±0.10	27.65702±0.32	16.80370±0.07	12.81772±0.06	4.520±0.02
210th	52.26±0.19	40.68742±0.27	25.39852±0.20	19.62390±0.10	5.020±0.02

Table 9: Synergetic effect of *T. harzianum/H. lixii* and *F.proliferatum* (pathogen) on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	11.08±0.11	0.18196±0.01	0.02364±0.01	-	-
30th	16.94±0.09	0.52072±0.01	0.06766±0.01	-	-
50th	20.18±0.04	0.73338±0.01	0.09532±0.01	-	-
70th	27.02±0.02	0.7989±0.01	0.10184±0.01	-	-
90th	25.22±0.08	1.1394±0.01	0.14806±0.01	0.05700±0.01	0.402±0.01
110th	31.82±0.21	1.79524±0.01	0.23324±0.01	0.09014±0.01	0.802±0.01
130th	33.78±0.08	2.91872±0.01	1.26698±0.01	1.10418±0.01	1.020±0.01
150th	35.52±0.20	17.51138±0.25	7.52756±0.01	5.93562±0.01	2.020±0.01
170th	45.68±0.08	25.40604±0.14	13.81542±0.04	9.85198±0.12	3.420±0.01
190th	51.44±0.14	30.35174±0.18	19.4732±0.21	16.54412±0.11	4.820±0.01
210th	55.84±0.04	41.7929±0.06	30.41258±0.29	25.80048±0.03	6.020±0.01

of the plantlets. *Fusarium* spp. are known to produce a number of mycotoxins that are reported to be harmful to plant, human and animals (Waœkiewicz and Stêpieñ 2012). *F. proliferatum* has been reported to produce a number of secondary metabolites such as trichothecene, zearalenone and fumonisins (Ma *et al.*, 2013). These mycotoxins have been reported to be most harmful compounds to human and animals as they can promote cancer and other serious diseases when consumed (Waœkiewicz and Stêpieñ 2012). There are many members of *Fusarium* spp. including *F. verticillioides, F. temperatum, F. polyphialydium, F. proliferatum* and *F. lactis* which can infect a number of host plants such as onion, garlic, pineapple, banana, wheat, maize and rice without showing any symptoms of infection (Waœkiewicz and Stêpieñ 2012). Moreover various biotic and abiotic factors have also been reported to influence the growth of these phytopathogenic fungi and hence their ability to produce mycotoxins (Alberts *et al.*, 2016). But abiotic factors play more important role in pathogen growth as compared to biotic factors (Alberts *et al.*, 2016). It has been reported that temperature and high humidity promote the growth and mycotoxin production of *Fusarium* spp. (Alberts *et al.*, 2016).

Table 10: Effect of consortium *of Trichoderma* strains on the growth and yield of onion at different time intervals

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	11.44±0.03	0.20948±0.01	0.02718±0.01	-	-
30th	18.06±0.04	0.60050±0.01	0.08060±0.01	-	-
50th	21.28±0.06	0.84992±0.01	0.10832±0.01	-	-
70th	27.34±0.04	0.88766±0.01	0.11820±0.01	-	-
90th	30.08±0.05	1.28106±0.01	0.16730±0.01	0.05870±0.01	0.402±0.01
110th	34.10±0.10	3.33044±0.08	0.42749±0.01	0.09606±0.01	0.920±0.02
130th	36.02±0.02	15.50956±0.31	8.07134±0.03	3.85542±0.06	1.520±0.02
150th	38.12±0.02	27.85688±0.03	15.51438±0.12	7.63586±0.11	2.120±0.02
170th	44.58±0.08	38.71758±0.09	21.77118±0.08	12.83840±0.13	3.520±0.02
190th	52.92±0.02	50.88236±0.24	27.33840±0.10	18.68134±0.27	4.820±0.02
210th	56.50±0.16	60.31690±0.28	41.25608±0.10	32.40450±0.14	6.220±0.02

Table 11: Synergetic effect of consortium *of Trichoderma* spp. in presence of the pathogen on the growth and yield of onion at different intervals of time

Day	LOS (in cm)	FWP (in g)	DWP (in g)	WOB (in g)	DOB (in cm)
10th	11.76±0.04	0.26000±0.01	0.03398±0.01	-	-
30th	18.50±0.09	0.62514±0.01	0.08122±0.01	-	-
50th	22.42±0.35	0.84936±0.03	0.11038±0.01	-	-
70th	28.60±0.03	0.99274±0.01	0.12924±0.01	-	-
90th	32.90±0.24	2.72138±0.04	0.36444±0.01	0.07040±0.01	0.62±0.02
110th	35.30±0.12	4.86952±0.02	0.65053±0.01	0.16586±0.01	1.02±0.02
130th	38.56±0.04	16.81246±0.09	12.95590±0.02	7.28970±0.36	2.12±0.02
150th	44.48±0.02	35.81298±0.18	18.73486±0.04	13.64284±0.32	2.88±0.02
170th	50.54±0.04	49.17110±0.26	31.94490±0.04	25.24852±0.38	3.72±0.02
190th	56.76±0.04	59.68586±0.01	37.16514±0.21	32.43890±0.17	5.38±0.02
210th	58.34±0.04	75.88786±0.07	48.84780±0.21	42.98822±0.02	6.58±0.02

These results are in accordance with the earlier findings that showed the harmful effect of *F. proliferatum* during the early stage of the plant growth (Palmero *et al*., 2012).

Table 12: Comparison of percent increase in the yield parameters of onion after different treatments

Treatment	Percentage (%) increase in growth and yield parameters				
	LOS	FWP	DWP	WOB	DOB
Control	0*	0	0	0	0
Pathogen	-**	-	-	-	-
T. harzianum/H. lixii	6.35*	23.56	36.20	41.31	144.72
fungicide + pathogen	-4.30†	4.42	-1.35	-1.57	87.80
fungicide + *T. harzianum/H. lixii*	2.33	5.52	11.61	13.03	14.63
Fungicide+ *T. harzianum/H. lixii* + pathogen	3.07	21.47	27.14	18.34	104.07
***T. harzianum/H. lixii* + pathogen**	10.14	24.78	52.28	55.61	144.72
consortium	11.44	80.08	106.56	95.42	152.85
Consortium + pathogen	15.06	126.57	144.56	159.20	167.47

*Value according to the formula of the percent yield as mentioned in materials and methods. **Not recorded †Value is less as compared to control

Effect of various treatments on growth and yield of onion plants

Various treatments (Table 2-12 below) were applied to the onion plantlets to see their effect on growth and yield of the plantlets. Parameters used to estimate the growth and yield of the onion plant were length of shoot (LOS), fresh weight of plant (FWP), dry weight of the plant (DWP), weight of bulb (WOB) and diameter of bulb (DOB). These observations were recorded at 10th, 30th, 50th, 70th, 90th, 110th, 130th, 150th, 170th, 190th, and 210th days after sowing (DAS). During experiments it was found that all the treatments had significant difference from the control (p d” 0.001). It was found that the treatment of the onion plant with consortium of *T. asperellum*, *T. harzianum/H. lixii* and *T. viride* with and without the pathogen treatment had maximum impact on the growth and yield parameters of the onion plant as compared to other treatments that were applied to them (Table 3 to 12).

Maximum shoot length was recorded with consortium of *Trichoderma* isolates (Table10 and 11, Figure.1) followed by *T. harzianum/H. lixii* (Table 5 and 9, Figure.1) and fungicide + *T. harzianum/H. lixii* treatments (Table 7 and 8, Figure.1) as compared to control (p d” 0.001) at 210th DAS. The fungicide + pathogen treatment had lesser effect on the shoot length of the plants as compared to control (p d" 0.001) at 210th DAS (Table 6 and 12, Figure.1). During experiments it was also found that shoot length was not too much affected with difference in treatments as there was almost equal shoot length under each treatment (Figure.1).

Fresh and dry weight of the plants showed variations. It was found that maximum fresh weight of the plant was recorded with consortium treatment (Table10 and 11, Figure. 2) followed by *T. harzianum/H. lixii* treatment (Table 5 and 9, Figure. 2), fungicide + *T. harzianum/H. lixii* (Table 7 and 8,

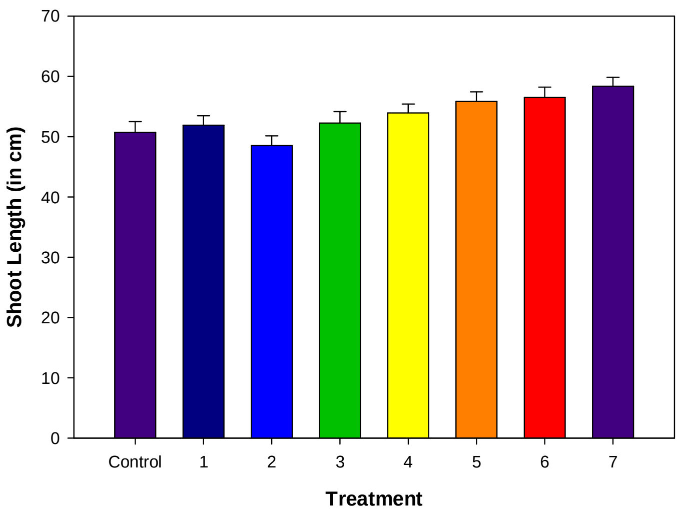

Fig. 1. Comparison of shoot length between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/ H.lixii* and pathogen **(4)** *T. harzianum H.lixii* **(5)** *T. harzianum /H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

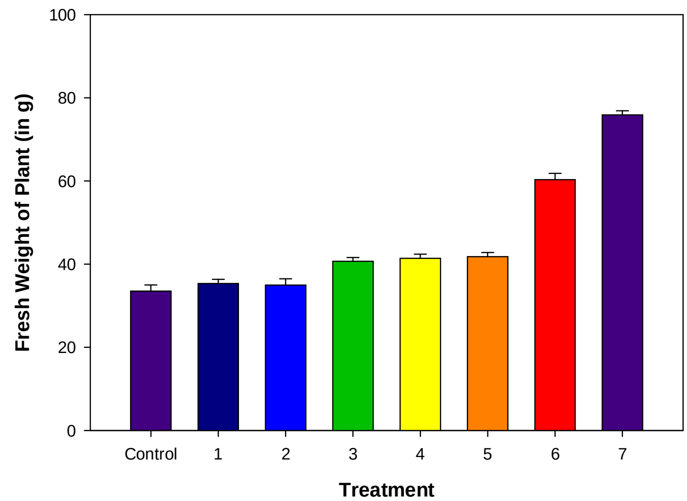

Fig. 2. Comparison of fresh plant weight between control and treatments; **(1)** Fungicide and *T. harzianum/ H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

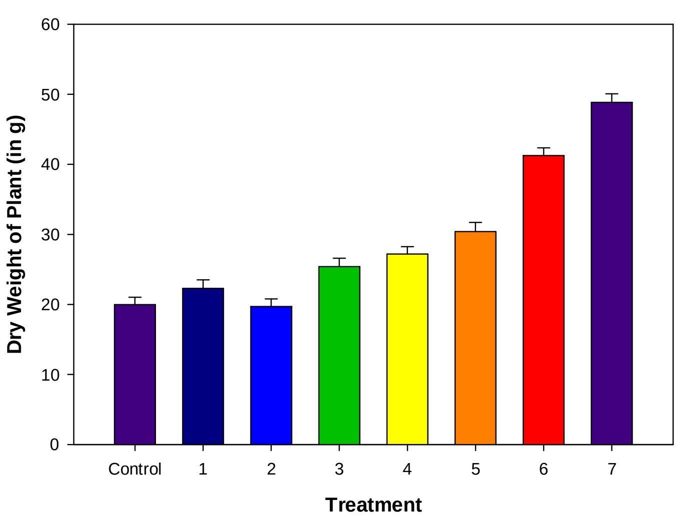

Fig. 3. Comparison of plant dry weight between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

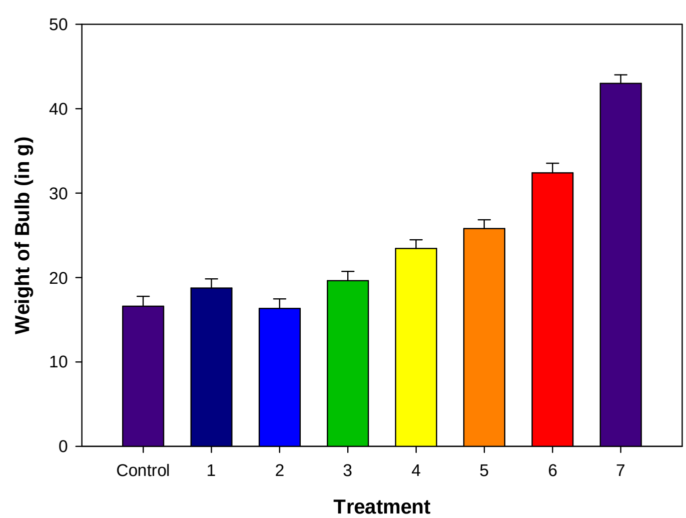

Fig. 4. Comparison of bulb weight between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

Figure.2), and fungicide + pathogen treatment (Table 6, Figure. 2) as compared to control (p d” 0.001) at 210th DAS. While in case of dry weight of plant highest weight was recorded with consortium (Table10 and 11, Figure.3) followed by *T. harzianum/H. lixii* (Table 5 and 9, Figure.3) and fungicide + *T. harzianum/H. lixii* treatment (Table 7 and 8, Figure.3) as compared to control (p d” 0.001) at 210th DAS. The fungicide + pathogen treatment had lesser effect on the dry weight of the plants as compared to control (p d” 0.001) at 210th DAS (Table 6 and 12, Figure.3). Fresh and dry weight of plants showed about one fold increase in case of consortium treatments as compared to control (p d” 0.001).

Maximum bulb weight was recorded with consortium treatments (Table10 and 11, Figure.4) followed by *T. harzianum/H. lixii* treatment (Table 5 and 9, Figure.4) and fungicide + *T. harzianum/H. lixii* treatment (Table 7 and 8, Figure.4) as compared to control (p d” 0.001) at 210th DAS. Again the fungicide + pathogen treatment had slighter effect on the weight of bulb of the plants as compared to control (p d” 0.001) at 210th DAS (Table 6 and 12, Figure.4). Whereas, in case of diameter of the bulb highest bulb diameter was recorded with consortium treatments (Table10 and 11, Figure. 5) followed by *T. harzianum/H. lixii* (Table 5 and 9, Figure. 5), fungicide + *T. harzianum/H. lixii* (Table 7 and 8, Figure.5), and fungicide + pathogen treatment (Table 6, Figure. 5) as compared to control (p d” 0.001) at 210th DAS. Weight and diameter of the bulb of the onion plants was about two fold increased for consortium treatments as compared to control (p d” 0.001).

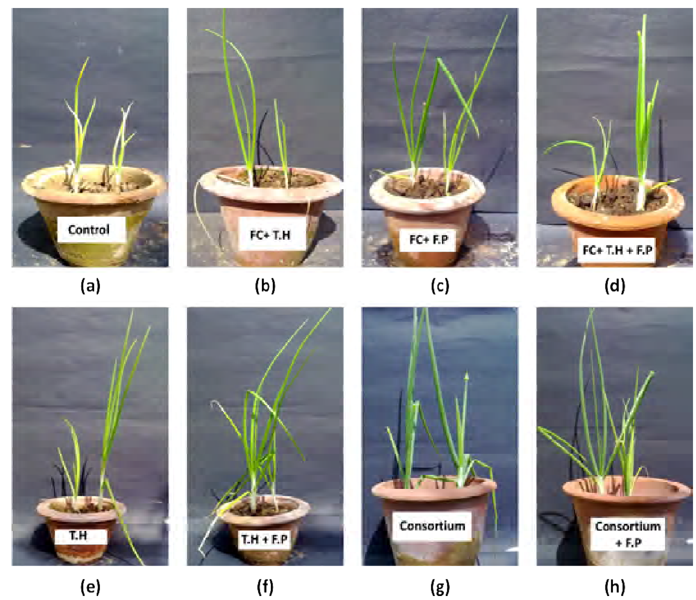

Fig. 6. Experimental pots comparison of treatments; **(a)** Control **(b)** Fungicide and *T. harzianum/H.lixii* **(c)** Fungicide and pathogen **(d)** Fungicide, *T. harzianum/H.lixii* and pathogen **(e)** *T. harzianum/H.lixii* **(f)** *T. harzianum/H.lixii* and pathogen **(g)** Consortium **(h)** Consortium and pathogen.

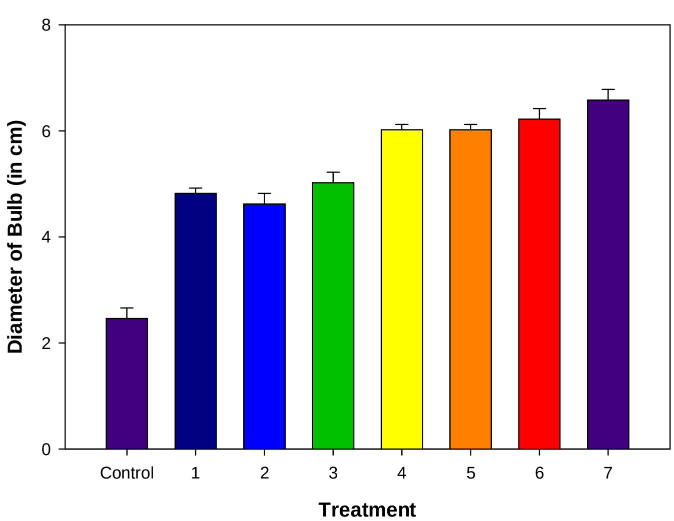

Fig. 5. Comparison of bulb diameter between control and treatments; **(1)** Fungicide and *T. harzianum/H.lixii* **(2)** Fungicide and pathogen **(3)** Fungicide, *T. harzianum/H.lixii* and pathogen **(4)** *T. harzianum/H.lixii* **(5)** *T. harzianum/H.lixii* and pathogen **(6)** Consortium **(7)** Consortium and pathogen.

Fig. 7. Freshly uprooted plants at different intervals of time **(a)** Seedlings at 1st day; inset- nursery **(b)** 10th day **(c)** 30th day **(d)** 90th day **(e)** 150th day **(f)** 210th day, having order of treatments; **(1)** Control **(2)** Fungicide and *T. harzianum/H.lixii* **(3)** Fungicide and pathogen **(4)** Fungicide, *T. harzianum/H.lixii* and pathogen **(5)** *T. harzianum/H.lixii* **(6)** *T. harzianum/H.lixii* and pathogen **(7)** Consortium **(8)** Consortium and pathogen.

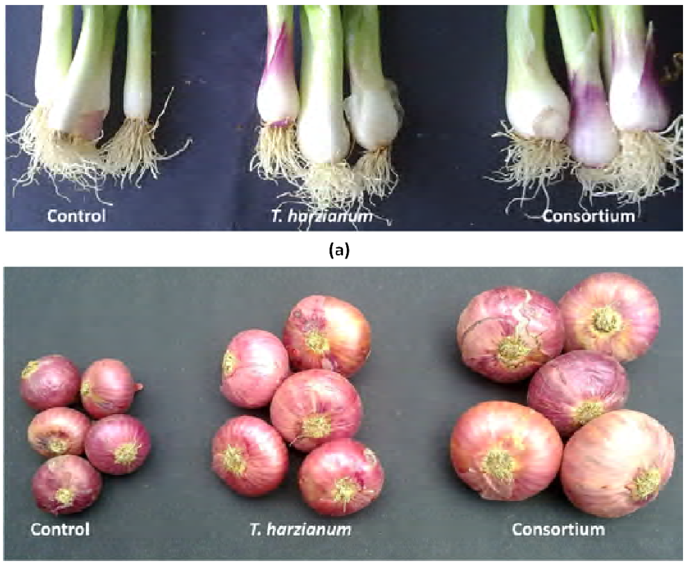

Fig. 8. Bulb Comparison on **(a)** 100th day and **(b)** 210th day

(a) (b)

Fig. 9. Effect of pathogen on onion plantlets **(a)** First day of plantation **(b)** Day fifth after plantation; Circle showing colonization of *F. proliferatum* with soil.

CONCLUSION

It was concluded that the consortium treatment not only inhibited the effect of pathogen on the plants but also increased the onion yield. Use of chemical fungicides alone to control the pathogen is not a prudent decision as the chemicals can lead to the development of fungicide resistant strains of the pathogenic fungi in due course of time and also have adverse effect on environment, humans and animals (Benítez *et al.*, 2004). Hence, the use of bio control agents such as *Pseudomonas* and *Trichoderma* spp. is better alternative (Ahmed and Upadhyay, 2009). *Trichoderma* spp. are most commonly known bio control agents. Species of *Trichoderma* are considered very effective because of their ability to produce a large number of cell wall degrading enzymes (CWDEs) that are responsible for cell wall destruction of the pathogens especially fungi and also play major role in induced systemic response (ISR) in plants (Hermosa *et al.*, 2012). Moreover *Trichoderma* spp. normally inhabits the rhizosphere of the plant (Alberts *et al.*, 2016). Many plant growth promoting fungi (PGPF) such as *Trichoderma* spp., *Aspergillus* spp. and *Penicillium* spp. have been reported to mineralize various organic substances present in the soil and also produce beneficial compounds aiding the plants in the uptake of necessary nutrients for growth (Nieto Jacobo *et al.*, 2017). Hence bulbs rot disease caused by *F. proliferatum* can be efficiently managed using *Trichoderma* spp. that also increase the yield of the onion plants.

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REFERENCES

Ahmed, M., Upadhyay, R. S. 2011. Role of soil amendment with *Trichoderma viride* and carbendazim in presence of the wilt pathogen on growth and yield of tomato. *Journal of Eco-friendly Agriculture*, **6**: 194-197.

Ahmed, M., Upadhyay, R. S. 2009. Rhizosphere fungi of tomato: their effect on seed germination, seedling growth and the causal agent of wilt of tomato. *Journal of Mycopathological Research*, **47**: 99-110.

Ahmed, M., Upadhyay, R. S. 2010. Effect of soil amendment with plant growth promoting fungi on growth and yield of tomato. *Journal of Mycopathological Research*, **48**: 35-43.

Akhtar, R., and Javaid, A. 2018. Biological Management of Basal Rot of Onion by *Trichoderma harzianum* and *Withania somnifera*. *Planta Daninha*, **36:** 1-7.

Alberts, J. F., Van Zyl, W. H., and Gelderblom, W. C. 2016. Biologically based methods for control of fumonisin-producing *Fusarium* species and reduction of the fumonisins. *Frontiers in microbiology*, **7**:1-33.

Benítez, T., Rincón, A. M., Limón, M. C., and Codón, A. C. 2004. Biocontrol mechanisms of *Trichoderma* strains. *International Microbiology*. **7:** 249-260.

Che Othman, S. F., Idid, S. O., Idid, S. Z., Koya, M. S., Mohamed Rehan, A., and Kamarudin, K. R. 2011. Antioxidant study of garlic and red onion: a comparative study. *Pertanika Journal of Tropical Agricultural Science*. **34:** 253-261.

Ferrigo, D., Raiola, A., and Causin, R., 2016. *Fusarium* toxins in cereals: occurrence, legislation, factors promoting the appearance and their management. *Molecules* **21:** 627.

Fuentes, Y. M. O., Ortiz, J. C. D., Chávez, E. C., Castillo, F. D. H., Olivas, A. F., Morales, G., *et al* ., 2013. The first report of *Fusarium proliferatum* causing garlic bulb rots in Mexico. *African Journal of Agricultural Reserrch*. **8:** 570-573.

Haapalainen, M., Latvala, S., Kuivainen, E., Qiu, Y., Segerstedt, M., and Hannukkala, A. O. 2016. *Fusarium oxysporum*, *F. proliferatum* and *F. redolens* associated with basal rot of onion in Finland. *Plant Pathology*. **65:** 1310-1320.

Hermosa, R., Viterbo, A., Chet, I., and Monte, E., 2012. Plant-beneficial effects of *Trichoderma* and of its genes. *Microbiology*. **158:** 17-25.

Griffiths, G., Trueman, L., Crowther, T., Thomas, B., and Smith, B. 2002. Onions—a global benefit to health. *Phytotherapy research*. **16:** 603-615.

Ma, L. J., Geiser, D. M., Proctor, R. H., Rooney, A.P., O'Donnell, K., Trail, F.,Gardiner, D.M., Manner, J.M., Kazan, K. 2013. *Fusarium* pathogenomics. *Annual Review of Microbiology,* **67**: 399-416.

Nieto Jacobo, M.F., Salazar Badillo, F.B., Rostás, M., Jiménez Bremont, J.F., Stewart, A. and Mendoza, A.M. 2017. Environmental growth conditions of Trichoderma spp. affects indole acetic acid derivatives, volatile organic compounds, and plant growth promotion. *Frontiers in Plant Science,* **8**: 102.

Nicastro, H. L., Ross, S. A., and Milner, J. A. 2015. Garlic and onions: their cancer prevention properties. *Cancer Prevention Research*. **8:** 181-189.

Palmero, D. A. N. I. E. L., De Cara, M., Nosir, W. A. L. I. D., GálvEz, L. A. U. R. A., Cruz, A. L. E. J. A. N. D. R. A., WooDWarD, S. T. E. P. H. E. N., ... and TEllo, J. C. 2012. *Fusarium proliferatum* isolated from garlic in Spain: Identification, toxigenic potential and pathogenicity on related Allium species. *Phytopathologia Mediterranea.* 207-218.

Rai, S., Kashyap, P. L, Kumar, S., Srivastava, A.K., and Ramteke, P .W. 2016. Identification, characterization and phylogenetic analysis of antifungal *Trichoderma* from tomato rhizosphere. *Springer Plus*. **5:** 1939.

Schuster, A., and Schmoll ,M. 2010. Biology and biotechnology of *Trichoderma. Applied Microbiology and Biotechnology.* **87:** 787-799.

Shivanna, M. B., Meera, M. S., and Hyakumachi, M. 1994. Sterile fungi from zoysiagrass rhizosphere as plant growth promoters in spring wheat. *Canadian Journal of Microbiology*. ***40*:** 637-644.

Wang, Y., Tian, W. X., and Ma, X. F. 2012. Inhibitory effects of onion (*Allium cepa* L.) extract on proliferation of cancer cells and adipocytes via inhibiting fatty acid synthase. *Asian Pacific Journal of Cancer Prevention*. **13:** 5573-5579.

Waœkiewicz, A., and Stêpieñ, £. 2012. Mycotoxins Biosynthesized by Plant-Derived Fusarium Isolates/Tvorba Mikotoksina U Vrstama Roda Fusarium Izoliranim Iz Biljaka. *Archives of Industrial Hygiene and Toxicology*. **63:** 437-446.

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