# National Symposium on Integrated Pest Management for Sustainable Crop Protection

Division of Entomology
ICAR-Indian Agricultural Research Institute
New Delhi 110 012, India

# National Symposium on Integrated Pest Management for Sustainable Crop Protection

**24 - 25 February, 2015**

# Souvenir and Abstracts

*Edited by*

**M.K. Dhillon and G.T. Gujar**

*Organized by*

**Division of Entomology**
**ICAR-Indian Agricultural Research Institute**
**New Delhi 110 012, India**

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# Foreword

The Green Revolution has helped the country in attaining and maintaining self-sufficiency in food grains from early 1970s to date. However, the Indian population is likely to cross 1.6 billion before near-stabilization by 2030, and the food demand is expected to rise up to ~400 million tonnes by the year 2050. Rising cost of cultivation has adversely impacted the profitability, and farming no longer remains an attractive option. Stagnation of growth rate in productivity of many crops, declining land resources, and biotic stresses including insects, pathogens, nematodes and weeds are the major limiting factors in realization of yield potential of crop plants to meet the challenge of increasing food demand. It is estimated that the losses due to pests in India range from 20 to 32%. Even considering an average annual loss of production, the country is loosing around 39 million tons of food grains and equal quantity of fruits and vegetables, which when added to the current production figures are targets of achievements by 2025. The problem will be further aggravated in view of climate change, the changing agricultural practices, environment, and more intensive cropping systems. Therefore, crop protection assumes high significance in the overall food security of the country in the years to come.

In recent years, crop protection has seen over-dependence on pesticides, which along with increase in crop production cost also causes harmful effects to the users, consumers, and to the environment. At the same time there has also been a tremendous change in the pest spectrum and qualitative shift in pest management tactics. Insect-resistant cultivars, natural plant products, biopesticides, and natural enemies are some of the safer alternatives to synthetic pesticides. Recently, the modern tools of biotechnology have also opened avenues to increase the efficacy of biopesticides and natural enemies, and to increase the levels of host plant resistance to insects through genetic engineering and gene pyramiding to minimize losses caused by insect pests. Integrated Pest Management (IPM) offers a unique opportunity to minimize over-reliance on insecticides through on-ground integration of all possible and best fit components of crop protection for sustainable crop production. In India several IPM modules have been developed, however these modules need location specific validation on large scale. The ground reality is that the actual IPM use is only 7-8%, and in the immediate future it must reach respectable position. Therefore, organization of a symposium on "*Integrated Pest Management for Sustainable Crop Protection*", and the deliberations published in the form of abstracts are highly timely to have a quick and critical view of currently available and future pest management technologies, and the issues related to their deployment and integration in IPM module for sustainable pest management. This souvenir and abstract book will be highly useful to pave a way to better engineer different components into an effective IPM module and recommend the future action plan to cater to the current and future needs of sustainable crop production.

**(Ravinder Kaur)**

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# Preface

India has made a remarkable progress in making the country self-sufficient in demand for food grains, fruits and vegetables, and milk and milk products. However, along with numerous accomplishments, newer challenges like increasing population and income, declining land and water resources, stability in crop production and productivity, and crop losses due to different stresses are the major limiting factors in realization of yield potential of crop plants to meet the challenge of increasing food demand. Looking at the current agricultural growth and rate of population increase, the food demand is expected to rise 35-40% by the mid of 21$^{st}$ Century. Furthermore, it is estimated that the annual growth in the productivity of food grains need to be maintained at the rate of 1.5% and 3.0% for food and horticultural crops, respectively to meet this increasing food demand. Crop losses due to insect pests range from 20 to 32%, which equals the increase in food demand by 2025.

Crop production is constantly threatened by increasing difficulties in controlling insect pests, which are a major impediment to improved livelihoods of the poor farmers. Of the several methods available to control these pests, conventional insecticides are still relied on by a vast majority of the farmers. However, an ‘insecticide treadmill’ situation is developing due to the use of poor application equipment, poor choice of insecticides, and the development of resistance to insecticides. In addition to huge direct economic costs, the indirect costs such as deleterious effects of pesticides on the environment and human health are becoming increasingly severe all over the world. Several natural plant products, biopesticides, parasites, predators, insect-tolerant cultivars have been proposed as a safer alternative to the synthetic pesticides. Significant progress has also been made over the past three decades in the introduction of exotic genes into genetically modified organisms, and deregulated as an environmental friendly method of crop protection. However, there has also been a tremendous change in the pest spectrum and qualitative shift in pest management tactics. Therefore, vigorous efforts are needed to develop suitable pest management packages to reduce the losses caused by insect pests. Several Integrated Pest Management (IPM) modules have been developed in India, however only 7-8% of them are in actual use. Therefore, organization of a symposium on "*Integrated Pest Management for Sustainable Crop Protection"*, is highly timely to critically review the currently available and future pest management technologies, and the issues related to their deployment and integration in IPM module for sustainable pest management. This souvenir and abstract book will be highly useful to pave a way to better engineer different components of pest management, and recommend future action plan to cater the current and future needs of sustainable crop protection. I congratulate Dr. G.T. Gujar and Dr. M.K. Dhillon for organizing and drafting the proceedings in a form useful to the community.

**(K.V. Prabhu)**

# Introduction

Agriculture is the primary interface between people and the environment, and therefore, agricultural transformation is essential to meet the global challenges of reducing poverty, food security, and environmental protection. To minimize the over-dependence on pesticides in crop protection, and to avoid harmful effects to the environment in general and hazards to the users of pesticides in particular, the Government of India has adopted Integrated Pest Management (IPM) as a main plank of the Government Policy on crop protection since the $7^{th}$ plan period. This program emphasizes surveillance for need-based and timely application of selective pesticides, conservation, augmentation and use of biocontrol agents, promotion of improved cultural practices including use of tolerant/resistant varieties, and IPM demonstration in farmer's fields. Therapeutic interventions into agroecological systems provide only a short-term relief. Long-term answers to pest problems can only be sought by re-structuring and managing ecosystems in a way that enhance the ability of in-built mechanisms to resist insect damage, while the therapeutic tactics serve as a back up to the natural regulatory processes. Recently, the modern tools of biotechnology for pest management to increase the efficacy of biopesticides and natural enemies, and to increase the levels of host plant resistance to insects through genetic engineering and gene pyramiding have also come in existence. At the same time there has also been a tremendous change in the pest spectrum and the pest management tactics, as the current package of practices to overcome the emerging insect pest problems are not yielding the desired levels of control. Therefore, vigorous efforts are needed to develop suitable pest management packages to reduce the losses caused by insect pests. It is therefore right time now to review the available pest management techniques, and their integration in IPM module for sustainable pest management. Hence, this symposium is focused on the issues related to IPM in theory and practice, deployment status of various pest management technologies, status of deployment and sustainability of GM crops in India, public acceptance of GM products, monitoring and management of pest resistance, and stewardship in IPM.

It would not have been possible to undertake this gigantic task without the encouragement and valuable suggestions from the concerned ICAR and IARI authorities; active participation of invited eminent speakers and participants

from different universities, public and private institutions; and the support of Division of Entomology, IARI. We are also thankful to the Association for Biotechnology Led Enterprises (ABLE), Agriculture Focus Group, India for their sponsorship and Bayer Crop Science for further desired support to organize this symposium in a highly professional and scientific manner.

**M.K. Dhillon**
**G.T. Gujar**

# Contents

# Division of Entomology – Some Leads

The Division of Entomology was established in 1905 as one of the five major Divisions of the then Agricultural Research Institute located at Pusa, Bihar. It was shifted to its present premises in 1936. Eminent entomologists like H.M. Lefroy, T. B. Fletcher, H.S. Pruthi, S. Pradhan and K.N. Mehrotra laid strong foundation for basic and applied research in insect science. Prior to getting the status of Deemed University, Division of Entomology at Indian Agricultural Research Institute used to conduct several training programs and an IARI Associateship Course equivalent to M.Sc. degree. The Division of Entomology has a specialized teaching faculty, and offers specialization in Biosystematics, Physiology, Toxicology, Biological Control, Ecology, and Pest Management under 26 different courses. It has attracted PG students from Thailand, Vietnam, Ethiopia, Sudan, Egypt, Iran, Trinidad and Tobago, Myanmar, Sri Lanka, Nepal, and Bangladesh. So far this Division has awarded 123 IARI Associateship, over 221 M.Sc. and 420 Ph.D. degrees, and several of the Division Alumni are occupying very prestigious and senior positions in India and abroad. The Division in its endeavour to develop trained human resources and to keep them abreast with the recent developments in the science of entomology, its postgraduate education and research programmes are being continuously upgraded.

Since insect pests were the major constraints in crop production, early investigations focused on insect systematics, biology and bionomics. Their pioneering contributions resulted in the publication of a monumental reference work viz., Indian Insect Life in 1906 by Lefroy and Text Book of Agricultural Entomology by Pruthi. Faunistic surveys led to the establishment of the National Pusa Collection (NPC), one of the largest collections of its kind in the world. Now this Insect collection houses more than half a million specimens of which 0.1 million are authentically identified, comprising about 20,000 species. Over the last 50 years, 1500 new species of insects have been described from NPC. As a national service for pest diagnostics, every year over 2000 specimens are identified by the taxonomists of this Division. Several taxonomic treatises on agriculturally important insects belonging to orders Lepidoptera, Coleoptera, Hemiptera, Orthoptera and Hymenoptera and class Acarina have been made in this Division. Currently, CD-ROM based diagnostics are being developed for various crop pests.

In the early sixties and seventies, studies on economic entomology and insecticide toxicology were carried out by Pradhan that led to more of basic research in understanding mode of action of insecticides and fate of insecticides in the environment. Pradhan's contribution to identification of the insecticidal principles of neem, the concept of Integrated Pest Management (IPM), periodicity of locust swarms, mode of action of DDT and development of grain storage structure 'Pusa Bin' to prevent losses due to stored insect pests stand out prominently in the annals of entomological research of our country. The biology and bionomics of major insect pests laid the foundation for adoption of eco-friendly IPM approaches. Significant contributions were made to understand the biology and host plant resistance of major insect pests viz., sorghum stem borer, sorghum shoot fly, American bollworm, pink bollworm, mustard aphid, cotton whitefly and white grubs. N.C. Pant studied nutritional requirements of insects and the role of symbionts. E.S. Narayanan and B.R. Subba Rao established a strong unit of biological control, with an emphasis on taxonomy of parasites and predators. Later, emphasis also included development of mass rearing technologies and evaluation of efficacy of parasites and predators. Division of Entomology exported parasite, *Apanteles flavipes* for the control of sugarcane borer in the seventies to Barbados, and predators viz., *Cryptolaemus montrouzieri* and *Scymnus coccivora* for the control of mealy bugs in mid-nineties to the Caribbean countries. Presently, more than two-dozen parasitoids and predators are being reared for extensive investigations. A major attempt is being carried out to develop temperature tolerant strains of *Trichogramma* for the subtropical climate. The discovery of nucleopolyhedrovirus (NPV) of the tobacco caterpillar by N. Ramakrishnan led to development of NPV based bioinsecticides for the control of tobacco caterpillar. Further studies on the genomics of NPV of major insect pests were carried out with an aim to delete egt gene to quicken pathogenicity in insects. These studies also gave an impetus to the isolation of other microbial pathogens like fungi and bacteria.

Insect toxicology dealt with relative toxicity of insecticides for major insect pests and development of their formulations. Besides, studies were also carried out on persistence, residues on crops, and estimations of waiting periods. This Division was the first to report insecticide resistance in the Singhara beetle, *Galerucella birmanica* and has played an important role in monitoring insecticide resistance management in *Helicoverpa armigera*. Mehrotra provided a biochemical basis especially differential acetyl cholinesterase inhibition and carboxylesterase activity for insecticide selectivity and resistance, respectively. Presently, insecticide resistance is extensively studied for its effective management in the major insect pests.

Besides elucidating the mode of action of Azadirachtin and plumbaginoids; many indigenous flora have been investigated for identification of insect growth regulatory properties (IGR); several chromenes from the goatweed (*Ageratum conyzoides*); a non-proteinous, giganticin, from the milkweed (*Calotropis gigantea*) and andrographolide from *Andrographis paniculata*.

Studies initiated during last decade of 20th century by G.T. Gujar on insecticidal *Bacillus thuringiensis* var. *kurstaki* strains led to isolation, characterization and short listing of potential isolates, some with unique combinations of cry genes and highly effective against the lepidopteran insects. Extensive investigations by him on the baseline susceptibility of the diamondback moth and the American bollworm to *B. thuringiensis* Cry toxins showed high efficacy of CrylAb, CrylB and Cry1C against the larvae of diamondback moth and Cry1Ac against the neonates of the American bollworm. These are used for monitoring resistance to Cry toxins. Mechanisms of Cry toxin resistance in *H. armigera* and *P. xylostella* have been investigated. Studies on the molecular biology of *H. armigera* showed wide genetic diversity (4-18%) of cadherin specific gene in the populations which differed at least 100-fold in their susceptibility to Cry1Ac. These studies have helped in the development of Bt resistance management for *H. armigera*.

The mandate of the Division is:

- To conduct basic and strategic research in Entomology
- To develop as centre for academic excellence in the area of research, post-graduate educational and human resource development
- To provide services in insect science and technologies.

# National Symposium on Integrated Pest Management for Sustainable Crop Protection

## 24 - 25 February, 2015

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## Convener

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# Technical Program
## Day 1 (24 February, 2015) (Tuesday)

09.30 -10.00: Registration of Participants

### Session 1: Inaugural Session (10:00 – 11:40)

| | |
|---|---|
| 10:00–10:10 | Welcome of Participants – Dr. Chitra Srivastava |
| 10:10–10:20 | Purpose of the Symposium – Dr. G.T. Gujar |
| 10:20–10:30 | Introduction of Chief Guest & Guests of Honor – Dr. R.K. Jain |
| 10:30–10:40 | Address by Guest of Honor – Dr. B.V. Patil |
| 10:40–11:00 | Keynote Address: IPM in Theory and Practice– Dr. N.K. Krishna Kumar |
| 11:00–10:15 | Address by Chief Guest – Dr. C.D. Mayee |
| 11:15–11:30 | Concluding Remarks by the Chairman –Dr. R.K. Jain |
| 11:30–11:40 | Vote of Thanks – Dr. M.K. Dhillon |
| **11:40–12:00** | **Tea Break** |

### Session II: Deployment Status of Different Pest Management Technologies (12:00 – 17:00)

| | |
|---|---|
| Chairman: | Dr. C.D. Mayee; Co-Chair: Dr. P.K. Chakrabarty; Rapporteur: Dr. Subhash Chander |
| 12:00–12:20 | Chemical Control in Pest Management – Dr. B.V. Patil |
| 12:20–12:40 | Host Plant Resistance Based IPM – Dr. M.K. Dhillon |
| 12:40–13:00 | Biochemical Interactions for HPR to Insect Pests – Dr. Sandeep Kumar |
| **13:00–14:00** | **Lunch Break** |
| 14:00–14:20 | The Industrial Perspectives of Biopesticides – Dr. Vimla Prakash |
| 14:20–14:40 | Integration of Programs and Functionaries for Integrated Pest Management – Dr. C. Chattopadhyay |
| 14:40–15:00 | Biological Control for Pest Management – Dr. Bishwajeet Paul |
| 15:00–15:20 | Pest Management Through Cultural & Agronomic Manipulations – Dr. S.P. Singh |
| 15:20–15:40 | Role of Agrochemicals and Stewardship in IPM – Dr. Sushil Desai |
| **15:40–16:00** | **Tea Break** |

**Panel Discussion: IPM Technologies in Indian Agriculture (16:00 – 17:00)**

**Panelists**

Dr. P.K. Chakrabarty (Moderator)

Dr. Sushil Desai

Dr. C. Chattopadhyay

Dr. R.K. Thakur

Dr. T.M. Manjunath

Dr. G.T. Gujar

Dr. P. Srinivas

**17:00–18:00 Poster Session***

**Note: Poster presenters are requested to be available with their posters for visit of Best Poster Judging Committee between 5:00 to 6:00 pm.**

## Day 2 (25 February, 2015) (Wednesday)
## Session IIIA: Deployment & Management of GM Crops Technology in India (09:30–14:40)

| | |
|---|---|
| Chairman: | Dr. Raj Bhatnagar; Co-Chair: Dr. Vipin Dagaonkar; Rapporteur: Dr. Vinay Kalia |
| 09:30–09:50 | Status and Future GM Crop Technologies for Pest Management – Dr. Raj Bhatnagar |
| 09:50–10:10 | RNAi Mediated GM Technology for Pest Management – Dr. Vinay Kalia |
| 10:10–10:30 | Issues Related to Public Acceptance of GM Products – Dr. Shivendra Bajaj |
| 10:30–10:50 | Conduct of Confined Field Trials in GM Crops: Protocols for Effective Management and Monitoring – Dr. S.J. Rahman |
| 10:50–11:10 | Farmer Perspectives about Transgenic Crops in India – Dr. R.N. Padaria |
| 11:10–11:30 | Status of Insect Pest Problems and Their Management in GM Cotton – Dr. R.K. Saini |
| **11:30–12:00** | **Tea Break** |

## Session III B

| | |
|---|---|
| Chairman: | Dr. T.M. Manjunath; Co-Chair: C. Srivastava; Rapporteur: Dr. S. Subramanian |
| 12:00–12:20 | Resistance Monitoring and Management in Transgenic Crops – Dr. G.T. Gujar |
| 12:20–12:40 | Refuge Strategy for Bt Resistance Management in GM Cotton – Dr. K.S. Mohan |
| 12:40–13:00 | The New IRM Implementation Paradigm Emerging from Latin America and its Relevance to India – Dr. Vipin Dagaonkar |
| **13.00-14.00** | **Lunch** |

**Panel Discussion: GM Crops for India: Scope and Challenges (14:00–15:15)**

**Panelists**

Dr. T.R. Sharma (Moderator)

Dr. B.V. Patil

Dr. Dhiraj Pant

Dr. Ramamohan

Dr. Shivendra Bajaj

Dr. Sanjeev Kalia

**15:15–15:45 Tea Break**

## Session IV: Plenary Session (15.45 -17:00)

| | |
|---|---|
| Chairman: | Dr. K.V. Prabhu; Co-Chair: Dr. G.T. Gujar; Rapporteur: Dr. M.K. Dhillon |
| 15:45–16:00 | Report Presentation – Dr. G.T. Gujar |
| 16:00–16:20 | Best Poster and Presentation Awards - Dr. K.V. Prabhu |
| 16:20–16:50 | Concluding Remarks – Dr. K.V. Prabhu |
| 16:50–17:00 | Vote of Thanks – Dr. M.K. Dhillon |

# Invited Oral Presentations

## Deployment Status of Different Pest Management Technologies

OP: 01

# Chemical Control in Integrated Pest Management

**B.V. Patil* and M. Bheemanna**

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Application of chemical pesticides dates back in India since 1948 with the application of miracle organochlorine insecticide, DDT. Currently, India is the second largest manufacturer of pesticides in Asia after China and occupies 12$^{th}$ rank globally. As on today, 250 pesticides are registered in India for use in agriculture including both conventional and new group of insecticides. Insecticides are some of the most potent, dependable substance that can be employed to manage insect pests. Conventional insecticides such as chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids were successful in controlling insect pests during the past five decades, minimizing thereby losses in crop yields. Unfortunately, many of these chemicals have been found harmful to man and beneficial organisms resulting in ecological disturbances. Indiscriminate use of insecticides lead to resistance development by insect and ill effects posed on environment opened the new modern era of chemicals having novel mode of action with higher bioefficacy and environmental safety. This new group of insecticides viz., neonicotinoids, spinosyns, avermectins, oxadiazines, IGR's, fiproles, pyrroles, pyrimidine azomethine, ketoenoles, benzene-dicarboxamides and diamides, etc., have played an important role in managing many arthropod pests with good bioefficacy, high selectivity and low mammalian toxicity, which make them attractive replacement for conventional synthetic pesticides and best fit in Integrated Pest Management (IPM) system as an important and ultimate component.

These new group of insecticides have several advantages over conventional insecticides such as new mode of action, low mammalian toxicity, short re-entry and pre-harvest intervals, and play an important role in current IPM programs. Many also have greater selectivity, less harmful to natural enemies than broad spectrum organophosphates, carbamates and pyrethroid insecticides. As such they are less likely to cause outbreaks of secondary pests that are well controlled by natural enemies and may be used as "clean up" sprays to manage outbreaks of pests caused by broad spectrum insecticides. In addition, many of the novel insecticides have fairly short residual activity, and effect only immature stages of insects. New technologies are important because they increase the diversity of options that will be required for effective and flexible pest management programs. IPM reduce pesticide use, utilize less toxic chemicals and to promote recommended application rates to prevent unnecessary runoff, thereby protecting surface and groundwater resources. The pesticides represent important tools for crop management and continue to play a significant role in the success of IPM.

**OP: 02**

# Host Plant Resistance Based Integrated Pest Management

**M.K. Dhillon***

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Host plant resistance is one of the most important, effective, economic, environmentally safe, and more over highly compatible component of pest management with other control measures. The insect resistant varieties have been deployed as principal method of insect control in several parts of the world, for example, corn varieties with resistance to corn borer, *Ostrinia nubilalis* (Hubner) and corn earworm, *Helicoverpa zea* (Boddie), sorghum to green bug, *Schizaphis graminum* (Rondani), and alfalfa to aphids, *Therioaphis maculate* (Buckton) and *Acyrthosiphon pisum* (Harris] in USA; cotton to jassids, *Jacobiella facialis* (Jacobi) in Africa; sorghum to midge, *Stenodiplosis sorghicola* (Coquillett) in India and Australia; and rice to brown plant hopper, *Nilapavata lugens* (Stal) and green leaf hopper, *Nephotettix virescens* (Distant), and wheat to Hessian fly, *Mayetiola destructor* (Say) and wheat stem fly, *Cephus cinctus* Norton in several parts of the world. Since last two decades, the quest to break yield plateau for sustainable increase in crop productivity of field crops through use of hybrid technology has diluted the emphasis on development of insect-resistant cultivars. Moreover, the levels of insect resistance in most of the recently released varieties/hybrids are inadequate, and therefore recent years have observed a paradigm shift in advocacy and deployment of techniques to diversify the bases of resistance through gene pyramiding from cultivated germplasm, closely related wild relatives of crops, and transfer of insect resistance genes in parental lines for developing insect-resistant hybrids. Furthermore, with the development of insect resistance to insecticides, adverse effects of insecticides on natural enemies and public awareness of environment conservation, there has been a renewed interest in the development of crop cultivars with resistance to insect pests.

Although, considerable progress has been made over the past two decades in manipulating genes from diverse sources to develop plants with resistance to insect pests, deployment of molecular techniques for insect resistance, understand nature of gene action and metabolic pathways, but rapid and cost effective development, and adoption of biotechnology-derived products will depend on developing a full understanding on the interaction of genes within their genomic environment, and with the environment in which their conferred phenotype interact. Augmentation of conventional breeding with the use of molecular techniques and transgenic approaches have a great promise to reduce pest associated crop losses, and accelerate the progress in developing cultivars with resistance to insects and increase crop productivity. Some of the strategies such as breed for polygenic resistance, sequential release of varieties with major genes, pyramid major genes, rotation of varieties with major genes, develop multiline varieties, varietal mixtures, genetic engineering with tissue-specific insect-resistant gene expression, and insect resistance as a criteria for release of new crop cultivars is highly desirable for sustainability of insect-resistant varieties and crop production. The host plant resistance alone has not be seen as rewarding, and therefore, host plant resistance should be included as one of the essential and basic component of integrated pest management in order to increase pro-duction and productivity of crops.

**OP: 03**

# Biochemical Interactions for Host Plant Resistance to Insect Pests

**Sandeep Kumar[1]* and M.K. Dhillon[2]**

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The insect-host interactions are dynamic in nature and have coevolved with fine tuning with each other. Insects need sophisticated means to identify suitable hosts on which they can feed and reproduce whereas plants require avoiding mechanisms to insect-pests, while still attracting the beneficial pollinators and natural predators. The space and time also play crucial roles in influencing the outcome of these interactions. Biochemical components constitute the base for various insect-host interactions. Even without knowing the biochemical components involved, these interactions can be used to protect plants from insect-pests. Development of a push-pull approach for integrated pest management of cereals, the most important staple food crops in Africa is the best example. In general, plants produce complicated odor blends which strongly influence the insect-plant interactions as insects rely heavily on olfaction for sensing. After selecting quality host, insect starts feeding and in response to that attack plants defence system is activated, resulting in upregulation of genes associated with the production of metabolites such as proteinase inhibitors, toxins or volatiles that repel pests and attract their natural enemies. The initial signal eliciting defence in plants is highly specific and differs between attacking organisms. Similarities have been reported in subsequent signalling and gene expression patterns during various types of attack. These defence responses involves salicylic acid, jasmonic acid, ethylene and abscissic acid pathways which interact, either positively or negatively. Aphids, leafhoppers and whiteflies, the phloem-feeding herbivores induce defence signalling pathways that are quantitatively and qualitatively different from other insects. Additional layers of regulation have also been reported depending upon the host and the insect. Once identified, the information on specific compounds involved in insect-host interactions can be used for development of resistant varieties. Further, priming with *cis*-jasmonate or salicylic acid which alter the speed and magnitude of subsequent plant reactions after exposure to a prior stimulus, can also be used for integrated pest management.

The role of biochemical component in plant defence can change over time and the insect species involved, as a result of coevolving mechanism. To defend themselves, these biochemical components through elicitation of cues too activate the third trophic level, and invite specialist natural enemies of the target insect pest species. As plant responses are often fine-tuned to particular herbivore and dynamic in nature, there is strong need to have integrated disciplinary approach to identify components involved and their functions. Recent developments in technologies based on untargeted approach particularly mass spectrometry in combination with transcriptomics, microarray analysis and bioinformatics, could be helpful in elucidating these complex interactions.

# Biological Control for Pest Management

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Insect pest management presents new challenges to farmers frequently. Insects are highly mobile and well adapted to farm production systems and pest control tactics. Today the focus is on managing insect pests rather than eliminating them, and biological control is an important management tool. In India, organized and systematic biological control research began with the establishment of Commonwealth Institute of Biological Control (CIBC) at Bangalore in 1957. Thereafter, to carrying out biological control research in different parts of the country, Indian Council of Agricultural Research (ICAR) established All India Coordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP) in 1977, which was further elevated to Project Directorate of Biological Control in 1993. So far more than 166 exotic biological control agents have been introduced in India, of which 33 could not be released in the field, 71 recovered after release, 8 providing excellent control, 8 substantial control, and 4 partial control.

*Rodolia cardinalis* successfully controlled *Icerya purchasi* by the end of 1930s. The population of San Jose scale, *Quadraspidiotus perniciosus* (Comstock) was reduced to about 95% due to introduction and release of *Leptomastix dactylopii* from Brazil in 1983 from Trinidad, West Indies. Biological control of *Eriosoma lanigerum* (Hausmann) was attained by introduction of *Aphelinus mali*, from UK at Saharanpur, Uttar Pradesh. However, the parasitoid failed to establish and provide effective control of woolly aphid in the Kumaon hills because of the intense activity of coccinellid beetle, *Coccinella septempunctata* which fed indiscriminately on parasitized as well as unparasitized woolly aphids. The coccinellid beetle, *C. septempunctata* however provided satisfactory control of the pest. *Encarsia guadeloupae* and *E*. sp. nr. *meritoria* collected from Minicoy Island of Lakshadweep and introduced to main land caused perceptible reduction in population of spiraling whitefly, *Aleurodicus dispersus*. Parasitism levels by these parasitoids vary from 29 to 70%, and exceed 90% during some parts of the year. The coccinellid predator, *Curinus coeruleus* (origin: South America) obtained from Thailand in 1988 for the suppression of *Heteropsylla cubana*, provided on par control to monocrotophos sprays at fortnight interval. *Epiricania melanoleuca* an important parasitoid of *Pyrilla perpusilla*, has proved a notable success for the management of sugarcane pyrilla, since its introduction in Gujarat from Maharashtra and Haryana in 1982. Similarly, the ichneumonid, *Isotima javensis* a key parasitoid of sugarcane top borer, *Scirpophaga excerptalis* in northern India, has been successfully colonized in southern India and plays an important role in the suppression of this pest.

Papaya mealy bug havoc in the past couple of years resulted in 60-80% reduction in papaya production in Tamil Nadu. The then National Bureau of Agriculturally Important Insects (NBAII), Bangalore took efforts in importing three exotic papaya mealy bug parasitoids such as *Acerophagus papayae*, *Pseudleptomastix mexicana* and *Anagyrus loecki* from Puerto Rico during July, 2010. These parasitoids especially *Acerophagus papayae*, established very well and brought significant control of papaya mealy bug not only on papaya, but also on other crops. Incidence of papaya mealy bug and sugarcane woolly aphid were very low in Maharashtra, Karnataka, Tamil Nadu, Kerala, Orissa, Assam and other parts of the country due to the intensive activities of the released parasitoids. Incidence of invasive Jack beardsley mealy bug, *Pseudococcus jackbeardsleyi* has been reported in Tamil Nadu and Karnataka. *Cryptolaemus montrouzieri* was identified as successful predator for this invasive mealy bug and the mass production technology has already been standardized for field application. Maximum of success with classical biological control agents in India has been achieved in biological control of aquatic weeds (55.5%) followed by homopterous pests (46.7%) and terrestrial weeds (23.8%). Deployment of biological control agents does not mean ruling out other pest management technologies or practices on ideological grounds. Currently, most of the state agricultural universities and crop based ICAR institutes although have several biocontrol agents, the most challenging hurdle that needs to be overcome today is their timely availability to the farmers for successful and sustainable pest management.

**OP: 05**

# Pest Management Through Cultural and Agronomic Manipulations

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Cultural or agronomic manipulations are based on habitat management and require a thorough understanding of different components of agro-ecosystem in which the pest thrive, also known as ecological management. Agronomic practices such as sowing date, sowing pattern and plant density, spatial arrangement, tillage, mulching, irrigation, biodiversity (intercrops, companion/trap crops), and several other cultural practices can be manipulated to reduce the initial pest populations by making the crop environment unattractive for the pest and favourable for its natural enemies or by way of enhancing the inherent capacity of the plant to tolerate the damage caused by the biotic stresses. Some cultural practices have shown significant effect on crop management, and hence recommended for pest management. The manipulation of sowing/planting time by either advancing or delaying helps in minimizing pest damage due to asynchrony between host plant and the pest or synchrony of insect pests with their natural enemies. Adoption of appropriate seed rate ensures proper stand and spacing. Use of high seed rate is recommended in the crops where removal of infested plants is helpful in minimizing the incidence of insect pests. Insect pests can also be managed by trap cropping, which either prevent the pests from reaching the crop or concentrate them in certain part of the field where they can be easily destroyed with an insecticide. Crop rotation involves alternate use of host and non-host crops in a field to reduce insect-pest abundance and damage, and is most effective against insect-pests having limited host range, long life cycle and limited mobility. Tillage operation can reduce pest populations indirectly by destroying food sources, wild vegetation and volunteer crop plants in and around crop production habitats. Controlling plant pests by using water management is very precise and practical method, and can be manipulated in such a way that the lush and attractive state of plants does not coincide with periods of peak insect activity. Beneficial organisms may also be encouraged through judicious use of water. Manures and fertilizers are although beneficial and usually necessary for crop health, their optimum use is important for pest control. For e.g., high nitrogen application in crops attract more insects, while use of potash and phosphorus either singly or in combination with nitrogen results in lower incidence of many insect pests. Inter and mixed cropping is an insurance against the risk of crops failure, better utilization of farm resources and labour, and protection from crop pests. It is always advisable to select the crops for intercropping which have no major common pests and competition with the main crop. The cultural manipulation is among the simplest and cheapest methods of pest management, which can easily be carried out with the usual agronomic operations without any disadvantage like associated with the use of insecticides. However, management of insect pests through cultural manipulation may not be effective under modern production methods, and need continuous efforts to evolve according to the agro-ecosystem suitability.

OP: 06

# The Industrial Perspectives of Biopesticides

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The global biopesticide market has grown exponentially in the last few years and growth is expected to continue. Factors such as toxicity of crop protection products, environment friendliness, innovative production practices, new product offerings, increased availability, and advent of new pests are increasing the market for biopesticide industry, globally. Though biopesticide market is primarily driven by bacterial biopesticides and botanical extracts, semiochemicals are gaining awareness and their usage is expected to contribute to further growth. Orchard, plantation, salad, and vegetable crops are the major crop segments behind the current biopesticide market growth, however, there is a rising trend for use of biopesticides on high value field crops such as corn, cotton, and oilseed crops. The global biopesticide market was estimated to be $1,358.6 million in 2011, and is expected to reach $3,222 million by 2017, with an estimated compound annual growth rate (CAGR) of 15.8% from 2012 to 2017. The main drivers of growth of biopesticide market are - low registration cost and time for development of new active ingredient, phase-out of highly toxic pesticides, and Government support and encouragement for the development of biopesticides due to their low toxicity, safety, and high efficacy in insect control, growing demand for organic products, biopesticide seed treatment, and GM crops competing with biopesticides due to disease and pest resistance and complementing for production of chemical residue free crops.

However, average shelf life and variable efficiency are some of the major restrain for biopesticide market. Considering the benefits and different areas of action, several types of bioagents such as biopesticides, biofungicides, bioherbicides, bionematicides, etc. have joined the contingent of biopesticide market in recent years.

OP: 07

# Role of Agrochemicals and Stewardship in Integrated Pest Management

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Food crops in the process of production till its consumption compete with weeds, nematodes insects and diseases. This competition leads to losses while the crop is growing in the field, transported to markets and is in its storage, which calls for use of crop protection products to guarantee an adequate and reliable food supply. Despite the use of modern agrochemical products 25-30% of potential food produced is lost every year. While the role of agrochemicals is recognized in the society, it is important to have safety of products for users, consumers, and environmental impact is carefully assessed. Product registrations, permitting sale within a country, are based upon comprehensive safety assessments and defined product uses. Each product has a specific application that is clearly indicated on the label. Whilst these regulatory aspects are carefully considered prior to commercial sale, the lifecycle approach to pesticide management dictates that manufacturers extend their safety considerations through the entire lifespan of the product. This commitment is referred to as "product stewardship". Safety considerations pertaining directly to the use of agrochemicals include education and training programs that relay how products can be used safely and efficiently. Whilst avoiding some of the inherent risks of sometimes harmful or toxic chemicals is critical, end-users aware of the hazards and taking the recommended precautions are keen to learn how products can be more effectively applied to increase productivity and save input costs. These two concepts bridge the areas of safe/responsible use and integrated pest management. The growing global populations constantly challenging food production and agrochemical products offer a mean towards meeting the challenge of more food in lesser land. The agro input industry is committed to sustainability through stewardship initiatives, integrated resistance management and showcasing interventions through pilot projects.

OP: 08

# Integration of Programs and Functionaries for Integrated Pest Management

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Crop pests have posed serious threat to global food security. Plant protection currently holds the key to redeeming much of the losses due to pests through convergence of stakeholders. Integrated Pest Management (IPM) policy should provide incentives to farmers to adopt IPM as a cardinal principle of plant protection. There is need to undertake a specific policy to encourage biopesticides, streamlining their label claim issues, simplification of process of registration for biopesticides with strict and adequate quality check from government departments, increased support to biopesticide industry for scaling up of production as a matter of government policy viz., subsidies to biopesticides, discouragement to chemical pesticide industries (as part of IPM policy), etc., which shall also enable generation of employment for small/micro-industries at village level in line with concepts of model bio-village. This shall bring a paradigm shift in the chemical pesticide industry and transform them towards producing biopesticides. Surveillance is the foundation of plant protection for early alert. Potential of Information and Communication Technology (ICT) has been witnessed by its impact on production and productivity under various programmes in different states as well as crops *viz.*, CROPSAP, HortSAP in Maharashtra, NISPM/OPMAS (DAC, GoI), TAP for African countries such as in Malawi, etc. The IPM technology has shown its potential in Indian mustard and several other food and horticultural crops. Bridging the gap between policy and practice is herculean task in plant protection in the wake of extensive diversity of crops, regions, pest problems and practices, and variegated resources (knowledge, experts, quality inputs, machinery, molecules and financial support), thus require highly motivated and focussed yet effective efforts towards research, education, extension to tackle the issues in plant protection. However, through well-coordinated efforts involving multi-stakeholders – policy makers, administrators, researchers, educationists, extension machinery, industry, media, etc., visible contributions could be made. The KVKs, NGOs need to play a vital role in improving awareness levels of field functionaries and farmers in IPM apart from fast-tracking of crop protection advisories for better livelihood security. IPM happens to be a knowledge-intensive holistic approach wherein advanced planning, good agricultural practices (GAP) towards environment-safety linked to maximum residue limit (MRLs) of chemical pesticides and cost-benefit management, crop monitoring coupled with accurate diagnosis of the pest problem, expert advice, timely decision-making, and quick action makes the real difference to tackle unforeseen pest outbreaks. Thus, an Integrated Decision Support System for Crop Protection Services need to be devised centrally to monitor the pest dynamics through e-pest surveillance, analyse pest risks, provide pest forecasts along with ICT-based dissemination of advisories keeping in view prevailing weather, and changes in climate. This would necessitate networking of all stake-holders so that they could contribute effectively in a cohesive manner. In the era of climate change, diagnostics of pests and diseases and capacity building of farmers, extension and even research personnel for adaptation to changed pest scenario under future climates assumes significance, wherein Integrated Crop Management in Private-Public-Partnership mode could be very effective. Future efforts in India do need to address the issue of future climates in pest management. Input dealers are stepping beyond their limits of supply of inputs and in several occasions have misled the farmers towards severe and avoidable losses. Efforts should be made to develop confidence among farmers in the advisories from the State Departments of Agriculture and State Agricultural Universities. Government should bring legislation to stop indiscriminate use of chemical pesticides and restrain the input dealers from misleading the striving poor millions of farmers who feed our Nation and the globe. Research need to be more oriented to cater the needs of farmers for solving field-related problems.

# Invited Oral Presentations

## Deployment and Management of GM Crops Technology in India

# Status and Future GM Crop Technologies for Pest Management

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Success of *Bacillus thuringiensis* (Bt) proteins in protecting crop against insect predation has prompted search and application of next generation of biomolecules as insecticidal agents. Several small RNA based approaches are being explored. Knock down of insect specific targets have yielded good success, and candidate dsRNAs are at advanced stage of application thorough transgenic route. Work from our laboratory has explored identification and application of two different classes of biomolecules as insecticidal agents. In the first approach we have investigated pro-peptides of insect origin as insecticides. Several insect development related and food assimilating hydrolytic enzymes are synthesized as inactive zymogens. These zymogens are activated upon removal of their pro-peptides. It has been demonstrated that the pro-region peptides inhibit the cognate enzymes at micro/nano molar concentrations. From diverse organisms representing diverse biochemical pathways we have demonstrated that the synthetic peptides of chitinase and protease from human disease transmitting vectors inhibit their corresponding enzymes. We have also explored zymogens from *Helicoverpa armigera* (Hubner), and identified the pro-region peptides of two proteases and one peptide of phenol oxidase as strong inhibitor of larval growth and development. Injection of pro-peptide corresponding to phenol oxidase resulted in collapse of redox state equilibrium of larvae, and the larvae died within fifteen minutes of administration.

Further continuing our work on insect chitinase we have examined the role of microRNA in metamorphosis of *H. armigera* larvae. During the larval-larval metamorphosis, chitinase gene expression varies from high to negligible. In the five-day development course of fifth instar larvae, chitinase transcript is least abundant on the third day and is maximal on the fifth day. A microRNA library preparation from these highest and lowest chitinase expressing larval stages of *H. armigera* resulted in the isolation of three miRNAs. Luciferase reporter having 3' UTR of chitinase investigated chitinase gene targeted specific action of these three miRNAs. Only one of the three miRNAs, miR24, was inversely regulated with expression of chitinase.

Further, a day-wise *in vivo* quantification of miR24 in the fifth instar larvae revealed a negative correlation with the corresponding chitinase expression levels. The most important morphological or phenotypic effect of this chitinase specific miR24, was shrinking of the larvae and the arrest of molting process due to force-feeding of larvae with synthetic miR24. The miR24 force fed larvae depicted a down-regulated profile of chitinase expression. We have constructed plant transformation vector and have raised transgenic tobacco plants. These transgenic plants expressing varying amounts of miR24 offer significant protection against predation by larvae of *H. armigera*.

**OP: 10**

# RNAi Mediated GM Technology for Pest Management

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Insect pests are one of the main constraints to agriculture production worldwide in the form of crop losses, insecticides usage and food security. Present pest control practices are directed by the principles of integrated pest management (IPM), which involves thoughtful consideration and integration of all available pest control techniques that are economically and socially acceptable. With the advent of genetically modified (GM) technology, real success has been attained in the field of plant protection by developing transgenic crops as an imperative tool for IPM. Since 1996, the area under insect-resistant GM plantation has increased histrionically to 28.8 million ha till 2013, thus representing greatest magnitude to adoption of GM technology globally. However, the success of this technology is threatened by development of resistance to Bt toxins in sprays and transgenic crops, just like synthetic insecticides. Therefore, there is a need to look for another sustainable and environment friendly approach to manage insect pests and one such approach is ribonucleic acid interference (RNAi) technology.

RNAi is a post transcriptional mechanism of silencing gene function by inserting short homologous sequence of messenger RNA (mRNA) to prevent translation of proteins. For decades, RNAi was known to occur in plants (as *posttranscriptional gene silencing*) and fungi (as *quelling*) but was reported for the first time in animals

(*Caenorhabditis elegans*). In 2003, Science named it as the "Breakthrough of the Year" and Fortune magazine hailed it as "Biotech's Billion Dollar Breakthrough". Andrew Fire and Craig Mello unveiled the underlying mechanism of this phenomenon in *C. elegans* for which they were awarded Nobel Prize. They systematically clarified that double-stranded RNA (dsRNA) was more effective than either sense or antisense RNA in silencing genes, and they called dsRNA-induced silencing phenomenon as RNAi. This technology is considered as a potential tool for crop protection against insect pests. The arbitrators of sequence-specific mRNA degradation are 21–23 nucleotides long, small interfering RNAs (siRNA). dsRNA is cleaved into siRNAs by the enzyme Dicer and then incorporated into an RNA-induced silencing complex (RISC). These siRNA are used as a template by Argonaute proteins, the catalytic components of RISC, to recognize and degrade the complementary mRNA. The available experimental data on RNAi showed variability in the sensitivity level among the insect orders based upon order-specific or species-specific peculiarities. The variability in RNAi efficiency has also been observed, depending on the dsRNA testing approach (oral feeding and injections), uptake mechanism and systemic transportation mechanism in insects. The *systemic interference defective* (s*id-1*) gene, in the *C. elegans*, plays a relevant role in up-take mechanism. *Sid-1* orthologs have been reported in some insects, like *Drosophila melanogaster* and explain the sensitivity of different insects to RNAi. Another important gene for the spread of signal and systemic properties of RNAi, is RNA dependent RNA polymerase (RdRP), and has also been discovered from *C. elegans*. Although insects do not possess RdRP, but sensitive species like *Tribolium castaneum* exhibit a strong RNAi response. Thus, the signal amplification must be derived from a different gene than the RdRP or from a completely different mechanism which is yet to be researched.

There is a growing interest in using RNAi for insect control, both as a traditionally applied insecticide and GM crops. Initially, Baum and his team in 2007 developed dsRNA GM corn plants targeting the *Snf7* ortholog in western corn rootworm, *Diabrotica virgifera* (Coleoptera). Feeding damage by western corn rootworm was significantly reduced, suggesting that the RNAi pathway can be exploited to control insect pests via in-planta expression of a dsRNA. Later on, Zha and his team in 2011 transformed rice plants to suppress the expression of several genes in *Nilaparvata lugens* (Hemiptera), although gene expression was suppressed but insects were not killed by feeding on the GM rice plants. Similarly, Mao and his team transformed cotton plants to produce dsRNA that reduced the expression of the P450 gene in cotton bollworms, *Helicoverpa armigera* (Lepidoptera) which caused deleterious effects on bollworms, but no mortality was observed. Monsanto has developed MON87411 maize, a GM crop which contain dsRNA molecule to target the *DvSnf7* gene to kill the *D. virgifera*. Being an emerging technology, RNAi has a potential and offers new opportunities for the generation of novel traits in GM plants. Subsequently, there is also a need to study the potential risks associated with RNAi-based GM plants for their non-target effects and environmental biosafety.

# Issues Affecting Public Acceptance of GM Crops in India

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The inconclusive debate on commercialization of genetically modified (GM) crop technology has resulted in avoidable opportunity-loss and social tension in the country. It has also exposed the Central and State Governments to constant criticism by all stakeholders. The arguments of all those on either side of the debate are highly polarized and often vicious. The strategies used by parties promoting GM are based on experiences elsewhere, especially in the American continents, and on excessive leverage with the variable success of Bt cotton across regions. This has drawn denunciation from critiques, often using similar threads of arguments. However, it is reasonable to conclude that the criticism is largely on the deployment tactics for GM products ('seeds of contention' – as these are marketed by private sector) rather than on technology itself. Unfortunately, the various ideas to bring about better mutual understanding and cohesiveness at societal and government levels is poorly stated or heard. It is clear that in this country with >85% small land-holding subsistence farmers, the consideration of power of technology in isolation of other factors is at best derisory, and often unjustifiable. All aspects of both region-, crop-, and trait-specific benefits and risks at each class of farm-level resource-base, are to be weighed jointly with the major local stakeholders. Further, to make sensible headway to deploy specific GM crop cultivars, synergy with other technologies and traditional practices need to be considered. It is understood that it may be impractical to get some of the hard-liners on either side on board, but if the relevance to the 85% small-farm holders are adequately addressed, many especially the environmentalists and social activists may be convinced. The most vital national and international issues such as IPR and country's competitiveness rarely publicly-debated, they are the overriding factors delaying decision making at the government level. Failure of the public sector to come up with very relevant products (such as those boosting oilseed or pulse production to reduce nearly 70 crores rupees out-go in foreign exchange), and poor regulatory environment for agricultural inputs (e.g., even after a decade-long debate in the Parliament, the Seed Bill is yet to be passed to

protect farmer' interests!) are also responsible for the current stagnation on policy front. In such a situation how can we rationalize and harmonize concerns and move ahead to appropriately and selectively develop and deploy GM products for Indian Agriculture?

We need to make these debates more structured and purposeful so that pragmatic actions can be initiated at the government level. First, we need to provide sufficient knowledge and information from independently and objectively verifiable sources on benefits and risks of each GM product on a case-by-case basis. Concede the adage "*One man's food is another man's poison* ", for the arguments' sake! Second, state clearly the policy parameters for deployment right in the beginning assuring scope for informed choices, and co-existence. Third, create responsible and confidence building machineries for both rational and scientific deployment of GM products and to promote constant post-release monitoring and stewardship activities right from the beginning of commercialization. Liability and redressed mechanisms are to be addressed as is the case with the nuclear energy. Finally, if both public and private sectors provide alternative and competitive technologies, much of the debate, especially in the developing countries like ours can be toned-down; we need to ignore the residual protests, but with continuous and careful stewardship activities.

Much blame is placed on poor communications, which is often over-stated. Current thrust in goading with information (propaganda from opposing sides of the GM debate) must find way for emphasis on building trust and mutual understanding based on informed consent of stakeholders. The risk-benefit balance must be made clear for each specific production system, and to risk-taking communities of marginal farmers in less-endowed environments. Independently verifiable information gathered from ethically motivated public institutions or by 'transparent' NGOs, academies and individuals are to be made widely available to put at rest needless issues in the public debates. The fragmented and competitive approaches of government departments and scientific organizations are doing much harm to the cause of integrating GM technology into Indian farming; GM products need to be advocated along with other competing approaches to enhance farm productivity on a sustainable basis. It is absolutely essential to be humble and withdraw the instincts of 'flag-waving type of nationalism' and accept the current leadership of MNCs, and work towards building true capacity in the long-run through realistic joint-programs just as we are attempting to do in case of defence production. We need to recognize the reasons for failure of the public system to deliver are also much beyond their often stated resource-shortage; and any retrospection must deal with managerial competence especially for teamwork, and to advice on governance issues. The emerging new techniques of developing GM crops (such as those based on genome editing) are more suited to Indian scientific communities, and therefore young scientists need to be promoted to acquire such skills at the highest-possible speed. Unlike the case with Pharma largely built on the plank of off-patented drugs, the case with GM crops will be complex as soon as stacking is approved which has the potential to perpetuate monopoly. Such issues like monopoly and the related one on distributive justice related to benefits and risks are better dealt with proactive and transparent negotiations, taking into account long-term interests of country as a whole.

**OP: 12**

# Farmers' Perspectives About Transgenic Crops in India

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Adoption of Bt (*Bacillus thuringiensis*) cotton is the first but phenomenal transgenic venture of Indian farmers. The rates of diffusion and adoption of Bt cotton in India were unprecedented. There is escalating predominance of Bt Cotton hybrids as they ensured opportunity for double cropping, 34 to 63% higher yield, about 142% higher income, reduction in pesticide usage from 4-12 to 2-4 sprays (though for last few years due to higher incidence of sucking pests and mealy bug, 1-2 extra sprays are required), reduction in the incidence of pesticide-led health hazards from 4-6 cases per season per village to none to one, and increased employment days for women during cotton picking. The farmers held positive perception about Bt cotton. The experience in cultivation of Bt cotton has certainly established the importance of transgenic technology in terms of profitability and ecological benefits.

However, the society is on cross-roads while considering the acceptance of genetically modified food crops. The transgenic technology faces criticism primarily for the bio-safety concerns, which include transgene movement to other varieties and wild relatives leading to possible development of super weeds, erosion of genetic diversity and ecological disturbance; widespread apprehension about toxicity or allergencity induced by transgenic products to humans and animals; its adverse impact on non-target organism; emergence of more virulent forms of pests and pathogens, etc. Besides biosafety concerns, IPR, ethical and moral issues form the basis of debate towards adoption of transgenic crops. An analysis of risk aggravating and attenuating factors revealed that unfamiliarity with the subject and lack of credible source and authentic information as prominent factors. For facilitating preparedness as well as informed debate and choice, educational drive is necessarily required to upgrade the knowledge and skill of farmers and other stakeholders. Also what is desired is the availability in public domain of rigorous scientific experimentation based evidences and explanation about the facts of biosafety and health related concerns. Concerted efforts of educational campaign, scientists and end-users interface, extension literature and aids, large scale demonstration and on-spot scientific explanation of biosafety concerns and misconceptions will go a long way in developing favourable perception and enhanced acceptance of transgenic technology. Further, efforts should be initiated to address the field level and infrastructural constraints to facilitate development of supportive and caring climate for the end-users.

Emphasis should be laid upon augmenting the role of public extension system in deployment and dissemination of transgenic technology. Since the farmers find public extension system as the most credible and reliable source of information, it is essential to develop programmes for capacity building of extension workers in transgenic technology so that they could put in the desired educational efforts, which often is overlooked by the seed agencies at present. Necessary initiatives are required in areas of biosafety regulation mechanism, capacity building of stakeholders for prudent compliance of biosafety measures, and involvement of farmers and extension workers in deployment of transgenic to harness the potential benefits of transgenic technology with adequate biosafety.

**OP: 13**

# Status of Insect Pest Problems and Their Management in GM Cotton

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With the large scale adoption of Bt cotton cultivation in India, the pest scenario and pesticide use have considerably changed. Some new pests have appeared while status of some other pests has altered. There is virtually no problem of bollworm pests whereas an increasing trend in population of sucking insect pests is quite obvious. The problem of sucking pests aggravates when environmental conditions become highly conducive for these pests during certain periods of the cotton season.

In the recent past, a number of new pest problems have emerged in Bt cotton which include mealybugs (*Phenacoccus solenopsis*, *Paracoccus marginatus*), mirids (*Creontiades biseratense, Campylomma livida, Hyalopeplus linefer*), flower bud maggot (*Dasineura gossypii*), safflower caterpillar (*Perigea capensis*), and tea mosquito bug (*Helopeltis bryadi*), etc. At the same time, pests like whitefly (*Bemisia tabaci*), leafhopper (*Amrasca biguttula biguttula*), thrips (*Thrips tabaci*), and tobacco caterpillar (*Spodoptera litura*) have started appearing invariably in large numbers forcing the farmers to go for repeated applications of chemical insecticides to manage them. Sporadic occurrence of cotton leaf roller, *Sylepta derogata,* has also been observed in North India.

In northern states of the country solenopsis mealybug, *Phenacoccus solenopsis,* caused serious damage to cotton crop during 2006-2008 in certain pockets. However, with the appearance of solenopsis mealybug parasitoid, *Aenasius bambawalei*, its spread and heavy parasitization, along with feeding by several coccinellid predators, and spot application of recommended pesticides like profenophos, thiodicarb and quinalphos, the pest is well under control. Monocrotophos and cypermethrin sprays caused resurgence of mealybug. Mealy Kill, a terpenoid pesticide of botanical origin, has also been found effective against mealybug. In Central and South India, the mirid bugs are serious problem, particularly *Creontiades biseratense* which is dominant and regularly occurring species. Mirid bug infested tender bolls have a number of black patches on the rind while feeding on matured bolls leads to parrot beaking and improper opening. Acephate sprays have been reported to be effective against mirid bugs. There have also been reports of tea mosquito bug and flower bud maggot infesting Bt cotton in certain areas from Central and South India.

The most serious problem the cotton cultivation is facing in North India for the last 2-3 years is heavy damage inflicted by whitefly, particularly when cotton sowing gets delayed. Being highly polyphagous, this pest in Haryana has been found to breed on 114 host plants belonging to 32 families. Fabaceae, Asteraceae, Solanaceae, Malvaceae and Cucurbitaceae were identified as the most important families supporting whitefly populations. Less frequent and unevenly distributed rains lacking heavy downpours together with longer drier spells favour its faster multiplication. Presently recommended insecticides are not providing satisfactory reduction in population of this pest, probably apart from other factors, due to development of resistance to these insecticides, or to killing of natural enemies and thereby resulting in its resurgence. A number of natural enemies such as the parasitoids, *Encarsia* spp. and *Eretmocerus* spp., several coccinellid and other predators, and pathogens are reported to play an important role in suppressing whitefly populations. Spraying neem based insecticides and mass trapping of adults with yellow sticky traps have been reported to be useful in checking whitefly build up in cotton. Therefore, adoption of bio-intensive integrated pest management involving practices such as timely or early sowing of pest tolerant varieties/hybrids, conservation and encouragement of natural enemies, destruction of alternate host plants, use of neem based insecticides and/or IGRs or effective chemical pesticides, regular pest monitoring, etc., could greatly help in keeping its population below damaging levels. A community based approach for its management would be more effective. Thrips and leafhopper can be effectively managed by some older insecticide molecules such as dimethoate rather than the currently used neonicotinoids like imidacloprid, acetamiprid, thiamethoxam, etc. *Spodoptera litura* is not a problem in BG II cotton, while it can be successfully managed in other varieties/hybrids with sprays of novaluron or thidicarb.

**OP: 14**

# Resistance Monitoring and Management in Transgenic Crops

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Insect's ability to evolve resistance to xenobiotics was reported as early as 1914. It is a natural phenomenon of selection amongst the living species to abiotic and biotic stresses. More insights in evolution of resistance in insects were gained after it was found that insects like houseflies, mosquitoes had evolved resistance soon after few years of use to the wonder chemical, DDT discovered as insecticide in 1939. As more and more of organochlorines, organophosphates, carbamates, pyrethroids were developed for pest management, insecticide resistance became more common. Pyrethroid resistance in cotton bollworms in 1970s and 1980s attracted a worldwide attention, because the target insects (heliothines) of the broad-acre cash crops were found very difficult to control. The cost of resistance evolution was estimated at about $1 billion annually, despite the efforts of resistance monitoring and management. It is likely to be more now. In mid-1990s, plant resistance mediated insect management (PRIM) became a dominant factor, as the insect protective transgenic cotton expressing toxins from the soil bacterium, *Bacillus thuringiensis* (Bt) was cultivated over a million hectare in US. Because of the fact that Bt is a natural source of effective toxins and need to sustain the novel genetic engineering technology, the resistance management in insect protective transgenic crops is made mandatory for their development. This is in contrast with the insecticide based control wherein their sustained use is equally important like that of insect protective transgenics. This indifference is despite the fact that these insecticides are used on a large scale, often indiscriminately, with an evidence of failures of insecticide based control under field condition in many crops. In fact, there are until now as many as 546 cases of insecticide resistance, cross-resistance and multiple resistances in target pests. Insecticide development costs have multiplied over the years with fewer and fewer novel chemicals being available for control of a wide range of insect pests. Associated with this, are other issues like environmental contamination and possible health hazards even to the humans.

Resistance management includes the monitoring for evolution of resistance spatially and temporally. The monitoring is useful to predict field level resistance evolution. Alteration of pesticide use with differential mode of action is one that is quite useful as IRAC or other similar groups have suggested. However, manufacturers preferred to develop the pesticide mixtures which protect their intellectual property and help in with more revenues. Often, studies have shown that insecticide alone is as effective as their mixture. The need of mixture is only when the target pest has evolved resistance to one of its components and spectrum of pest is wide enough. Sometimes, pesticide mixtures contain more than two components which could be homologous for insects or heterologous for more than one kind of pest.

Biotechnology companies too followed with development of transgenics stacked with many traits, some time as many as seven. The principle of alternating with different genes is least preferred option over the multiple stacks (mixture). The expected benefits may not match costs and the doubts, if the reports of easier or faster evolution of resistance to such crops turn out to be true. Further, refuge or alternate host crops are essential for delaying resistance evolution. The foresight of Melander (1914) of intentionally leaving some insects untreated with insecticides holds true even 100 year later for resistance management. The studies on contribution of natural refuge for delaying resistance in the cotton bollworm, *Helicoverpa armigera* (Hubner) to Cry1Ac toxin show their efficacy. Further, genetic purity of such Bt transgenics must be maintained to get best expression of the trait. Insect protective transgenic crops will need a better agronomy than ever before for socio-economic acceptance in a complex landscape that Indian agriculture represents and sustainability an ultimate goal.

# Refuge Strategy for Bt Resistance Management in GM Cotton

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The Bt (*Bacillus thuringiensis*) cotton, worldwide, has a unique requirement for a 'refuge' area, which are portions of the crop, or another suitable host for cotton bollworms which does not express the Bt protein. This requirement will be needed for all insect-protected crops, present and future, where insect suppression is brought about by novel/enhanced production of a toxicant. The refuge maintains a population of susceptible insects and is designed in such a way as to maximize the probability that rare resistant survivors on the Bt crop will mate with the large number of susceptible moths produced by the refuge. In order to delay resistance development, the Genetic Engineering Appraisal Committee in 2002 approved commercial cultivation of Bt cotton (Bollgard®) with a requirement to plant 'refuge' crop of non-Bt cotton in a perimeter belt of five rows or 20% of total sown area whichever is more. Although the farmers are provided with the recommended quantity (120 g) of non-Bt seeds along with each packet of Bt cotton seeds, the farmers are reluctant to sow the refuge non-Bt seeds, in spite of education and awareness imparted by the technology provider and Bt seed companies. Instead, the farmers only sow the Bt seeds in the entire field with the contention that there would be yield loss from the 'refuge' crop. Other reasons for not planting refuge could be (i) small land holdings and hence reluctance to set aside a portion of land for refuge (ii) intricacy of refuge implementation, and (iii) ignorance of its necessity.

The lack of refuge planting puts Bt cotton technology at greater risk of bollworms developing resistance to Bt cotton and also poses risk to the entire cotton value chain, one of the largest employers in the country. Poor refuge planting in ~12 million hectares of Bt cotton cultivated by Indian farmers, could lead to increasing 'selection pressure' for bollworm resistance. For insects like pink bollworm which feed only on cotton, it is very important to have non-Bt cotton as refuge. Hence it is imperative that other approaches of refuge planting are thought of, and one such approach, which has been implemented for Bt maize in other countries, is to blend the required level of non-Bt seeds with the Bt cotton seeds (Built-in-refuge) and offer the product as a single packet making it easier for the farmer in sowing operations.

Concluding, the success of Bt cotton in India also places a great responsibility on scientists and policy makers for its sustenance. In view of poor compliance on recommended planting of 'refuge' non-Bt crop, durability of the technology is at risk as the strong selection pressure of an all Bt cotton crop has the potential to trigger development of resistance in bollworms to the technology. A scientifically sound approach of 'Refuge' delivered through blending of Bt and non-Bt cotton seeds in a single bag is undergoing experimentation and appears to be a robust field-viable option that needs to be encouraged and swiftly adopted.

**OP: 16**

# Insecticide Resistance Monitoring and Management in Major Field Crops and Cropping Systems

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Insecticides are important component of integrated pest management (IPM) due to the constraints in adoption of cultural practices, bio-agents, lack of resistant cultivars and other non-chemical approaches. Insecticide resistance in insects is a shift in the genetics of a pest population that allows individuals within a previously susceptible population to survive. Resistant pest populations inherit traits that reduce their susceptibility to individual insecticides or groups of insecticides. Insecticides damage or prevent specific processes in an organism that are required for life and a genetic difference may protect the organism from damage due to the insecticide. Insecticide-resistant individuals are initially quite rare in pest populations. The frequency of resistant genes to novel chemistries varies, but the resistant individuals are expected to be present in all pest groups.

According to "Global Insecticide Resistance in Arthropods" there were more than 7747 insecticide resistance cases documented. Resistance occurs in thirteen orders of insects, yet more than 90% of the arthropod species with resistant populations are in Diptera (35%), Lepidoptera (15%), Coleoptera (14%), Hemiptera (14%), and mites (14%). Agricultural pests account for 59% of harmful resistant species, while medical and veterinary pests account for 41%. The insecticide resistance occurs in at least more than 500 species of insects and mites documented during 1986 and at present more than 700 insect species have developed resistance to different insecticides. The long-term monitoring of insecticide resistance in populations of agricultural pests in Russia over the last 45 years, recorded resistance development in 36 arthropod pest species across 11 agricultural crops. There were 56 cases of insecticide resistance within 2013 alone, and the silver leaf whitefly *(Bemisia tabaci)* populations were reportedly resistant to over 54 active ingredients. Prior to the Second World War, inorganic insecticides with multiplicity of modes of action ('target sites') might have prevented the evolution of resistance. Only 12 cases of insecticide resistance were reported before 1946. The newer lipophilic organic insecticides (organochlorines, organophosphates, carbamates and synthetic pyrethroids) were generally safer and were more selective against insects because each affected only a single biochemical site. However, this target-site specificity may also result in rapid evolution of resistance. Adaptations are known that increase behavioral avoidance, reduce cuticle permeability, conversion of insecticides to excretable polar compounds, or decrease sensitivity of the biochemical target. Insecticide resistance management is an effort to slow or prevent the development of resistance. Management factors that influence resistance development include frequency and persistence in the field, application thresholds and strategies for using available insecticides. Using insecticides unnecessarily, same or of same group, eliminating natural enemies, using low or high rates may also result in development of resistance to insecticides. Resistance management strategy is based on the study of specific insect-insecticides interactions and focus on practical strategies that growers can implement and are often grouped as management by moderation, rotation and mixtures, and saturation. Due to the development of resistance in insects to insecticides, the monitoring and management of insecticide resistance is priority for sustainable pest management. The IPM program may not sustainable without taking actions to delay or minimize pest resistance. The insect pest organisms develop resistance to new insecticides within 2-20 years of release. The resistance evolves most readily in those with an intermediate number of generations (four to ten) per year that feed either by chewing or by sucking plant cell contents. Resistance can be monitored by using conventional standard bioassay methods published by International Resistance Action Committee (IRAC), biochemical, immunological and molecular methods. The IRAC mention more than 180 standard methods for various inset pests. Among these, easy-to-use toxicological methods have gained the most recognition worldwide. Monitoring insect population and need based application of insecticides, follow label claim, rotate different insecticides throughout the season and from season to season with different mode of action, are some of the ways to manage or delay insecticide resistance. The IRM strategies as component of IPM have been devised, validated and demonstrated in pests of different crops and cropping system.

However, the implementation of IRM strategy requires political will and stewardship of pesticides industry. Availability of farmer friendly monitoring of pest population, economic threshold and economically viable IRM strategies are also the main constraints. The failure of cotton crop in different cotton growing area of world indicated the lack of awareness and strategies for management of resistance. IRM strategies thereafter were adopted in many cotton growing countries, which resulted in reduction of insecticide use with higher production and more profits. The success of IRM in cotton is classical example in various cotton growing countries which revived the cultivation of cotton after failure due to development of resistance to bollworms and related problems with excessive use of insecticides. The goal of resistance management is to delay evolution of resistance in pests. The best way to achieve this is to minimize insecticide use. Thus, resistance management is a component of integrated pest management, which combines chemical and non-chemical controls to seek safe, economical, and sustainable suppression of pest populations.

**OP: 17**

# The New IRM Implementation Paradigm Emerging from Latin America and its Implications for India

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The genetically modified (GM) technologies for insect resistance were launched in 1996 and since then, a significant area in agriculture has been occupied by transgenic crops. Transgenic crops are widely cultivated in North America, Latin America, South Africa and Asia. Technologies for insect resistance are mainly available in crops such as corn and cotton. Different classes of Cry proteins are being used for control of important lepidopteran pests appearing in the crops. If we look back and review the situation, resistance development has been a moderate concern in North America, South Africa and Asia, but in Latin America resistance development against the transgenic technologies are already under severe impact. Laboratory and field data has confirmed development of resistance in *frugiperda* to *Cry 1F* protein in corn in Brazil, Argentina and Puerto Rico. Resistance has also been reported in *Diatraea saccharalis* in corn to Cry1Ab x Cry2 proteins although it is in a limited geography. Although economic impacts of field relevant resistance have been moderate in cotton, there is a need to an attention and not remain complacent. In recent years the tropical savanna ecoregion of Brazil has encountered intensification of agriculture with three cropping cycles, three major pests being common in corn, cotton and soybean creating a continuity of the pest cycles. To add up to this, performance issues with some insecticides, rapid adoption of Bt crops and use of same class of proteins have intensified the problems. The year 2013 recorded severe pest management crisis in eastern state of Bahia with severe damage from *Helicoverpa zea, Helicoverpa armigera* and *frugiperda* causing high risks to Bt technologies and conventional insecticides in corn. The mechanisms for mitigating these risks in Brazil and lessons learnt have been discussed in the presentation.

**OP: 18**

# Integrated Pest Management for Sustainable Crop Protection: The Way Forward

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Integrated Pest Management (IPM) has been one of the classical strategies developed and adopted by Plant Protection scientists to combat the menace of pests, diseases and weeds, and reduce the losses induced by them. The wisdom to adopt this technology has come from the very fact that no single method of pest control was useful in containing the losses and those like chemical use had created problems of residue, resurgence and resistance in the pests. The IPM strategy aims at using all the available options, their integration at ground level to achieve the desired economic and ecological benefits while reducing the losses caused by the pests of all kinds. It is estimated that the overall losses due to pests in India range from 20 to 32%. Even considering an average annual loss of production, the country is loosing around 39 million tons of food grains and equal quantity of fruits and vegetables, which when added to the current production figures are targets of achievements by 2025. Therefore, crop protection assumes high significance in the overall food security of the country in the years to come.

In India several IPM modules have been developed. However, these modules need location specific validation on large scale. The ground reality is that the actual IPM use is only 7-8%, and in the immediate future it must reach respectable position. Except cotton and to some extent rice, the adoption of IPM in other crops is low to negligible. In fact IPM should by now the backbone of the entire crop protection umbrella, but still awaiting the due attention in field that it deserves. The way forward replicate some of the achievements in IPM such as - Ashta project, FFS concept, and IRM success in cotton. Further the way grape pest management has shown through the monitoring program, a substantial reduction in the chemical use can be achieved without any residue problem. These technologies can effectively be replicated in oranges, pomegranate, apple, several vegetables where chemicals become an integral part of IPM as they cannot be avoided totally. To increase the reach of IPM amongst the farmers, it is also essential to invest in developing forewarning technologies for epidemiologically potential pests. Similarly, strengthening the surveillance mechanisms and educating the farmers through the transfer of technologies shall be of great help in adoption of IPM in future.

# Poster Presentations

# Chemical Control

## Evaluation of Efficacy of Some Novel Chemical Insecticides Against Stem Borer, *Chilo partellus* (Swinhoe) in Maize

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The spotted stem borer, *Chilo partellus* (Swinhoe) is one of the most important yield reducing biotic constraint, and it's control with insecticides is one of the major challenge due to it's concealed feeding habit. Therefore, we tested the efficacy of different insecticides as seed treatment and need based foliar application for it's management. The present studies were conducted at the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. during 2011 cropping season. There were seven treatments with three replications in randomized block design. Among all the treatments, seed treatment with chlorantraniliprole 18.5 SC @ 4ml/kg seed and one spray @ 350 ml/ha performed best with minimum infestation (4.5% and 7.42%) and deadhearts (2.33% and 1.66%) at 25 and 40 days after sowing (DAS), and minimum tunnel length (1.94 cm). The seed treatment with fipronil 5SC @ 4 ml/kg seed and 625 ml/ha spray was adjudged as second best treatment with 7.84% and 10.27% infestation, 2.66% and 2.33% deadhearts at 25 and 40 DAS, and 2.41 cm tunnel length. The maximum infestation (30.45% and 31.30%) and deadhearts (7.33% and 6.33%) at 25 and 40 DAS, respectively, and maximum tunnel length (11.07 cm) per plant were recorded in the untreated control. The coccinellid population was found minimum viz., 2.4, 3.13 and 3.87 per plot at 15, 30 and 45 DAS, respectively, under chlorantraniliprole 18.5 SC @ 4ml/kg seed treatment and foliar application @ 350ml/ha, being highest 14.68, 10.81 and 11.67 per plot under untreated control. The maximum grain yield (73.33 q/ha) and net profit (Rs. 32714/ha) was obtained due to the treatment of chlorantraniliprole and followed by fipronil as compared to untreated control (37.78 q/ha).

PP: 02

# Management of *Helicoverpa armigera* (Hubner) Using Chemical Method in Chickpea

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Efficacy of different insecticides *viz.,* indoxacarb 14.5 SC, profenofos 50 EC, imidacloprid 17.8 SL, novaluron 10 EC, fipronil 5 SC and lambda cyhalothrin 5 EC tested against *Helicoverpa armigera* (Hubner) larvae revealed that at first spray of indoxacarb was most effective among all the treatments with minimum larval population of 1.53, 0.46, and 0.73 larvae/five plants. The indoxacarb treatment recorded 89.45, 97.01, 95.83% reduction in larval population over control at 3, 5 and 7 days after spray (DAS), respectively. At the second spray, the larval population was 0.00, 0.26 and 0.00 larvae/five plants, giving 100, 98.74 and 100% reduction in larval reduction over control at 3, 5and 7 DAS, respectively, with minimum of 0.83% pod infestation. The treatment with indoxacarb 14.5 SC was also found best with the highest grain yield (24.3 q/ha), and maximum increase of 69.13% yield over control.

PP: 03

# Insect Pests Management in Tomato

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Tomato, *Lycopersicon esculentum* Mill, is one of the most popular and widely grown vegetables across world. It is infested by number of insect pests, of which fruit borer, *Helicoverpa armigera* Hubner; whitefly, *Bemisia tabaci* Gen; jassids, *Amrasca devastans* Ishida; leaf miner, *Liriomyza trifolii* (Blanchard); potato aphid, *Myzus persicae* (Thomas); and hadda beetle, *Epilachana dedecastigma* Widemann are among the most important pests of this crop. *Bemisia tabaci* and *Amrasca devastans* cause direct feeding damage as well as indirect damage by acting as a vector of several viral pathogens especially gemini virus. Economic significance of crop produce compelled the commercial farmers to use heavy doses and frequent application of insecticides, leading to development of resurgence and resistance. Therefore, we tested the efficacy of newer insecticides for the management of whitefly and jassids in tomato under field conditions. For whitefly and leafhopper management we used spinosad 45% SC, fipronil 5% SC, profenofos 50% EC, indoxacarb 14.5% SC, NSKE 5% and NPV. The total two numbers of sprays were done when sucking pest's complex were severe on tomato. For control of whitefly and leafhopper, fipronil 5 % SC was found most effective among all the test insecticides followed by profenofos 50% EC.

**PP: 04**

# Effect of Seed Treatment With Insecticides on Grain Yield and Infestation of Termite (*Odontotermes obesus*)

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The present experiment was conducted at Crop Research Farm, Nawabganj, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur under rainfed condition during *Rabi* 2010-11. Present studies were aimed at observing the effect of insecticide seed treatment on germination, termite damage and yield of wheat variety, K-8027. Seeds were treated with insecticides, viz., bifenthrin 10 EC @ 5 ml/kg seed, thiamethoxam (cruiser 35 FS) @ 2 g/kg seed), fipronil 5 SC @ 6 ml/kg seed, imidacloprid 70 WS @ 2 g/kg seed, carbosulfan 25 DS @ 4 g/kg seed, and chlorpyriphos 20 EC @ 4.5 ml/kg seed, one day before sowing. The crop was sown on 5 x 4 m plot size and there were three replications in a randomized block design. The observations on termite damage were recorded at fourth week after germination and at heading stage, and seed yield at harvest of the crop. Minimum termite damaged effective tillers/ha were recorded in Fipronil treated plots followed by imidacloprid and thiamethoxam. Grain yield was significantly higher in fipronil (18.17 q/ha) followed by imidaclorpid (17.75 q/ha) and thiamethoxam (17.50 q/ha) treated plots.

# Effect of Newer Insecticides and Biopesticides on the Population of Tobacco Caterpillar *Spodoptera Litura* in Cabbage

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Tobacco caterpillar, *Spodoptera litura* F. is a polyphagous pest which especially causes serious damage in cruciferous crops. For the management of this pest with IPM packages for sustainable agriculture, it is important to know about promising pesticides that are effective and eco-friendly. Results showed that the application of fipronil, spinosad, acetamaprid and indoxacarb were found superior over control, having 2.52, 2.87, 3.10 and 3.52 larvae per 10 plants after 5 days after 1$^{st}$ spray. The application of achook was also found effective against *S. litura* and 5.14 larvae per 10 plants with 54.79% reduction in larval population was recorded. Thiamethoxam and biolep were also found better to manage the pest but they did not differ significantly, where 5.87 and 6.03 larvae per 10 plants were observed compared to 11.37 in the control showing 48.37% reduction in larval population. Fipronil, spinosad and acetamaprid were found equally effective against the larval population of *S. litura* after second spray. The application of indoxacarb, thiamethoxam and azadirchtin were also found effective in comparison to control.

# Management of Sucking Insect Pests of Capsicum Under Protected Cultivation

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The present studies were carried out under polyhouse condition during *kharif* season 2013-14 in Vegetable Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar. The experiment was comprised of chemical, botanicals and biorational insecticide treatments having four sprays each, and there were three replications. The observations were recorded on the sucking insect pests i.e., thrips (*Scirthothrips dorsalis*), Whiteflies (*Bemisia tabaci*), Aphids (*Aphis gossypii*), and Mites (*Polypha gotarsonemus latus*) from 10 randomly selected plants. The infestation of sucking insect pests such as aphid, thrips, mites, and whitefly commenced on the crop around 25-30 days after transplanting, which then gradually increased attaining peak infestation during December and January under polyhouse conditions. Mealy bug incidence which was seen in low levels initially but attained peak during February month and then declined. The evaluation of biorationals, botanicals and newer pesticides against mite in *Capsicum* grown under protected condition indicated that Imidacloprid 17.8SL @100ml/ha as an effective treatment followed by Emamactin benzoate 1.9% EC @325ml/ha. Lowest leaf curl damage was noticed in Imidacloprid 17.8SL @100ml/ha treated crop followed by Thiamethoxam 25% WG @100ml/ha, Monocrotophos 36EC @ 100 ml/ha, Neem oil @1000ml/ha, and *Beauveria bassiana* @1kg/ha treatments. With respect to thrips, Imidacloprid 17.8% SL @100ml/ha and Monocrotophos 36EC @ 100 ml/ha were found to be significantly superior followed by Thiamethoxam 25% WG @100ml/ha. Other promising treatments were *Beauveria bassiana* @1kg/ha, Neem oil @1000ml/ha, Emamactin benzoate1.9%EC@325ml/ha, and *Metarhizium anisopleae* @1kg/ha. Imidacloprid 17.8% SL @100ml/ha was found to be the suitable treatment against mealy bug damage on leaves and fruits followed by Emamactin benzoate 1.9% EC @325ml/ha. Imidacloprid 17.8% SL @100ml/ha was found to be the best treatment against whitefly damage followed by Neem oil @1000ml/ha. Similarly, Imidacloprid 17.8% SL @100ml/ha recorded significantly less number of aphids followed by Neem oil @1000ml/ha and Thiamethoxam 25% WG @100ml/ha. Chemical control was found significantly superior for the control of *Capsicum* pests followed by biopesticides and botanicals, which also highest net

returns as against biopesticide and botanicals. Maximum *Capsicum* yield (21433.3kg/ha) was obtained under protected condition treated with Thiamethoxam 25% WG and minimum (13382.0 kg/ha) under neem oil treatment. No natural enemy population was found in *Capsicum* crop grown under protected condition.

**PP: 07**

# Toxic Effects of Herbicides on the Life Table Parameters of *Zygogramma bicolorata* Pallister


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Leaf feeding beetle, *Zygogramma bicolorata* Pallister is the most prominent biocontrol agent of *Parthenium hysterophorus* L. Five commonly used herbicides i.e., glyphosate (4.4 ml a.i. liter$^{-1}$), atrazine (1.42 mg a.i. liter$^{-1}$), metribuzin (0.75 mg a.i. liter$^{-1}$), alachlor (6 ml a.i. liter$^{-1}$) and 2,4-D (2.08 mg a.i. liter$^{-1}$) were evaluated to determine toxic effects on the fitness parameters of *Z. bicolorata*. A total of 118 days were required for survivorship in alachlor exposed and unexposed groups. However, it was 116 days in glyphosate, metribuzine and 2-4D exposed groups. Life expectancy ($e_x$) declined to 35.26, 29.47, 28.75, 26.75 and 25.76 days on glyphosate, atrazine, metribuzine, alachlor, and 2-4D exposed groups, respectively. An overall 97, 95, 93, 91 and 89% eggs were hatched with glyphosate, atrazine, metribuzine, alachlor and 2,4-D exposed groups, respectively. Herbicidal treatments strongly affected the developmental time of immature stages of *Z. bicolorata*. A total of 7.10 days were required for egg hatching when exposed to 2,4-D, which was found to be significantly prolonged compared with other herbicidal treatments and the control. Females survived up to 76.75 days in control and reduced to 74.51 and 73.06 days when treated with glyphosate and atrazine, respectively. Daily fecundity rate ($m_x$) of *Z. bicolorata* was found to be 6.00, 5.80, 5.45, 4.69 and 3.98 offspring/day in glyphosate, atrazine, metribuzine, alachlor, and 2,4-D treated groups, respectively. Pre-oviposition period was significantly shortened in glyphosate exposed groups compared to those exposed to other herbicides. Oviposition period was significantly shortened in 2,4-D exposed groups compared to other herbicides tested. Potential fecundity ($p_f$) was significantly reduced to 151.26 offspring when treated with 2,4-D. Similarly, net reproductive rate ($R_0$) was decreased in glyphosate followed by atrazine,

metribuzine, alachlor and 2-4D. Intrinsic rate of increase ($r_m$) was 0.0687 females/female/day in control, while significant reduction was noticed when treated with 2,4-D and glyphosate. Doubling time (DT) was 10.09 days in untreated control and prolonged to 17.32 days in glyphosate exposed groups.

**PP: 08**

# Effect of Profenofos on Four Populations of *Phenacoccus solenopsis* and it Parasitoid *Aenasius bambawalei*

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Mealy bug pests have become a potential threat to economically important crops in the recent years. Farmers rely on a number of plant protection chemicals to suppress these pests. Recently, sever occurrence of *Phenacoccus solenopsis* has been recorded on cotton brinjal and tomato. The insecticides meant for managing the insect pest tend to cause ill effect on the natural enemy associated with the insect pest. In the present study the effects of profenofos on four populations of cotton mealy bug and it parasitoid were studied. A commonly used insecticidal compound against mealy bug i.e., profenofos was tested for its efficacy against *P. solenopsis* and its parasitoid, *Aenasius bombawalei* collected from Madhya Pradesh, Maharashtra, Punjab and Gujarat. Differential levels of susceptibility in field populations of mealy bug were observed. Log dose probit analysis revealed that mealy bug population from Punjab was found to be more susceptible while, *P. solenopsis* from Maharashtra population was found to be more tolerant. The $LC_{50}$ values of the four populations were 27.74, 88.00, 54.76 and 82.23mg/L against Punjab, Maharashtra, Madhya Pradesh and Gujarat, respectively. The activity of detoxification enzyme Mixed Function Oxidase (MFO) measured in these populations indicated that specific activity was high in Gujarat population, while low in Punjab population. Similarly the effect of profenofos on survival of *A. bambawalei* studied by film coating method showed that the parasitoid population from Madhya Pradesh was more susceptible and the Punjab population was more tolerant to this insecticide at $LC_{50}$ dose of the chemical.

# Susceptibility of Laboratory and Field Populations of *Chilo Partellus* (Swinhoe) to Insecticides

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The susceptibility of *Chilo partellus* (Swinhoe) to different strains of *Bacillus thuringeinsis* is well known. However, differential response of geographical populations of *C. partellus* to *Bt* in India has also been reported. Moreover, the information on relative susceptibility of *C. partellus* larvae reared for different generations under laboratory conditions to *Bt* and other insecticides is lacking. This kind of information is helpful to find the differences in baseline susceptibility of such populations as laboratory reared test insects are used to find their baseline susceptibility of both chemical and bio-insecticides. Therefore, to generate such an information, we conducted bioassays with $3^{rd}$ instar larvae (each weighing 10–15 mg) of 3 different *C. partellus* populations i.e., laboratory population reared for 8 generations (P1), field collected population reared for 3 generations under laboratory conditions (P2), and field collected population reared only for 1 generation under laboratory conditions (P3) with *Bt* formulation Dipel 8L (*Bacillus thuringiensis* var. *kurstaki* strain HD-1) and recommended insecticide Decis 2.8 EC (deltamethrin). The standard leaf disc dip method of bioassay was employed to determine $LC_{50}$ values of both the test insecticides. A total of nine concentrations along with a control check were tested for both insecticides and replicated 5 times. There were 10 larvae per replication. Circular leaf discs (2.5 cm) were cut from central whorls of 3 weeks old maize plants. The leaf discs were dipped with the test insecticides for 5–10 seconds and then allowed to dry at room temperature for about one hour. After drying, each leaf disc was placed in the plastic Petri plate (4.9 cm in diameter) having 10 larvae, and were incubated at 25 ± 1°C and at 70% RH after wrapping with Para-film. The $LC_{50}$ values were calculated based on the mortality data obtained after an exposure of 48 h using POLO statistical method. On the basis of $LC_{50}$ values, the order of susceptibility in 3 test populations to Decis 2.8 EC and Dipel was $P_1 > P_2 > P_3$. The $LC_{50}$ value for $P_3$ after an exposure of 48 h was highest (0.00047 & 0.00796 %), comparatively lower for $P_2$ (0.00031 & 0.00605 %) and was lowest for $P_1$ (0.00005 & 0.00181%) in Decis and Dipel, respectively. The increased susceptibility of continuously laboratory reared populations in the present studies might be due to some deleterious genetic effects or inbreeding depression occurred during continuous laboratory rearing for 3 and 8 generations thus suggest careful selection of test insects for testing insecticides.

**PP: 10**

# Estimation of Economic Threshold Level of Aphid, *Acyrthosiphon pisum* (Harris) on Fenugreek *Trigonella foenum graecum* Linn

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Pea aphid, *Acyrthosiphon pisum* (Harris) an important pest of Fenugreek, *Trigonella foenum graecum* L. sucks plant sap thereby severely reduces the vitality and yield potential. The Economic Threshold Levels (ETL) is indispensable because it indicates the time of action in any given pest situation. Therefore, present studies were conducted to find the ETL of aphid on the fenugreek during *Rabi* 2010-11. The experiment consisted of 8 treatments including control with three replications in a randomized block design. Insecticides *viz.*, dimethoate 30EC @ 0.03% and malathion 50EC @ 0.05% were sprayed alternately to create differential levels of aphid infestation. Insecticide application frequency varied from one to a maximum of four during different crop growth stages. Wherever single spray was done, only dimethoate was used. The aphid population in each treatment was recorded at weekly interval on five randomly selected plants, and crop yield was recorded at harvesting. Minimum yield (12.20 q/ha) was recorded under untreated control, and single dimethoate spray (14.37 q/ha) at 45 days after initiation of aphid population conditions. However, maximum yield (19.30 q/ha) was recorded under four spray treatment condition. The expenditure incurred in maintaining various levels of aphid population ranged from Rs. 432 to 1894.4 per ha, minimum being in one spray and maximum in four spray treatments.

The aphid population and seed yield of fenugreek had a significant and negative correlation (r = -0.94). The gain threshold and EIL was found to be 94.72 kg/ha and 9.48 aphids/central shoot, respectively, whereas, the ETL was found to be 5.18 aphids/central shoot at the current market prices.

**PP: 11**

# Contact Toxicity of Two Insecticides on Egg Parasitoids, *Trichogramma chilonis* and *Trichogramma japonicum*

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*Trichogramma* spp. are the most important egg parasitoids used for managing the lepidopteran pests under different cropping systems. Any attempt to suppress the insect pest populations by biological control measures have often failed because of the ill effect of pesticides on beneficial insects. The present study was carried out to know the effect of two newer insecticides i.e. chlorantranilprole 18.5% SC and sulfoxaflor 21.8% SC on the survival of *Trichogramma* spp. by contact residue method. Parasitised tricho cards were treated with different concentration of insecticides. The results showed that the treatment of sulfoxaflor was more toxic *Trichogramma* spp. than chlorantranilprole. The $LC_{50}$ value for sulfoxaflor and chlorantranilprole were 0.00146 and 0.00174 mg a.i./L against *T. chilonis* and 0.00242 and 0.00261 mg a.i./L for *T. japonicum*. The mean percentage emergence was higher in *T. japonicum* as compared to *T. chilonis* under both the insecticide treatment conditions.

# Residue Analysis of Effective Insecticides Used Against Honeydew Moth, *Cryptoblabes Gnidiella* Miller in Sorghum Grains

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Chemical insecticides used to control insect pests on food commodities impose a great risk on human health. In sorghum various chemical insecticides are used to control *Cryptoblabes gnidiella* Miller, and some of them give a promising control, but residue of these insecticides in sorghum grains need to be analyzed. Therefore, we analyzed residues of three important insecticides i.e., monocrotophos, endosulfan and phosphamidon through chromatography. The initial deposit of two fortnightly sprays of monocrotophos, endosulfan and phosphamidon were 3.669 ppm, 3.139 ppm and 2.675 ppm on sorghum grains, respectively. Further, they get degraded below the tolerance limit of 0.2 ppm, 1.172 ppm and 0.5 ppm in 17.2, 5.0 and 11.0 days, respectively. The half life of monocrotophos, endosulfan and phosphamidon were 14.19, 11.95 and 13.87 days, respectively. Present studies indicated that three important insecticides viz., monocrotophos, endosulfan and phosphamidon which provide better protection to sorghum ear heads against *C. gnidiella* have no toxic residues left above the tolerance limit after a waiting period of 11.0, 5.0 and 11.0 days, respectively.

# Host Plant Resistance

## Host Plant Resistance: A Base Component of Integrated Pest Management

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Host plant resistance to insects is an extremely successful strategy for regulating pest populations without imparting any adverse effects on the environment. Integration of other control tactics, i.e., cultural, biological, microbial and chemical with resistant/tolerant crop genotypes have added advantage for better suppression of insect pests than the individual control tactics. Integrated pest management (IPM) system is not a new concept for more stable agroecosystem. It has been practiced by the farmers since centuries with insect tolerant crop genotypes as one of its major component. With advancement in agricultural research for pest management, several insect-tolerant crop genotypes have been developed and released in India and elsewhere in the world, and have been found suitable and compatible with other pest management technologies. However, deployment of these resistant varieties have not found right place in the IPM model development, except in a few cases. Development of a IPM model having resistant variety as one of its main component for the management of sorghum midge in Africa, is the only success story we came across demonstrating real integration of different pest management components such as use of resistant sorghum varieties, early planting and uniformly in an area, destruction of johnsongrass, deployment and conservation of indigenous parasites and predators, and need based use of insecticides. Last few decades in the quest to break yield plateau for sustainable increase in crop productivity of field crops through use of hybrid technology, have further diluted the emphasis on development of insect-resistant/tolerant cultivars. Moreover, it is also desirable to understand basic biological processes and interactions that occur among plants, pest and beneficial species in a particular crop agroecosystem in order to successfully engineer different pest management components in the current changing climate scenario. Increased pressure to reduce pesticide usage in agriculture, changes in pest management technology with emphasis on development and release of insect resistant/tolerant crop varieties now seems to have practical relevance in pest management system in the present context for economic and environmental sustainability, and social acceptability.

**PP: 14**

# Developmental Biology of Spotted Stem Borer *Chilo partellus* on Diverse Maize Types and Their Protein Interactions

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Host plant resistance is one of the effective means of minimizing losses due to insect pests. Biochemical mechanism of insect defence in crop plants is mainly governed by constitutive and/or induced plant metabolic compounds. Poor understanding of biochemical mechanisms of insect-plant interactions has been the biggest impediment in development and deployment of insect-resistant crop plants. Therefore, we studied the developmental biology of *Chilo partellus* (Swinhoe) on different maize types to gauge the level of antibiosis mechanism of resistance in maize genotypes with different specialties, and the total protein content present in seedlings of different maize type *vis-à-vis* the *C. partellus* larvae reared on these genotypes. The studies suggested that there were significant differences among different maize types for larval weight at 30 days after feeding, larval survival, larval period, pupal period, and adult emergence. The larval weight of *C. partellus* was significantly lower on resistant check, CML 345 as compared to other genotypes, being highest on sweet corn and quality protein maize (QPM) genotypes, except in a few cases. The larval period and pupal periods were significantly higher on white kernel and yellow kernel genotypes as compared to that on sweet corn and QPM genotypes, and the susceptible check, Basi Local. In general, the larval survival and adult emergence were significantly lower on white kernel and yellow kernel genotypes as compared to that on sweet corn and QPM genotypes including susceptible check, Basi Local. There were significant differences among different maize types and the *C. partellus* larvae fed on these genotypes for total protein content present. Protein content in maize seedlings was lower as compare to that in stem borer larvae fed on them. Total protein content was significantly higher in QPM genotypes as compared to other

group of maize genotypes, except in few cases. Protein content in susceptible check, Basi Local was significantly lower than other group of maize genotypes. The present studies are highly important for understanding the mechanism of resistance and the host plant-insect biochemical interactions in different maize types.

**PP: 15**

# Varietal Screening of Mungbean, *Vigna radiata* Genotypes for Resistance Against Cowpea Pulse Beetles, *Callosobruchus maculatus* Fabricius

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Greengram, *Vigna radiata* (L.) Wilczek belonging to the genus *Vigna*, subgenus *Ceratotropis* is one of the important short duration grain legume widely grown in many Asian countries. In storage, a total of 25 insect species have been recorded as pests on pulses. Among these, *Callosobruchus maculatus* Fab. causing major damage to Mungbean during storage has greater economic importance. In this context, the present study was focused on the varietal screening of different Mungbean accessions to find out the levels of resistance against *C. maculatus*. Eighty five accessions of Green gram were subjected to infestation by *C. maculatus* under both free and force choice conditions under a completely randomized design (CRD) with three replications. In free choice method ten grains of each accession were kept in 24 separate circular disks like craters and five pairs of freshly emerged adults of *C. maculatus* were released. Under forced choice test, ten grains from each accession were taken in separate homeopathic vials and five pairs of adult insects were released. The setup was left undisturbed for 24 h and observations were recorded until adult emergence. All accessions exhibited significant differences in oviposition, percentage survival and mean developmental period. The accessions KM-12-10, KM-11-32 and KM-12-2 revealed lesser per cent survival of 6.4%, 6.6% and 7.8%, respectively, prolonged developmental period (29.7, 29.41 and 27.7 days, respectively) and lesser index of suitability (0.072, 0.078 and 0.080, respectively) in comparison to the susceptible genotype M1319B, which exhibited 91.0% survival, 22.1 days developmental period and 0.191 suitability index. These accessions can be effectively used as promising donors while evolving varieties resistant to bruchids.

# Screening of Wheat Genotypes for Resistance and Testing Efficacy of Powdered Spices Against *Tribolium castaneum* (Herbst.)

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The red flour beetle, *Tribolium castaneum* (Herbst.) is an important stored grain pest of cereals. In order to have cost effective and indigenous management, and in built resistance in the wheat genotypes against this pest, we evaluated efficacy of nine different spices and screened 23 wheat genotypes for resistance against *T. castaneum* at the Department of Entomology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during 2013-2014. There were three replications in a completely randomized design. Maximum grain damage (120.33) and adult population development (80.67) was recorded in genotype, UP 2565 being most susceptible genotype among all the screened genotypes. Maximum frass weight (119.83 mg) was recorded in genotype RAJ 3765. The wheat genotype, PBW 58 proved to be the most tolerant genotype as minimum number of damaged grains (47.67) and frass weight (53.17 mg) were recorded on this genotype. Minimum adult population (33.33) was recorded in genotype PBW 468. Among the nine spices tested, Black Pepper caused maximum mortality (9.67) after fifteen days of insect release and proved to be highly effective against *T. castaneum*, which also showed highest germination percentage (95.67%) as compared to other spices. Minimum germination percentage (86.00%) was recorded in Ginger treated wheat genotypes.

PP: 17

# Donor Validation Studies on Rice Differential Varieties Against Rice Brown Planthopper, *Nilaparvata lugens* (Stal.)

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Six differential varieties along with standard checks were evaluated for donor validation against rice brown planthopper under glasshouse conditions at the Department of Entomology, IGKV, Raipur during 2013-14. All the differentials were resistant to Raipur brown planthopper population. Among the differentials tested, ARC 10550 exhibited least plant damage score (0.64) followed by Sinna Sivappu (0.75). Honeydew excretion values were minimum in Sinna Sivappu (15.3 $mm^2$) followed by Rathu Heenati (15.8 $mm^2$). The average probing marks were maximum in Sinna Sivappu (38.3) followed by Rathu Heenati (30.7) which were significantly higher than TN1, while nymphal survival value was minimum in variety INRC 3021 (29.21%). All the differentials showed resistant reaction against Raipur population, and were designated as potential donors for brown planthopper resistance.

PP: 18

# Oviposition Preference of *Spodoptera litura* vis-à-vis Age of Cauliflower Host Plant

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Tobacco cutworm, *Spodoptera litura* (F.) recorded as a major pest on early season or rainy season cauliflower, and has been the most difficult to control pest. The deterrence and oviposition preference of generalist herbivores has been attributed to the age of the plants and leaves. Therefore, present studies were conducted to determine the most preferred age of the cauliflower plant for oviposition by *S. litura* and their relationship. Four different dates of sowing were undertaken to obtain differently aged plants to conduct the oviposition preference test. Choice test under net house condition and no-choice test under screen cage were conducted. Age of the plants was categorized based on leaf-age and total life span of rainy season cauliflower. In choice test, number of egg masses varied from 0.25 to 4.75 with highest being at 65 DAS (days after sowing) of the crop. *Spodoptera litura* female laid significantly more number of egg masses at 65 DAS (8.46), being least at 110 DAS (4.60) under screen cage conditions. The young (<60 DAS) and aged (>90 DAS) plants were least preferred by the *S. litura* females for egg laying under both choice and no-choice test conditions. However, no significant correlation was observed between age of the plant and number of egg masses. All the ages of the cauliflower plant subjected to oviposition test were acceptable to *S. litura* females, however, more number of eggs were laid on maturing plants particularly 60-80 days old plants. Quadratic nonlinear relationship exists between age of the plants and oviposition preference.

# Biological Control

## Impact of Beneficial Arthropods on Sugarcane Insect Pests in Haryana

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The present investigations on the incidence of insect pests and natural control of arthropods on sugarcane variety Co 0283 were undertaken during 2013 at CCSHAU, Regional Research station, Karnal. It was observed that the incidence of top borer, root borer and stalk borer was lowest 2.9, 1.1, and 1.5% during the month of December, February and August, while it was highest 13.2, 8.2 and 41.6% during the month of November, September and January, respectively. Black bug population was significantly more (7.3 nymph and adults/shoot) in the month of August and less (0.8 nymph and adults/shoot) in the month of February. Leafhopper population was high (13.1/plant) in the month of October and low (6.1/plant) in the month of August. Webbing mite and thrips showed peak incidence of 9.3% and 3.7% in October and August, respectively. However, peak population (6.8 nymph and puparia/2.5 sq cm) of whitefly was recorded in the month of November. Spiders, lace wing, beetles and earwigs were the major bioagents recorded during post monsoon period. However, the population of spiders, coccinellids, beetles and earwigs remained low i.e., 2.5, 1.8, 1.5 and 2.1%, respectively. A strong natural parasitism (50.5-78.4 %) of nymphs and adults of *Pyrilla perpusilla* was observed from mid August to last week of October by *Epiricania melanoleuca*. The parasitism of pyrilla eggs by *Cheiloneurus pyrillae* varied from negligible to a maximum of 41.0% in the mid of September. However, parasitism of pyrilla eggs by *Tetrastichus Pyrillae* varied from 0.3 to 11.0%. Top borer larvae were recorded with 8.1, 4.5 and 14.7% parasitism by *Isotima javensis, Cotesia flavipes* and *Beauveria bassiana*, respectively during the post-monsoon period. Whereas, stalk borer larvae were found with 11.9, 3.8 and 5.6% parasitism by *Sturmiopsis inferens, Cotesia flavipes* and *Beauveria bassiana*, respectively. The larvae of root borer collected from field showed 10.4% infection by *Beauveria bassiana*.

# *Diaeretiella rapae* (Mc'Intosh) as Biological Weapon for *Lipaphis erysimi* (Kaltenbach), *Brevicoryne brassicae* (Linn.) and *Myzus persicae* (Sulzer) Infesting *Brassica* Crops for Maintaining Environmental Sustainability

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The bio-intensive or non-chemical means of pest management through naturally available and mass multiplied bioagents need to be focused for crop protection and environmental sustainability. To reduce the reliance on synthetic pesticides for crop protection, terrestrial and aquatic life contamination, it is pertinent to explore the effectiveness of *Diaeretiella rapae* (M'Intosh) an efficient bio-agent against devastating specialist (*Lipaphis erysimi* Kaltenbach), (*Brevicoryne brassicae* Linn.) and generalist (*Myzus persicae* Sulzer) aphid species infesting *Brassica* crops (cabbage, cauliflower and mustard). The respective aphid species colonized on cabbage, cauliflower and mustard plants were collected from the field and maintained for culture in the laboratory at room temperature (25-27ºC, 60-80% RH). Mummified aphid bodies from respective crops were collected randomly and brought to laboratory to collect the parasitoids. Male and female pairs (*Diaeretiella rapae*), were collected and released with the aspirator to allow mating. Twenty aphids of each species were selected to release on each captured parasitoid, replicated ten times and allowed for parasitization on aphids till its survival. The parasitized aphids were identified on the basis of showing jerking action along with the appearance of wax free punctured areas at abdominal ends formed by parasitoid ovipositor. Parasitization (%) and emergence potential (%) was calculated by counting the number of aphids undergone to mummification. Results revealed that significantly highest ($F = 83.95$, $p < 0.0001$) parasitisation was obtained on cauliflower (68.0±1.13 %), whereas least potential (48.67±1.04 %) was noticed when mustard was provided as host plant. Emergence potential was statistically similar ($F = 2.41$, $P = 0.09$) on all three crops. Significantly ($F = 12.08$, $P < 0.0001$) the Highest parasitisation (64.0 ± 1.89) and emergence potential (92.89 ± 0.49) of parasitoid, *D. rapae* were recorded on *Lipaphis erysimi*, whereas *B. brassicae* (59.83 ± 1.91%) and *M. persicae* (56.33 ± 1.84%) received lower parasitisation under lab conditions.

# Biological Control With Reference to Integrated Pest Management in Sugarcane

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Sugarcane is an important cash crop grown in India. It is infested by 287 species of insect and non-insect pests. Pest management in sugarcane is suited to an integrated pest management (IPM) approach since some pest damage can be tolerated. Cultivar differences in insect preferences, biological control agents, cultural practices, and pesticides are all used in sugarcane. An effective IPM program helps protect the environment and potentially saves money for the grower. Under this model, biological control agents are found only at the top and are limited only by the availability of resources. Predators and parasitoids result in regulation of herbivore numbers in the sugarcane ecosystem. These biological control agents are highly specific and manage the pest very effectively without leaving any harmful effect on the environment and the non-target insects. The conservation and augmentation of biocontrol agents like *Beauveria bassiana*, *Hirsutella patouillard*, *Metarhizium anisopliae*, *Paecilomyces fumosoroseus*, *Verticillium*, *Nomuraea*, *Entomophthora*, *Neozygites*, *Bacillus*, *Tetrastichus*, *Trichograma*, *Apentalis*, *Bracon*, *Dipha*, *Stanobracon*, *Pheroscymnus*, *Trichoderma* spp., *Trichogramma* spp., *Coccinellids*, *Syrphids*, etc. have been found effective for the management of insect pests and diseases in sugarcane. The sugarcane sett treatment with the *Trichoderma harzianum* and *Trichoderma viride* can reduce the severity of red rot and sugarcane wilt.

# Status of Hymenoptera Associated with Galls

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Galls are structures composed of plant tissue with distinct microhabitats support specialized inhabitants. Galls range in complexity from relatively open pits or folds to structures that completely enclose the inhabitants. Insect galls occur on a wide variety of forestry and agricultural plants and from an eco-evolutionary point of view, these galls are adaptations of the gall forming insects that ultimately evolved under selection pressure. Diverse groups of insects comprising of an estimated 13,000 species induce plant galls. Unlike oriental region including India, their study has attracted greater attention in the Australian and Holarctic regions with recent updates on their systematics, biogeography and ecology. An annotated check list of Hymenoptera associated with galls recorded from India during the last two centuries was compiled. The check list is mainly based on available literature, compiled with the aid of Zoological records, catalogues, and original descriptions, wherever available. Gall forming hymenopterans are microscopic around 2-8 mm, making them often difficult to study, but their intricate host relationships and biology make them interesting members of systematics, biogeography and ecology studies. Among the gall forming families, it is not always easy to separate the obligatory gall inhabitants and those which have a discrete association with the galls. However the hymenopterans associated with plant galls can be classified into following three categories: (i) gall inducers, (ii) inquilines associated with plant galls, and (iii) parasitoids attacking either gall inducers or inquilines. Gall-inducing Hymenopteran families include Agaonidae, Eulophidae, Eurytomidae, Pteromalidae, Tanaostigmatidae, and Torymidae; inquilines associated with galls include members of the families Eulophidae, Eurytomidae, Torymidae and Agaonidae, while the parasitoids attacking either gall inducers or inquilines belong to Chalcididae, Eulophidae, Eupelmidae, Eurytomidae, Ormyridae, Pteromalidae, Tanaostigmatidae and Torymidae.

Evolutionary trends among gall-associated species are not well known because of the lack of knowledge in their biology and their relationships. The biogeography of gall-associated Chalcidoidea is related to the distribution of their respective host plants. The genera of hymenopterans inducing plant galls include *Blastophaga, Ceratosolen, Josephiella, Ceratoneura, Goethella, Leptoybe, Quadrastchodella, Quadrastichus*, while genera like *Eupristina, Aprostocetus, Ceratoneura, Sycophila* and *Megastigmus* are gall associated inquilines. Hymenopteran genera which are associated with galls other than the above two categories include *Hockeria, Aloencyrtus, Trechnites, Ceranisus, Ceratoneura, Chrysocharis, Chrysonotomyia, Closterocerus, Euderus, Goethella, Neopediobopsis, Pediobopsis, Sigmophora, Tetrastichus, Anastatus, Eupelmus, Neanastatus, Eurytoma, Prodecatoma, Mangoma, Syceurytoma, Sycophila, Narayanella, Ormyrulus, Ormyrus, Gastrancistrus, Notanisus, Pachyneuron, Propicroscytus, Pteromalus, Systasis, Protanaostigma, Tanaostigmodes, Mangostigmus, Megastigmus, Pseudotorymus, Torymoides* and *Torymus*.

# Biopesticides

## Toxicity of *Bacillus thuringiensis* Strains Against *Aphis gossypii* Glover

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Many species of aphids are important sucking insect pests that cause direct damage by feeding on crops or indirect damage by transmission of plant viruses. Presently, management of sucking pests relies almost on chemical insecticides. Moreover, the pest status of sucking pests including cotton aphid, *Aphis gossypii* Glover on *Bt*-transgenic plants has increased in the absence of insecticides application. The changed pest status of these sucking pest species, along with increased incidence of resistance to chemical insecticides, provides momentum for the development of alternative management strategies. Presently, emphasis has been given to insect pathogens including the bacterium *Bacillus thuringiensis* (*Bt*) for the management of insects of different orders. However, the efficacy of *Bt* toxin against aphids is least studied, due to lack of rearing protocols and artificial diet bioassays. During the present studies, we evaluated the toxicity of four reference *Bt* strains *viz., Bt k*urastaki HD-1, HD-73, *Bt tolworthi (Btt), Bt israelensis (Bti)* along with five native *Bt* strains *viz.,* VKK-SO, VKK-LO, VKK-EV, VKK-AG2 against cotton aphid. Feeding bioassays by diet incorporation method were carried out with three different forms of *Bt* i.e., pre-solublized form (spore + crystal), solubilized form (pre-toxin form) and trypsinized form (toxin form) at single concentration (10µg/gm of diet) on the basis of total protein concentration under controlled conditions against adult aphids. Mortality was recorded after every 24 h till 96 h. The adults of *A. gossypii* were found to be more sensitive to trypsinized form of HD-1 (80% mortality) followed by *Bti* (70% mortality). However, with native *Bt* strain a maximum of 96% mortality (VKK-LO) was attained with pre-solubilized form followed by 90% with trypsinized form. However, with solubilized form of all the tested *Bt* strains only 6.6 to 46% mortality was observed. HD-1(Cry1Aa, Cry2Aa, Cry1Ab, and Cry1Ac Cry2Aa) having five Cry toxins was found to be most effective in trypsinized form followed

by *Bti* (Cry4, Cry10, Cry11) in both pre-solubilized as well as trypsinized form, whereas HD-73 (Cry1Ac) was found least toxic. None of the native *Bt* strains possess any of these Cry toxins, but showed better toxicity, indicating potentiality to use them as biopesticide against aphids.

**PP: 24**

# Evaluation of Vegetable Oils as Grain Protectant Against *Rhyzopertha dominica* (Fabricius) on Maize Under Storage Conditions

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Maize is the third most important food crop after rice and wheat. Lesser grain borer, *Rhyzopertha dominica* (Fabricius) appears to be closely associated pest of maize grains in the storage environment. For the management of this pest under storage conditions, we evaluated certain vegetable oils as grain protectants against *R. dominica* in stored maize at the Department of Agricultural Entomology, B. A. College of Agriculture, AAU, Anand. Five edible and 4 non-edible oils @ 1% (v/w) were evaluated based on periodical mortality, half-life, gross persistency, population growth and germination loss. Castor, neem and pongam oils (1%) gave higher mortality at different storage periods of maize, whereas coconut and groundnut oils (1%) were least effective against *R. dominica* in maize. The half-life value was 2.5 to 3 months under neem, castor and pongam oil treatments, whereas it was below 2 months in groundnut oil. Gross persistency varied between 3100 to 4550 for mahua, pongam, neem and castor oils, whereas it was lowest (>2000) in groundnut oil. Castor, neem and pongam oils were found highly effective as less number of adults emerged. Groundnut and coconut oils were less effective with higher adult emergence. On the basis of per cent loss in germination, neem, castor and pongam oils had lower germination loss, while groundnut and coconut oils had higher germination loss.

PP: 25

# Repellent Efficacy of *Crotalaria burhia* Buch. Ham and *Anacardium occidentale* L. Against *Odontotermes obesus* (Rambur) Under Laboratory Conditions

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Laboratory studies were carried out at the Institute of Pesticide Formulation Technology, Gurgaon to incur the repellent efficacy of *Crotalaria burhia* Buch.-Ham and *Anacardium occidentale* L. against *Odontotermes obesus* (Rambur). Aqueous root extracts of *C. burhia* at different concentrations *viz.,* 0.5, 1.0, 2.5, 5.0, 10.0 and 20.0%, and powdered leaf dusts of *A. occidentale* at 0.7, 1.0, 1.5, 2.2, 3.3, 5.0 and 7.5% concentrations were prepared and tested for their repellent action against *O. obesus*. Chlorpyriphos 20EC was maintained as standard check. An area of preference test were carried out using stantard mathord. Results revealed that root extracts of *C. burhia* at of 10.0% and 20.0% concentration gave 67.0% and 70.0% repellency, whereas 5.0% and 7.5% powdered leaf dust application with *A. occidentale* recorded 57.0% and 60.0% repellency. The lower doses of *C. burhia* and *A. occidentale* were not found effective in repelling the *O. obesus*. The standard check, chlorpyriphos 20EC resulted in 97.0% and 100.0% repellency during both the studies. Thus higher doses of root extracts of *C. burhia* and powdered leaf dust of *A. occidentale* can be further tested for their repellent efficacy in field against *O. obesus*, and included as an important component of integrated termite management program.

PP: 26

# Effect of Neemazal on Fitness of *Helicoverpa armigera* (Hübner)

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Effect of 20, 15, 10 and 5 mg/L of neemazal was evaluated on the fitness of *Helicoverpa armigera* (Hubner) through life table method. Survivorship was prolonged

to 46 days with 20 and 15 mg/L and reduced to 42 and 43 days with 5 and 10 mg/L, respectively as compared to 45 days in the control. Mating occurred after emergence and females start laying eggs after 3 days of pre-oviposition period treated with 10 mg/L and the unexposed groups, while reduced to 2 days with 20, 15 and 5 mg/L. Potential fecundity (pf) was significantly ($P < 0.05$) reduced with all concentrations being lowest with 20 mg/L (209 females/female/generation) and highest in the control (449 females). Significantly higher reproductive rate (99.29 females/female/generation) was recorded in the unexposed groups than to 16.04 and 19.91 with 20 and 15 mg/L, respectively. The intrinsic rate of increase was non-significant due to neemazal treatment. Reduction in the $r_m$ (0.0262 females/female/day) was greater with 20 and 5 mg/L as compared to 10 and 15 mg/L treatment and the unexposed groups (0.0444). A total of 1.107 females/female/day were born in unexposed groups and considerably lower birth rate ($\lambda$) (1.062 females/female/day) was observed by exposure with 20 mg/L of neemazal. Corrected generation time ($\lambda$) was significantly ($P < 0.05$) extended to 46.0 days under the influence of 20 mg/L, while 44.96 days in the unexposed groups. *Helicoverpa armigera* took longer time (11.48 days) to double its population after exposure to 20 mg/L of neemazal as comapred to other concentrations unexposed groups (6.67 days).

**PP: 27**

# Laboratory Evaluation of Different Botanicals Against Red Cotton Bug, *Dysdercus cingulatus* (Fabricius) and Cotton Mealy Bug, *Phenacoccus solenopsis* (Tinsley) in Okra

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The efficacy of some locally available botanicals against the red cotton bug, *Dysdercus cingulatus* and cotton mealy bug, *Phenacoccus solenopsis* has been investigated under ambient laboratory conditions using leaf and surface treatment. The data on the mortality of the 2nd instar red cotton bugs and mealy bugs show that all the treatments were highly significant over control. At 24 hours, the per cent mortality ranged between 2.20 to 45.40 and 1.80 to 87.80 for *D. cingulatus* and *P. solenopsis*, respectively. The highest per cent mortality was observed in neem excel at 0.3 per cent concentration compared to other treatments for both the insects.

# Biocontrol Potential of Native *Bacillus Thuringiensis* Strains Isolated from Warehouses Against *Tribolium castaneum* (Coleoptera: Tenebrionidae)

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The use of insect pathogens such as *Bacillus thuringiensis* (*Bt*) is a possible alternative to chemical insecticides for storage insect pests owing to their relative specificity and lower environmental impact. *Bt* is an aerobic, gram positive, spore-forming, facultative bacterial pathogen that produces parasporal crystals containing one or more insecticidal proteins (Cry toxins). They are selectively toxic to insects and widely used as biopesticides against many insect pests including those of stored products. In the present study, 24 native *Bt* isolates from ware houses were evaluated for their toxicity against neonates and adults of red flour beetle *Tribolium castaneum* by feeding assays using diet overlay method at 100 µg/gm of diet. Toxicity of the isolates ranged from 26-56% against the neonates and 16-73% against adults on 7th day of treatment. Five isolates *viz.,* VKK-FCI-1, VKK-GA-6, VKK-GA-7, VKK-GJ-4 and VKK-MGA-3 against neonates, and seven isolates viz., VKK-GA-2, VKK-GA-3, VKK-GA-5, VKK-GA-6, VKK-GA-7, VKK-GJ-1 and VKK-MGA-1 against adults showed more than reference strain *Bt tolworthi* (50% and 60% respectively) mortality and were further evaluated by full bioassays. The most effective isolate was VKK-GJ-4 ($LC_{50}$=7.02 µg/gm of diet) against neonates followed by VKK-GA-6 ($LC_{50}$=19.03 µg/gm of diet) against adults. PCR characterization was performed to identify the toxin-encoding genes using eighteen oligonucleotide pairs specific for *cry* genes. Out of ten strains, gene *cry3* was identified in four isolates, *cry7*, *cry8* and *cry 9* in two isolates each, and c*ry11* was found only in one isolate along with *cry3* and *cry 28* (VKK-GA-3). *cry24* was present in VKK-GA-7 (most effective isolate against adults), and *cry28* along with *cry3* and *cry 8* were found in VKK-MGA-3 and VKK-GJ-4, respectively. However, no *cry* gene was found in VKK-FCI-1 and VKK-MGA-1. During the present studies, *cry9* and *cry24* were also found effective against coleopteran, besides *cry3, 7, 8* and *28* genes, which could be adopted for developing bio-insecticides for the management of storage pests.

# Entomopathogenic Fungus: Reliable and Effective Tool of Integrated Pest Management

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The Class Insecta contains nearly one million described species comprising of approximately 67% of the world's described living organisms. However, it's in their role as herbivores that decrease the agricultural production due to direct consumption of cultivated crops and indirect damage by plant virus and other plant pathogenic microorganism transmission, or spoilage of potential yield. Natural enemies such as predators, parasitic wasps and flies, as well as microbes which induce diseases in insects have long been studied for exploitation in biological control and integrated pest management (IPM) module. Fungi, which induce disease symptoms in insects, include fungi from quick killers to absolute parasites. Entomopathogenic fungi cause lethal infections and regulate insect and mite populations in the form of epizootics that provide disease symptoms in the host. They are host specific with a very low risk of attacking non-target organisms or beneficial insects. They are reported to infect a very wide range of insects including lepidopteran larvae, aphids and thrips, which are of great concern in agriculture worldwide. Entomopathogenic fungi, which illustrate the principles or strategies, can be used to reduce losses by insect pests. Entomopathogenic fungi are found in the division viz., Zygomycota, Ascomycota, Deuteromycota, Chytridiomycota and Oomycota. It includes *Beauveria bassiana*, *Hirsutella patouillard, Metarhizium anisopliae*, *Paecilomyces fumosoroseus*, *Verticillium*, *Nomuraea*, *Entomophthora*, *Neozygites*, and many more. These fungus releases various kind of enzymes like lipases, proteases and chitinases. The use of these kind of entomopathogenic fungus in controlling the insect lead to non-chemical but a natural management of insect pest by which it becomes an effective and important tool in IPM.

# Nano-Pesticides: Solution for a Cleaner and Greener Agriculture

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Nanotechnology has developed tremendously in the past decade, and opened a wide array of opportunities in various fields like medicine, pharmaceuticals, electronics and agriculture. The potential uses and benefits of nanotechnology are enormous including management of insect pests through formulation of nanomaterials-based insecticides, encapsulated nanoparticles for slow release and efficient dosage of water and fertilizer, nanocapsules for herbicide delivery, nanoparticle-mediated gene or DNA transfer in plants for the development of insect-resistant varieties, and nanosensors for pest detection. The secondary metabolites in plants have been used in the formulation of nanoparticles through increase in effectiveness of therapeutic compounds to reduce the spread of plant diseases. Nanoparticles have been used as physical approach to alter and improve the properties of synthetic chemical pesticides or to increase the production of bio-pesticides. Nano-pesticides also have the potential to reduce environmental contamination through reduction in pesticide doses. However, there is a great concern regarding the use of nonmaterial in nano-pesticide, which have potential to exert hazardous effects on human and the environment, and becomes a double edged weapon. Nanomaterials need to be evaluated, so that this novel technology does not meet the same apprehensions and bottleneck as faced by the genetically modified crops.

# Cultural and Agronomic Manipulation

## Effect of Trap and Intercropping on the Management of *Helicoverpa Armigera* in Chickpea Agroecosystem

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Chickpea was sown with intercrops (wheat, barley, mustard, carrot and lentil) and trap crops (pea, tomato, marigold, faba bean and berseem) in ratio of 4:2, 6:2 and 8:2 during 2010-11, 2011-12 and 2012-13. Two way analysis of intercropping showed that the average population of *Helicoverpa armigera* (Hubner) significantly (P<0.05) reduced on chickpea under different intercrops as compared to chickpea alone. A total of 2.0 larvae/meter row were observed on chickpea + wheat (4:2) intercrop as compared to 4.0 larvae larvae/ meter row in sole chickpea at 105 days after sowing (DAS(. From 120 DAS onwards, chickpea + carrot (4:2) was superior to other intercrops in reducing the larval count over chickpea alone, while 4.8 larvae/ meter row were observed at the time of harvesting. Pod damage was 34.83% with highest yield of 1033.60 kg/ha in chickpea + carrot (4:2) as compared to that under chickpea alone condition. Two way analysis of trap crop showed that three years average larval population of *H. armigera* reduced significantly (P<0.05) on different trap crops compared to chickpea alone. Chickpea + tomato (4:2) was superior in reducing the density to 0.33 and 2.10 larvae/meter row at 90 and 105 DAS, respectively as compared to that in chickpea alone condition. However, chickpea + pea (4:2) was efficient in bringing down the density to 5.7 larvae/meter row as compared to control (9.93 larvae) at 150 DAS. At the time of harvesting, pod damage was 39.0% with highest yield of 1018 kg/ha in chickpea + tomato (4:2) intercrop which was statistically similar with chickpea + pea (4:2). Hence, chickpea + tomato (4:2) and chickpea + pea (4:2) can be used as trap crops for *H. armigera* management in chickpea.

# Supression of Biotic Stress in Mustard Through Microenvironment Improvement by Selecting Appropriate Crop Row Direction

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Rapeseed and mustard, *Brassica juncea* is the second most important oilseed crop in India. About 30-40% crop of mustard is damaged every year by biotic stress, i.e., attack of pests and diseases. So far, chemical control is the major intervention practiced against these pests. The chemicals are costly and harmful to the human, animals and environment. Generally, the crop is sown in the field through broadcasting and line-sowing. In line-sown crop, rows are maintained as per orientation of the plot and without any scientific basis. By selecting appropriate row direction, the microenvironment can be modified within mustard crop which can be useful to suppress the pests and diseases. Therefore, present studies were conducted to find appropriate row direction as well as cultivars to suppress pests and diseases without use of harmful chemicals. Three mustard cultivars namely, Pusa Vijay, Pusa Mustard 21 and Pusa Bold were sown in two row directions, *viz.*, North-South (N-S) and East–West (E-W) at the Indian Agricultural Research Institute farm, New Delhi during the *Rabi* season of 2013-2014. Split plot design was followed with three replications in 4m x 4m plot size. Regular observations on micro-meteorological parameters (solar radiation interception, crop temperature and relative humidity within the canopy, aphid (*Lipaphis erysimi*) and white rust (*Albugo candida*) disease were recorded. Aphid population was highest in Pusa Vijay initially and in Pusa Mustard 21 at later stage. Overall the high aphid infestation was observed in Pusa Vijay throughout the season. The highest infection of white rust was recorded in Pusa Bold. Aphid population and percent disease index of white rust were substantially low in N-S rows. Solar radiation penetration with in the crop canopy was found to be more in N-S direction. More radiation penetration and interception in N-S rows increased the crop profile temperature and decreased humidity within the canopy and made the crop microenvironment unfavourable for pest (aphid) and disease (white rust). Finally, it could be concluded that the cultivar, Pusa Mustard 21 sown in N-S direction might

be efficient in terms of suppressing the major pest and disease to some extent in the semi-arid environment of North-West India. This simple practice would reduce the cost of crop protection, protect the environment and can be incorporated as a component of IPM in mustard.

**PP: 33**

# Aphid Population in Mustard Under Conservation Agriculture in Rice-Mustard Cropping System

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Mustard (*Brassica juncea* L.) production in India suffers from aphid (*Lipaphis erysimi* Kalt), infestation considerably which reduces both quality and quantity of produce. One of the options to minimize these losses is the suppression of aphid population by modifying the crop microenvironment through conservation agricultural practices. The studies on crop micro-environment under conservation agriculture and conventional practices with respect to pest and disease infestation are very limited. The aim of this study was to know the aphid population under eight different treatments of conservation agriculture in rice-mustard cropping system so as to determine best treatment to suppress their population. Numbers of mustard aphid per 10 cm top portion of the central shoot were counted on randomly selected plants at weekly intervals in all the treatment. Among the 8 treatments Mungbean residue + Zero till direct seeded rice - Rice residue + Zero till mustard (MBR+ZTDSR-RR+ZTM) treatment recorded least number of aphids per plant (25 aphids/plant), whereas the conventional treatment TPR - CTM (Transplanted rice – Conventional till mustard) had moderate number of aphid population (90 aphid /plant). The treatment of Zero till direct seeded rice + Brown manuring – Zero till mustard (ZTDSR+ BM –ZTM) showed maximum aphid population (150 aphids/plant), could be because of congenial canopy environment for aphid attack under such manipulations. Present studies suggest that the modification of microenvironment of mustard crop under different CA treatments may decrease aphid infestation thus reducing application of harmful chemicals, reduce the cost of plant protection and save the environment, could be included as one of the important component in the integrated pest management module.

# Sodium Silicate Promotes the Growth Parameters of *Lycopersicon esculentum* Mill

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Tomato, *Lycopersicon esculentum* Mill. plants are often exposed to various abiotic and biotic stresses which adversely affect their growth. Silicon has been recognized as an agronomically essential element to enhance the resistance of plants to multiple stresses including drought, insect pests and diseases tolerance. Tomato has been recognized is an important source of minerals, vitamins and antioxidants such as carotenoids, lycopene and phenolic compounds. Present studied were aimed at evaluating the effect of sodium silicate on growth parameters of tomato plants. The healthy and uniform seeds of tomato var. Pusa Sheetal were procured from Indian Agricultural Research Institute (IARI), New Delhi, and stored in sterilized polythene bags to avoid contamination. The tomato seeds were thoroughly washed with tap water and surface sterilized with 10:1 distilled water:bleach (commercial NaOCl) solution for 5 minutes, and then washed with distilled water. Ten viable seeds of tomato were sown at equal distance in petriplates and treated with different concentrations of sodium silicate (1 mM). The maximum seed germination and seedling length was observed with 75% concentration of 1 mM sodium silicate. The seed germination and seedling length of tomato were significantly increased with 50% and 25% concentrations of sodium silicate in comparison to control, indicating their role as fertilizer, and can be used under field conditions to enhance productivity of this crop.

# Adoption of IPM Practices in Paddy Crop in Haryana

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The adoption of integrated pest management (IPM) practices in paddy crop was estimated during the present study. It was conducting in Faridabad district of Haryana, India. It was observed that only 60% of farmers were aware of IPM practices, and 30% were found technically capable of implementing IPM at field level. Only 24% of IPM-trained farmers practiced this approach. In total, it was found that only 7% of agriculture workers practiced IPM and rest (93%) were dependent on chemical pesticides. Educational data about IPM farmers revealed 100% literacy, and 60% being with graduate degrees. On the contrary, among non-IPM farmers' literacy rate was 70% and only 20% were graduates. Importance of constraints for impending IPM was measured by using important constraints score index (ICSI) technique. The important impediments, lack of knowledge and skill about seed treatment, laborious nature of IPM technology, non-availability of IPM tools at appropriate time, lack of skill in using IPM tools, non-availability of bio-pesticides at appropriate time and lack of knowledge about benefits of harvesting to ground level, were ranked. Nearly after three decades, IPM-oriented farmers were only 3%, hence sincere efforts are required to be taken by all agencies to make IPM a reasonably adopted strategy. The Poisson count regression model have been used to analyze technology adoption. Mixed evidence has been observed about the relationship between farm-size and adoption of IPM practices. The study has concluded that a higher gross value of crops does not appear to have a positive impact on IPM technology adoption in paddy. Hence, investment in IPM education through these programmes will have long-term beneficial impact.

# Integrated Pest Management of Diamond Back Moth in Cruciferous Crops

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The diamondback moth, *Plutella xylostella* (Linnaeus) is a worldwide pest of cruciferous crops. The larvae attack a wide range of cole crops including cabbage, cauliflower, rape, kale, turnip, and brussels sprouts. The DBM problem is usually most severe in the tropics and subtropics where year-round Brassica cultivation and a life cycle as short as 14 days make this pest a continuous threat to production. This continuous cultivation and short life cycle can result in more than 25 generations of DBM in a year being exposed to the synthetic insecticides routinely used by growers. This high level of selection pressure and high fecundity of DBM are key factors which have contributed to this species developing resistance to a wide range of insecticides in the field. The rapid evolution of resistance to insecticides makes DBM particularly challenging to control in a sustainable fashion. Collard greens (*Brassica oleracea* var. *acephala* L.) were planted in the peripheries of cabbage (*Brassica oleracea* var. *capitata* L.) fields in the spring growing seasons to evaluate their effectiveness as a trap crop to manage the diamondback moth *P. xylostella*. The numbers of DBM never exceeded the action threshold for application of insecticides in any of the fields that were completely surrounded by collards, but did exceed the action threshold in three of the fields without collards. The numbers of DBM larvae in the collards exceeded the action threshold of 0.3 total larvae/plant in eight of nine fields. Larval counts in cabbage surrounded with collards were not significantly higher than in the conventionally planted cabbage, even though the number of pesticide applications was reduced in the former. The few pesticide applications in fields surrounded by collards probably targeted the cabbage looper *Trichoplusia ni* (Hübner), which was not impeded by the collards from infesting the interior cabbage. There was no significant reduction in marketability, and damage to cabbage was similar to that in fields having planted with collards and applied with conventional pesticides. The reduced number of pesticide sprays, as well as the high concentration of host larvae in the collards could help in maintaining DBM natural enemy populations in the agroecosystem, thus, making collards planting in field peripheries a potentially effective tactic to manage DBM in cabbage.

# IPM Modules for Management of Yellow Stem Borer in Irrigated Rice Ecosystem

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Integral India has the largest area under rice cultivation in the world (44.6 million hectares) and ranks second in production (104.31million tonnes in 2011-12). In India, rice is grown under different agro ecological conditions viz., water logged, deep water, hills, high humidity, high temperatures, salinity, alkalinity and flood prone areas. The rice crop is prone to stress throughout the crop growth period due to onslaught from different insect pests, nematodes, diseases, weeds and rats. Adoption of integrated pest management (IPM) strategies is the best solution to tackle these pest problems. Rice IPM provides a framework for integrating knowledge, skills and information on rice pest management. In this regard, several efforts have been made to develop, verify, demonstrate and document location specific IPM technologies suited to irrigated ecosystems. Since IPM is a dynamic process, it needs continuous up gradation as per the changing pest scenario. Yellow stem borer is an important insect pest of paddy, which can even sustain their off season survival on alternate host plants including wild rice species viz., *Oryza rufipogon*, *O. nivara*, *O. lapifolia* and *O. glaberrima* and a grass weed *Leptochloa panicoides*. To overcome the problems associated with management of this pest, we suggest some IPM tactics such as Summer ploughing and destruction of crop residues; growing tolerant/resistant varieties (like Mahsuri, Saket-4, Ratna, IR 36, IR 72); clipping off the tips of seedling before planting helps in reducing the egg masses; balance use of fertilizers; collection and destruction of moths from 5:30 – 7:00 a.m.; collection of egg masses and putting them to a bamboo cage cum percher; release of *Tricogramma* spp. @ 50,000/ha/ week for 6 weeks starting from 30 days after transplanting; spray of Azardirachtin 2% @ 300 ppm; Bt spray @ 2.0 Kg /ha at 5 % deadheart or white ear appearance; application of Carbofuron 3G @ 20 Kg or cartap 4G 25 Kg in 3-5 cm standing water; spray chloropyriphos 20 EC @ 2.5 lit/ha at 5% deadheart formation or 1 egg mass at vegetative stage or 1 moth/$m^2$ at panicle emergence to flowering stage, and harvest the crop close to the ground level, which upon their appropriate integration can successfully maintain this pest under check.

# Eco-friendly Management of Insect Pests in Maize and Sorghum

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Maize and sorghum are the most important cereal crops after rice and wheat being cultivated since centuries across the world. These crops are susceptible to insect pests and are attacked by several pests viz., stem borers, aphid, leaf hopper, ear head bug, sorghum shoot bug, leaf folder and grass hopper, etc. Overreliance on insecticides has eliminated natural enemies, and we therefore investigated the impact of alternative insect pest management strategies such as cultural, mechanical and biological techniques in maize and sorghum crops. Select resistant varieties like CSV-4, CSV-5, CSV-6 and hybrids like CHS-5, CSH-7R and CSH-8R for escaping from the sorghum pests. In the shoot fly and stem borer prone area 20% higher seed rate is used and sowing should be done within 10-15 days after onset of monsoon, which reduces the pest incidence especially in case of shoot fly and midge. To use polythene fish meal trap@12/ha and release of *Trichogramma chilonis* @50000/ha 4-6 times weekly intervals against shoot fly and stem borer, respectively are good tactics to check the pest population. Summer deep ploughing and balanced use of fertilizers also help in reducing the population of insect pests. The results suggested that employing cultural, mechanical and biological control together could reduce the need for insecticide treatments and offer a sustainable method for maize and sorghum insect pests control.

# Global Trade and Risk of Intensive Pest Management of Insect Pests

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Alien species are non-native or exotic organisms that occur outside their natural adapted habitat and dispersal potential. Many alien species support farming and forestry systems in a big way. The spread of Invasive Alien Species (IAS) is now recognized as one of the greatest threats to the ecological and economic well being of the country. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems. Direct and indirect health effects are increasingly serious and the damage to nature and environment is often irreversible. The impact on the environment and agricultural production of invasion of a pest species is tremendous. Such impacts can be minimized with integrated pest management (IPM) like mechanical, chemical, biological, habitat management legislation, tools for dealing with invasive alien species, precaution, prevention, permit system, polluter pays principle, public participation, access to information, risk analysis processes, and environmental impact assessment could play important role in management of invasive insect pest, e.g., for water hyacinth or firearms, for large mammals or traps for animals.

# Pollinators: A Key to Successful and Sustainable IPM

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Pesticides have played a commendable role in increasing our food production and protecting our crops against various pests and vectors. However, sole reliance on pesticides has created several problems such as development of insect resistance to insecticides, secondary pest outbreak, residue hazards, destruction of beneficial insects, not only upsetting the balance between biological agent and pests on one hand but also insect pollinators and flowers to be pollinated on the other hand. Adverse effects of pesticides prompted scientists to look for safer and environment friendly pest management practices. The use of pesticides for pest control and the role of insect pollinators for crop pollination have become essential components of modern agriculture, without which food production would be seriously impaired. Unfortunately, these two practices are not always compatible, as insect pollinators are susceptible to broad spectrum pesticides for the control of insect pests. The major constraint confronting pollinator-plant interactions is the indiscriminate and excessive use of pesticides effecting the population of these beneficial insects incurring significant environmental, ecological consequences leading to economic losses.

Pest management emphasizes on an ecological approach to tackle pest problems with minimum use of insecticides with the objective to attain higher yields by keeping pest problems below economic injury level. However, if the pollinating behaviour of honey bees is integrated with pest management strategy, the yields could further be enhanced. Pollinators are attacked by variety of pathogens and predators within their nesting/ hiving environment, due to presence of good protein and carbohydrate sources. Various maladies within hive are required to be managed by employment of integrated management tactics to ensure contaminant/ residue free hive products and maintaining adequate pollinator's population. It can be ensured by adopting Integrated Hive management (IHM) practices along with minimizing the chemical use. An IHM approach involves the use of all available tactics in the design of a program to manage bee populations. An important component of this approach is the use of sustainable management practices with as little reliance as possible on chemical treatments. The IHM/IPM concept used by farmers is beneficial for beekeeping industry as well as for the pollinator's fauna.

Pollinators and pollination are crucial in the functioning of almost all terrestrial ecosystems including agricultural ecosystems. Two thirds of the world's 3000 species of agricultural crops require pollination. Animals provide pollination services for more than 75% of all staple crops and 90% of all the flowering plants of the world. The economic value of such pollinated crops to India is estimated to be $726 million. Of the total pollination activities, over 80% is performed by insects among these bees contribute nearly 80% of the total insect pollination. In India, of the 160 Mha of the cropping area, more than 55 Mha is under bee dependent crops. India is one of the mega diversity region of pollinators and native honey bee species. The area cultivated with pollinator-dependent crops has increased disproportionately to the pollinator population over the last decades, suggesting that the need for pollination services will greatly increase in the near future. *Apis mellifera,* highly social bee, has occupied dominating position in commercial pollination around world. But on the other hand wild bees are also valuable pollinators. Their contribution has always been undermined. For agriculture as a whole, the diversification of pollination assemblages for crops is clearly significant. Wild and domesticated non-*Apis* bees effectively complement honey bee pollination in many crops. Examples of management of non- *Apis* species for agricultural pollination include the use of bumble bee primarily for the pollination of green house tomatoes, the solitary bees *Nomia* and *Osmia* for the pollination of orchard crops, *Meghachile* for alfalfa pollination and social stingless bees to pollinate coffee and other crops.

Indian population is increasing day by day, thereby proportionately increasing the demand for food. Cultivable land has been decreasing due to population explosion and related activities of urbanization. Bee pollination is expected to be a tool of 2nd green revolution, if we consider it as fifth input after land, labor, cost and capital in agricultural development strategies. Pest control and pollination both are essential for agro-ecosystem. Therefore, IPM is best practice to minimize the crop loss and conservation of insect pollinators. Adequate pollinator populations are required not only for the pollination but also for production of many vegetable, fruit and other crops, which otherwise would have been impossible. In India, the main thrust of beekeeping so far remained on honey production, and the vital role honey bees played in augmenting the productivity of agricultural and horticultural crops remain neglected. In fact, the major significance of honey bees lies in the pollination services rendered by them, whereas hive products are of secondary importance. This fact is highlighted by an estimate that pollination services by honey bees result in 20 times more value of the produce than the value of honey and wax produced by them.

# Diversity and Abundance of Insect Pollinators and Impact of Mode of Pollination on Yield Parameters of Coriander (*Coriandrum sativum* L.) in India

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Biodiversity of pollinators on coriander, *Coriandrum sativum* L. cultivar DH 246, was studied in Hisar, Haryana, India. Thirty insect species belonging to fifteen families of five Orders were recorded from the coriander flowers, among which ten belong to Order Lepidoptera, ten to Hymenoptera, six to Diptera, three to Coleoptera, and one to Odonata. Among the insect pollinators, *Apis florea* F., *A. cerana indica* F., *A. mellifera* L., and *A. dorsata* F. were the most frequent pollinators. Among different bee species, the maximum mean population was observed for *A. florea* (6.81 bees/m$^2$/5 min) followed by *A. mellifera* (4.06 bees/m$^2$/5 min) and *A. dorsata* (3.91 bees/m$^2$/5 min), whereas least abundance was of *A. cerana indica* (2.01 bees/m$^2$/5 min). Among different *Apis* species, *A. florea* spent maximum time (4.48 sec/umbelet) followed by *A. mellifera* (2.20 sec/umbelet) and *A. cerana* (1.26 sec/umbelet). The least time per umbelet was recorded in case of *A. dorsata* (1.23 sec). Among different bees, *A. dorsata* visited maximum number of umbelets (23.57 umbelets/min) followed by *A. mellifera* (17.57 umbelets/min) and *A. cerana* (13.19 umbelets/min), whereas *A. florea* visited least number of umbelets/minute (7.85 umbelets/min). The yield/plant (18.58 g), yield/m$^2$ (183.40 g), test weight (17.24 g) and per cent germination (76.40%) were significantly higher in case of open pollination as compared to without insect pollination (13.48 g, 134.62 g, 13.04 g and 58.8%, respectively). In case of open pollination, the per cent increase in yield/plant, yield/m$^2$, test weight and per cent germination over without insect pollination was 37.83, 36.24, 32.21 and 30.82%, respectively. Hence, insect pollinators were found essential to get good returns in this seed crop.

# Diversity of Bee Fauna in Organic *v*is-a-vis Conventional Agro-ecosystems of Doon Valley, Uttarakhand

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Pollinators play a vital role in terrestrial flowering plant reproduction. They contribute ecosystem services of cross pollination which are beneficial in improving genetic fitness and productivity in natural and cultivated plants. Recent declines in pollinator populations (specifically honeybees) are reported which question the future of food security for humans and other animals globally. Habitat fragmentation, global climate change and upsurge in agricultural intensification are identified as potential drivers of pollinator fall offs. Natural environments act as refuges for pollinators especially bees. We present the preliminary outcome of a comparative study of two agro-ecosystems *viz.* organic and conventional. Since organic methods of agriculture are devoid of intensive chemical use, grow a diversity of crops and provide natural habitat to pollinators we hypothesize they support greater number of species in comparison to conventional farms. Our study was carried out in the organic and conventional farms in Doon Valley. Our data also demonstrates the benefits of forests in improving pollinator species richness in agro-ecosystems. Passive pan trap sampling was carried fortnightly with 35 sampling units in each agro-ecosystem with yellow, white and blue coloured traps each during peak flowering season from January to May during 2012, 2013 and 2014. The conventional farms had monocultures of wheat and mustard with few wild flower species (weeds) as farm hedges. The organic agro-ecosystems consisted of a diversity of crops such as mustard, rapeseed, radish, cabbage, turnips, carrots, sesame, etc. Distance of agro-ecosystems from forest habitats were also taken into consideration. There was an interval of approximately 250 m between subsequent sampling sites. The bee specimens were collected and preserved in 70% alcohol. Identification of the bee fauna was done at the Division of Entomology, IARI, Delhi. The bee specimens were grouped into various taxonomic units to further compute their diversity indices. A total of 520 individual bees were recorded belonging to 4 families *viz.*, Apidae,

Megachilidae, Andrenidae and Halictidae which were further segregated into 51 morpho-species, Halictids being the most, while Megachilids being least abundant. A comparison between two agro-ecosystems showed that the bee species richness in organic agro-ecosystem was greater than conventional farms. Agro-ecosystems near forest supported a higher number bees (H' for 1000 m= 0.500402) compared to those further away (H' for 1000 m= 0.500402). This investigation indicated the importance of natural environments as refuge for pollinators for not only nesting and breeding but also as foraging resources during lean periods which are evident in organic farms. The presence of these habitats around agro-ecosystems improves diversity of these beneficial fauna. Hence, encouraging these habitats is essential for the native bee diversity as managed species (honeybees) are difficult to maintain.

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# Effect of Different Modes of Pollination on Quantitative and Qualitative Parameters of Radish Seed Crop

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The present study was conducted at CCS Haryana Agricultural University, Hisar, Haryana, India. A total of 18 insect species visited radish flowers out of which 10 belonged to hymenoptera, 5 to Lepidoptera, and 3 to Diptera. Among these, *Apis mellifera* L., *A. dorsata* F., *A. florea* F., *A. cerana* F., and syrphid fly were found to be the most frequent pollinators. Effect of different modes of pollination on yield and seed quality parameters of radish showed that the number of siliqua/plant, siliqua length (cm), number of seeds/siliqua, seedling length (cm), seed vigour-I, seed vigour-II, test weight (g), dry seedling weight (g) and germination (%) were significantly higher under open pollination (5.2, 1076.1, 6.8, 35.8, 3462.7, 11.5, 11.6, 0.118 and 96.7, respectively) as compared to without insect pollination (3.4, 430.5 3.3, 14.4, 1378.1, 5.9, 7.2, 0.091 and 65.3, respectively).

# Diversity of Bee Pollinator Fauna and Their Influence on Productivity of Mustard

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A trial was laid out at the experimental farm of Indian Agricultural Research Institute, New Delhi during *Rabi* season of 2009-10 to evaluate the role of pollinators in increasing the productivity of mustard. Pusa Agrani variety of *Brassica juncea* was sown on 3rd November 2009 in two plots of 5 x 4 m size. All the recommended agronomic practices were followed to raise a good crop. At initiation of flowering one plot was covered by a nylon net (5m x 4m x 3m) to prevent pollinators from visiting the covered plants. Another plot of the same size was kept open to allow honey bees and other pollinators to visit the flowers. The pollinators visiting were recorded weekly during morning hours. Pollinators were collected and brought to the laboratory for identification. The pollinators diversity observed belonged to four bee families, viz., Andrenidae, Halictidae, Apidae, Megachilidae and six subfamilies. The diversity of bees within each subfamily being Andrenidae (1), Halictidae (4), Megachilidae (2) and Apidae (8). The species were identified as *Apis dorsata* Fabricius, *A. mellifera* Linneus, *A. cerana indica* (Fabricius), *A. florea* Fabricius, *Anthophora cingulata* (Fabricius), *Trigona irridepennis* Jurine, *Ceratina smaragdula* Fabricius, *Andrena savignyi* Spinola, *Megachile bicolor* (Fabricius) *Megachile lanata* (Fabricius), *Nomia intersttialis* Cameron, *Halictus fimbriatus,* Smith, *Nomia oxybeloides* (Smith), *Lassioglossum albescens* (Smith)and *Xylocopa violacea* (Linneus). At maturity, data on number of pods/ plant, number of seeds per pod, 1000 seed weight and seed yield were recorded. There was significant difference for mean number of pods per plant in the two plots being 285.4 in open pollinated compared to 212.9 in net covered plot. Significant differences were recorded in the seed weight of 1000 grains also being 6g and 4.2 g in the open pollinated and covered plots, respectively. Total seed yield per plot also differed significantly being 3.7 kg and 2.96 kg in open pollinated and covered plots, respectively. Pollination due to honeybees and other insect pollinators increased the seed yield by 25%, number of pods per plant by 34.1%, number of seeds per pod by 22.2%, and 1000 seed weight by 33.3%, thereby indicating greater role of insect pollinators in increasing the mustard yield for sustainable crop production.

# Potential Competitiveness of Asia I and Asia II -1 Populations of Whitefly, *Bemisia tabaci*

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Whitefly, *Bemisia tabaci* (Gennadius) has become a global pest with its distribution spreading across tropical and subtropical region. It is one of the most destructive pest causing direct damage by sap sucking and indirectly by transmitting plant viral disease. It constitutes of 34 morphologically indistinguishable populations which differ in their host range, host plant adaptability, induction of phytotoxic reactions, insecticide resistance, esterase banding patterns, RAPD-PCR analysis and plant virus-transmission capabilities. The aim of this study was to find difference in esterase catalytic activity between Asia I and Asia II-1 group of *B. tabaci*. The isofemale lines were developed by rearing these populations up to 4-5 generations in climatic control chamber, and samples were collected for further analysis. Purity of population was checked by MtCo1 gene sequencing (mitochondrial encoded cytochrome c oxidase1). Significantly higher esterase activity was found in Asia I (14.08 ± 0.08) compared with Asia II-1 (6.98 ± 0.08). Both populations showed highest enzymatic activity at pH 6 and temperature 30ºC. The specific activity also greatly differed in both Asia I and Asia II-1 populations with respect to protein content, i.e., 16.19± 0.21 and 7.5± 0.34, respectively. Kinetic constant determination of both the populations revealed that the substrate utilization capacity of enzyme for Asia I was higher (21.29 ± 1.735) than the Asia II-1 (11.75 ± 1.035), indicating that Asia I could be more competitive and successfully spread viral disease over a wide range with a diverse host community than Asia II-1.

# Association of Gut Bacterial Community in Developmental Stages of Two Indian Populations of Whitefly, *Bemisia Tabaci* (Gennadius)

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The whitefly, *Bemisia tabaci* (Gennadius) transmitted plant diseases are a major challenge worldwide for improving crop productivity. This pest has an association with bacterial endosymbionts which play a significant role in the host insect morphogenesis, food digestion, nutrition, antifungal toxin production, pheromone production, regulation of pH, synthesis of vitamins, temperature tolerance, resistance against parasitoid development, and detoxification of noxious compounds. In our study, gut bacteria were identified by sequencing 16S rDNA gene through culture dependent method in all the six developmental stages of two populations of *B. tabaci,* Asia II-1 and Asia I from Delhi and Andhra Pradesh, respectively. As a whole, 17 genera with 32 species belonging to Firmicutes, Alpha-, Beta-, Gamma-proteobacteria and Actinobacteria has been identified. Among these, six genera *viz., Bacillus*, *Lysinibacillus, Kocuria, Acinetobacter*, *Pseudomonas* and *Staphylococcus* were found to be common in both the populations. *Bacillus* for Asia II-1 and *Bacillus*, *Lysinibacillus* in Asia I was associated throughout the developmental stages revealing their importance. Additionally, *Ralstonia* was found to be present in egg and nymphal stages of Asia II-1. Shannon-Wienner's diversity index was estimated to be 3.13 and 2.41 for Asia II-1 and Asia I populations, respectively, enlightening more diversity in Asia II-1 than Asia I whereas, evenness was greater in Asia I (0.94) than Asia II-1 (0.93) which was again supported by Whittakers rank abundance curve. Thereby manipulation of gut bacterial community may be a better weapon of management against this cosmopolitan pest.

# Diversity of Bacterial Flora in the Gut of *Plutella xylostella* and *Helicoverpa armigera* Larvae

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Diamond Back moth, *Plutella xylostella* (Lepidoptera: Plutellidae) and *Helicoverpa armigera* (Lepidoptera: Noctuidae) are the most dominant and diversified group of phytophagous pests. Insect gut provides myriad opportune for the growth of diverse group of microorganisms. Interaction of insect and microorganisms has evolutionary origin as the gut microbiota are associated with several physiological functions including digestion, absorption, degradation of toxic metabolites, semiochemical production and resisting the colonization of entomopathogens. Among these myriad interactions, nutritional contribution by gut bacteria is considered to be foremost important as it enhances the survival value of insects. The aim of our study was to determine the composition of the gut microbiota of two Lepidopteran pests *P. xylostella* and *H. armigera*. We applied the cultivation dependent techniques based on 16S rRNA gene sequencing and screened the gut bacterial flora as cellulolytic and lipolytic based on qualitative enzyme assay by using CMC agar plates and the Rhodamine B agar plates. A total of 50 bacterial strains were isolated from the larvae of *H. armigera* and around 50% of these bacterial strains were found to have the ability to degrade Celluloses and Lipids. In case of *P. xylostella,* total 40 bacterial strains were isolated, among which 8 having the cellulolytic activity and 7 having the lipolytic. Current studies revealed that the gut of these pests consist of a diverse group of bacteria that belongs to the genera of *Bacillus*, *Alcaligens*, *Serratia, Pseudomonas*, *Salmonella*, *Paenibacillus*, *Stenotrophomonas*, *Cedecea* and *Delftia*. The study will allow a better understanding of the interaction between the pest and their symbionts. Finding a way to disrupt or harness the enzymatic mechanisms that allow these pests to digest cellulose and other lipopolysaccharides may be a key to discover new approaches in pest control.

# Determination of Thermal Constant and Development Threshold for the Development of Gram Pod Borer, *Helicoverpa armigera* (Hubner)

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Gram pod borer, *Helicoverpa armigera* (Hubner) is a cosmopolitan and polyphagous pest, causing huge crop losses across the globe. Besides, it is reported to have developed high levels of resistance to different insecticides. The climate change is expected to have both direct as well as indirect effects on insect populations. Temperature is the major factor in global climate change that directly affects insect development, reproduction and survival. Present study was thus undertaken to determine the developmental threshold and thermal constant of different developmental stages of *H. armigera*. The developmental stages of the pest were reared at 8 constant temperatures, 12 ± 1, 15 ± 1, 18 ± 1, 21 ± 1, 24 ± 1, 27 ± 1, 30 ± 1 and 33 ± 1°C in BOD incubators with 65 ± 5% relative humidity and 14:10 (L:D) photoperiod. Observations were recorded on duration moulting, pupal formation and adult emergence at 24 h intervals. Rates of development were then regressed against temperatures to estimate thermal constant as reciprocal of regression coefficient (1/b) and development threshold as ratio between intercept and b (-a/b). The developmental periods of different instars of *H. armigera* declined with increase in temperature from 12 to 33°C. Thermal constants of 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 4$^{th}$, 5$^{th}$, 6$^{th}$ instar larvae and pupae were, 50.0, 45.5, 62.5, 47.6, 52.6, 47.6 and 166.7 degree days (DD), respectively with corresponding development thresholds as 12.1, 11.3, 10.4, 12.0, 11.8, 13.9 and 16.0°C. The thermal constants and development thresholds will be used to develop a mechanistic population simulation model of the pest, which will then be helpful in climate change impact assessment.

# Influence of Weather Factors on Population Dynamics of Brown Planthopper (*Nilaparvata lugens*) in Mid Indo-Gangetic Plains

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Rice is extensively grown in Indo-Gangetic plains occupying an area of 3.23 Mha in *kharif*, with an average yield of 1.81 t/ha. Life cycle of most of the insects is greatly influenced by abiotic factors such as temperature, relative humidity and rainfall. Changes in climatic conditions will directly affect the survival and development of the insects and subsequently act upon population build up which decides the severity of pest on host plant. Among other five species of sap feeders, brown planthopper (BPH), *Nilaparvata lugens* (Stal.) is one of the serious pest of rice. The objective of the study was to investigate the influence of biotic factors such as temperature, humidity and rainfall on population fluctuation of BPH. Number of nymphs and adults of BPH were recorded at fortnight interval from randomly selected ten hills by counting and with the help of sweep net. Weather data were collected from meteorological observatory. Daily weather parameters of corresponding time of milking stage (20$^{th}$ to 30$^{th}$ October) was analyzed. Correlation matrix was developed between BPH population and meteorological parameters to find most correlated meteorological parameter influencing BPH population. In general, the correlation coefficients between BPH incidence and the meteorological parameters *viz.*, maximum temperature, minimum temperature, mean temperature, maximum relative humidity, minimum relative humidity, and mean relative humidity were positive. Highest correlation coefficient was observed between mean temperature and BPH incidence (0.69). Correlation between BPH incidence and other meteorological parameters like maximum temperature, minimum temperature, maximum relative humidity and minimum humidity were 0.30, 0.68, 0.35 and 0.50, respectively. The forecasting model (regression) developed to predict BPH incidence (no. of insect/hill) revealed significant and positive association of temperature and relative humidity (0.70) with BPH incidence.

# Impact of Meteorological Parameters and Food Availability on Diversity of Grasshoppers With Special Reference to Their Management

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Orthoptera is one of the largest order of insects comprising 26,330 valid species found throughout the world. The order is divided into two suborders *i.e.*, Caelifera (short horned grasshoppers) and Ensifera (long horned grasshoppers). Acridoidea is the largest super family comprising 11,000 species worldwide, out of which 290 species representing 138 genera have been reported from India. Family Acrididae shows maximum diversity, comprising of 8,000 species of which 285 species belonging to 135 genera are found in India. The Acridids are dominant ground invertebrates in cultivated crops and natural vegetation, causing considerable damage to agricultural crops, pastures and forests all over the world. The primary diet for grasshoppers is grasses, forbs and sedges. Thirty three species of grasshoppers representing 23 genera belonging to eight sub-families have been explored from Aligarh during the period of three years (2010-2012). Maximum species recorded were of subfamily Oedipodinae (15) followed by Acridinae (5), Catantopinae (4), Cyrtacanthacridinae (2), Eyprepocnemidinae (2), Gomphocerinae (2), Hemiacridinae (2) and Spathosterninae (1). Its losses are not limited to cereals and pastures they also destroy the food sources for many animals, alter biogeochemical cycles of the ecosystem, thus affect the biodiversity.

# Effects of Various Hosts and Constant Temperatures on the Biology of *Bracon hebetor* say

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Development time and the sex ratio of different stages of *Bracon hebetor* Say reared on different host larvae (*Corcyra cephalonica, Helicoverpa armigera*, and *Earias vittalla*) were compared at seven constant temperatures (15, 18, 21, 24, 27, 30 and 33°C). Development time of immature stages of *B. hebetor* decreased as the temperature increased from 18°C - 33°C on three different hosts. However, no larvae survived at 15°C. Overall development time from egg to adult was shortest on *C. cephalonica* (7.92 days) followed by *H. armigera* (9.91 days) and *E. vittella* (11.29 days) at 33°C, being longest on *E. vittella* (34.32 days) followed by *H. armigera* (33.32 days) and *C. cephalonica* (30.99 days) at 18°C. Pupal mortality was lowest on *C. cephalonica* at 27°C. Adult emergence was highest at 27°C and 30°C on all the hosts. Sex ratio was biased towards male on all the host insects at every test temperature, except at 27°C. Present studies revealed that at 27°C temperature and *C. cephalonica* as host insect recoded lowest mortality, shorter development time and higher adult emergence in the parasitoid, *B. hebetor* suggesting them as suitable factors for mass rearing of this parasitoid.

# Impact of Elevated $CO_2$ on Population Dynamics of Brown Planthopper, *Nilaparvata lugens* (Stal.) in Rice Ecosystem

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Existing projections indicate that future population and economic growth will require doubling of current food production, including an increase from 2 to 4 billion tons of food grains annually. However agricultural production in many countries including India would be severely impacted by climate change. Effect of rising $CO_2$ on insects occur indirectly through changes in plant chemistry and thus nutritional quality. Present study depicts the effect of elevated $CO_2$ on brown planthopper (BPH) population on potted rice (Pusa Basmati 1401) plants in open top chambers (OTCs), using $CO_2$ @ 570 ± 25 ppm (elevated) and @ 400 ± 25 ppm (ambient) during *kharif* 2014. Elevated $CO_2$ exhibited positive effect on BPH multiplication that resulted in tripling of its population (39.9 ± 13.9 hoppers/hill) compared to ambient $CO_2$ (13.2 ± 4.8 hoppers/hill) during the crop season. Elevated $CO_2$ also showed nutritive effect on rice crop by increasing the number of tillers (15.7%), reproductive tillers (14.6%) and seeds/panicle (13.8%). Stimulatory effect of elevated $CO_2$ on BPH population could be attributed to denser plant canopy in terms of increased number of tillers (15.7%) and canopy circumference (22.6%) that created more congenial micro-habitat for BPH multiplication. Elevated $CO_2$ resulted in 24.8% higher fecundity and 72.7% higher honey dew excretion compared to ambient $CO_2$. Despite the positive effect of elevated $CO_2$ on rice crop, aggravated BPH population caused higher yield loss (29.9%) than under ambient $CO_2$ condition (17%). However, $CO_2$ not being the only factor involved in climate change, ultimate effect on BPH population and crop-pest interactions will also depend upon temperature rise, changes in rainfall pattern and predation rate of natural enemies, which also needs to be investigated.

# Species Composition of Sorghum Stem Borers in Climate Change Scenarios

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Sorghum is a candidate crop for farmers operating in harsh environments where other crops do poorly. Lepidopteran stem borers are among the most important pests of sorghum in India. Spotted stem borer, *Chilo partellus* (Swinhoe) and Pink stem borer, *Sesamia inferens* Walker are the two important borer species present in India. Feeding by borer larvae in whorls of the sorghum plant usually leads to dead hearts and early leaf senescence. After the larvae have penetrated the stems, they create tunnels by eating through the vascular bundles, leading to reduced translocation of nutrients and assimilates. A number of studies that consider climate change effects showed an expected alteration in the seasonal distribution of cereal borers. According to one of the first studies that focused on the impacts of climate change on the populations of European corn borer, *Ostrinia nubilalis* in Europe, a temperature increase associated with climate change would lead to a northward shift and occurrence of a second generation of *O. nubilalis* each year in currently univoltine areas. The studies on the species composition of cereal stem borers of sorghum with seven varieties at DSR during *Rabi* seasons of 2011-12 and 2012-13 have given an indication that the incidence of pink stem borer is on rise in comparison to the spotted stem borer. Sweet sorghums in general have supported more *Sesamia* population than *Chilo*. The *C. partellus* population was found to be 17.3% and 16.0%, while, *S. inferens* was predominant having 82.7% and 84.0% population during the *Rabi* 2011-12 and 2012-13 seasons, respectively across the test genotypes.

# Biotechnology and Transgenics

# Transgenic Plant: An Important Component of Integrated Pest Management

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In the first half of this century, global demand for food, feed and fiber is expected to grow by 70 percent thus imposing intense growing pressure on already scarce agricultural resources. Therefore, there is a need to have innovative approaches to either increase crop productivity and/or crop losses due to biotic stresses. Insect-resistant transgenic plants offer a captivating possibility for such innovation. They can offer a solution to the limited availability of insect resistant cultivars, and also can be a key component of environmentally benign and durable pest management system. However, an integrated approach is required to maximize the benefits of transgenic technology instead of considering it as a jack of all trades. Host plant resistance based on classical breeding for increased resistance to insect pests may lead to linkage drag and also time consuming, however, insect-resistant transgenic plants under the umbrella of integrated pest management (IPM) offer unique opportunity to mitigate severe losses due to insect pests. It has already been demonstrated that currently available insect- resistant transgenic plants are compatible with other IPM approaches, such as biological, cultural, chemical, biorational control, etc. Transgenic plants have proved their worth to reduce use of harmful chemical insecticides, thus increasing population of generalist natural enemies to manage herbivores other than the target pests. Moreover, transgenic plants have very selective toxicity, thus the beneficial insects such as pollinators and natural enemies are unaffected directly by these insecticidal toxins. The field trials of Bt cotton and conventional cotton with IPM practices (cleaning of fields for leftover, balanced use of chemical fertilizers, regular scouting and monitoring through pheromone traps, application of *Trichogramma chilonis*, neem seed extract, HaNPV, mechanical collection of larvae, and ETL based use of chemical pesticides) in India have shown approximately 25.0% reduction in fruiting body damage 35.0% higher return per hectare in Bt cotton than the conventional cotton. Risks such as resistance development in target pest due to intense selection pressure imposed by transgenic plants, secondary pest outbreak after elimination of major pest and due to decrease in use of broad spectrum pesticides have been considered as bottlenecks of transgenic crops, however, these risks can be minimized by integrating this component of pest management in IPM approach.

**PP: 55**

# Ingestion of Bacterially Expressed Double-stranded RNA Induces *chitinase* Gene Specific RNA Silencing in *Spodoptera litura*

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RNA interference (RNAi) phenomenon is a budding tool for insect pest control. RNAi is a sequence-specific interaction of small interfering siRNA with mRNA to silence target gene. dsRNA is a strong initiator of gene silencing in a varied group of organisms including insects. The efficacy of RNAi varies among insects of different orders. During the present studies we used economically important polyphagous pests, *Spodoptera litura* L. The *Escherichia coli* strain BL21 (DE3) which is unable to degrade dsRNA, was genetically engineered to produce dsRNA segments targeting the catabolic genes *chitinase* (*chi*), to determine whether RNAi was induced in the test insect by ingestion of bacteria expressing dsRNA. Feeding bioassays were carried out by diet incorporation method against neonates of *S. litura* at 27 ± 1 °C at 65-70% RH. One control consisted of diet incorporated with equivalent amount of BL21 without vector and other control with sterilized water (SW). Observations were made after every 24 h up to adult emergence to record mortality and the phenotypic effects on larvae, pupae and adults. Results suggested that RNAi in *S. litura* could be triggered by ingestion of dsRNA expressing bacteria. As expression of *chi* gene coincided moulting process, the feeding of dsRNA expressing bacteria caused insect mortality up to 53.0% especially during moulting leading to morphological symptoms like incomplete shedding of old exuviae larval-pupae intermediates and malformed adults. Cumulative per cent mortality in treatment was found to be significantly higher than in the control. However, the mortality was found concentration independent. Significant reduction of *chitinase* transcript was observed when compared to that of control larvae fed with bacteria containing the empty vector, indicating that the ingestion of bacterially expressed dsRNA can induce specific gene RNA silencing. Present studies suggest that Slchi dsRNA have a potential for insect pest control.

# Genetically Modified Crops in Integrated Pest Management

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The use of integrated pest management (IPM) to keep pests under control in modern agricultural systems without relying solely on pesticides has been developed. Although effective IPM strategies have been successfully developed for many crops, need based improvement in the IPM programme and their promotion too is equally important. A big improvement will be to release new cultivars with high level of resistance to insect pests. However, classical breeding for increased host plant resistance is time-consuming and labour-intensive, and the desired beneficial trait can be linked to or associated with undesirable traits. Therefore, there is a need to nave biotechnological interventions to develop insect-resistant transgenic plants as a valuable component of IPM. Genetically modified plants are often called "transgenic plants", as they contain one or more transgenes from other organisms, however, this term also includes plants in which the transgene was integrated by naturally occurring processes. In genetic engineering approaches, plant traits can be modified by inserting DNA from a different species. The use of transgenic crops in agriculture has increased since they were first commercialized in the mid-1990s. The use of genetic modified crop to create insect-resistant plants can solve the problem of limited availability of highly insect-resistant cultivars. Commercially available insect-resistant transgenic crops like Bt cotton show clear benefits in increasing agriculture production, and there are many interesting new developments such as transgenic plants that enhance biological control of pest. There is much need of effective evaluation tools to ascertain that genetically modified plants do not cause undesired non-target effects. If these conditions combined together, there are opportunities for transgenic plants to become key component of environmentally friendly and durable pest management system. The inclusion of genetic modified crops in IPM will make it too beneficial and durable pest management strategy.

# Biotechnological Approaches in Insect Pest Management

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Insect pests are one of the major constraints which affect the global production of food, feed and fiber, and their management continues to be a tedious challenge to the agricultural community. Use of synthetic and broad spectrum insecticides is satisfactory and permanent solution for pest management, however, health risk, environmental disturbance, insecticide resistance and detrimental effects on non-target community can not be ignored. Therefore, to overcome the threats caused by chemical pesticides, alternate and innovative approaches need to be developed and adopted. Bio-control agents, plant derived insecticides and insect hormones are receiving significant interest as alternative to chemical pesticides, and major component of integrated insect management system. However, as such efficacy of most of these agents need to be improved against the target pests, thus biotechnology could play a significant role in improving efficacy, cost effectiveness and expanding the global market of these agents and/or their products. Biotechnology helps in selecting potential natural enemies from different strains of biocontrol agents for a particular species of insect using molecular markers. Nevertheless, it provides an opportunity to develop superior natural enemies with quality traits like pesticide resistance, heat tolerance, cold hardiness and sex ratio alteration. Moreover, could also help to maintain the quality of laboratory reared insects to overcome the problems of inbreeding depression, founder effect and genetic drift by using DNA based methods like DNA sequencing, RFLP-PCR, RAPD-PCR, mitochondrial genome analysis, PCR and ribosomal DNA analysis. Introduction of gene coding proteinacious insect toxins (scorpion toxin, mite toxin, and trypsin inhibitor), hormones (eclosion hormone, diuretic hormone) or metabolic enzymes (juvenile hormone esterase) into nucleopolyhedroviruses genome are some approaches to increase speed of kill, enhance virulence and extend host specificity of the virus. Moreover, in order to enhance the penetration potential of insect cuticle by entomopathogenic fungi an additional copy of the *Pr1* gene, which encodes a subtilisin-like protease was engineered into the genome of *Metarrhizium anisopliae*. *Bt* is most effective and most widely used bacterial entomopathogen used against a number of insects belonging to the Orders Lepidoptera, Coleoptera, Homoptera and Diptera. Nematodes are more susceptible to environmental stresses, and therefore to overcome this problem *Heterorhabditis bacteriophora* was genetically modified to express *Caenorhabditis elegans Hsp70A* (heat-shock protein genes) to enhance heat tolerance and use in insect control. Crop improvement through genetic manipulation by *Bt* toxin, inhibitor digestive amylase genes (amylase, cysteine, proteinases, etc.) and lectin synthesis genes and plant derived insecticides too have shown their potential in insect control. Genetic engineering has also shown promise to enhance the crop protection strategy by improving the effectiveness of arthropod natural enemies by modifying the volatile organic compounds (VOCs). Thus, understanding on the fundamental aspects and utilization of biotechnology is certainly helpful in deployment and development of biotech products for use in insect pest management.

**PP: 58**

# Effect of Gamma Irradiation on Quality Parameters and Sterility of Melon Fruit Fly *Bactrocera cucurbitae* (Coquillett)

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Fruit fly damage is the major limiting factor in obtaining quality fruits and high yield in most of the cucurbits. The females lay the eggs 2 to 4 mm deep in the fruit pulp, and the maggots feed inside the developing fruits. At times, the eggs are also laid in the ovary of the flower, and the maggots feed on the ovary. The extent of losses varies between 30 to 100%, depending on the cucurbit species and the season. Fruit fly contributes to a loss of 1.8 million tons of cucurbit production, amounting to Rs. 1775 crores per annum. Since the maggots feed inside the fruit they are not accessible to chemical control through contact pesticides. Systemic insecticides are extremely hazardous, as they easily enter into the food chain. The sterile insect technique is widely used in integrated programmes against tephritid fruit flies. During the present studies, we evaluated the effect of different doses of gamma radiation on biological

parameters and male sterility of melon fruit fly, *Bactrocera cucurbitae* (Coquillett) for their possible use in management of this pest through insect sterile technique. Pupae were irradiated at different doses of gamma radiation, 5, 10, 15, 30 and 50 Gy at Nuclear Research Laboratory, IARI, New Delhi. Average of male adult emergence for irradiated pupae (IRP) was recorded to be 89.00, 85.66, 84.00, 79.33, 72.33, and 91.33% with 5, 10, 15, 30 and 50 Gy doses, respectively as compared to 91.33% for unirradiated pupae. The percentage of deformed pupae increased with increase in dose of gamma radiation. The adult longevity was also decreased with increase in dose of gamma radiation, i.e., 38.33, 35.00, 32.00, 30.66 days, and 21.33 days at 5, 10, 15, 30, and 50 Gy doses, respectively. Egg laying ability of adult female flies that were confined and mated with irradiated males of equal age were 24.66, 22.00, 18.86, 11.00, and 8.33 eggs/female/day at 5, 10, 15, 30 and 50 Gy, respectively as compared to 27.66 eggs/female/day under control. The egg hatch was significantly declined with increased doses of gamma radiation. The percentage of sterility for 5, 10, 15, 30 and 50 Gy was 28.13, 30.00, 44.20, 84.80 and 88.30%, respectively as compared to 12.80% in unirradiated control. Results indicated that 30 Gy and 50 Gy is optimum and preferable gamma radiation dose to obtain maximum male sterility in melon fruit fly.

# Inheritance of Cry2Ab Resistance in Pink Bollworm, *Pectinophora gossypiella*

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Pink bollworm, *Pectinophora Gossypiella* (Saunders) has developed field level resistance to Cry1Ac cotton in India (Dhurua and Gujar, 2011). Introduction of Bollgard® II cotton in India has replaced most of Bollgard® I cotton in 2014. The unavailability of toxicity data and resistance status for Cry2Ab against Indian pink bollworm population necessitated the present study. The pink bollworm populations bioassayed with Cry2Ab toxin showed median lethal concentration ($LC_{50}$) ranging from 0.162 to 1.444 μg/g diet for the five different populations collected from Srivilliputtur (Tamil Nadu), Jalgaon (Maharashtra), Bharuch (Gujarat), New Delhi (Delhi), and Sri Ganganagar (Rajasthan). Selection of pink bollworm for evolution of Cry2Ab resistance led to the maximal of 37.75-fold resistance *vis-à-vis* the most susceptible strain. Inheritance studies using the resistant and susceptible parents showed autosomal and semi-dominant Cry2Ab resistance ($h$ = 0.69, 0.79). The inheritance of Cry2Ab resistance appeared to be governed by multiple alleles/genes. Cry2Ab resistance was associated with fitness costs like larval and pupal periods when resistant and susceptible parental populations were reared on the diet without toxin, and appeared to be inherited in $F_1$, $F_2$ and backcross progenies. These studies clearly advocate rigorous monitoring of Cry2Ab resistance in the pink bollworm for ensuring *Bt* cotton sustainability.

# Inheritance of Cry1Ac Resistance in Pink Bollworm, *Pectinophora gossypiella* (Saunders)

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Pink bollworm, *Pectinophora gossypiella* (Saunders) is an important pest of cotton in India. It damages fruiting bodies more during later part of cotton season, when Bt Cry toxin content declines after about 110 days. In India, evolution of field level resistance in pink bollworm to Bt cotton containing Cry1Ac has earlier been reported. The rate of resistance evolution and mode of inheritance of resistance have serious implications on resistance management strategies. Therefore, the mode of inheritance of resistance to *Bacillus thuringiensis* (*Bt*) toxin Cry1Ac was studied in the *P. gossypiella* along with some of the traits associated with fitness. The analysis of reciprocal crosses between the resistant strain (JALGAON-R) (605-fold) and susceptible strain (IARI-S) showed dominance (h) of 0.83-0.84, suggesting Cry1Ac resistance as a semi-dominant trait. The progeny of reciprocal $F_1$ crosses (resistant female × susceptible male and susceptible female × resistant male) responded alike in bioassays, indicating autosomal inheritance. The progeny of back cross of $F_1$ with that of susceptible parents showed more susceptibility to Cry1Ac than that of $F_1$ and resistant parents, suggesting inheritance of Cry1Ac resistance. Further analysis based up on toxicity of Cry1Ac against the resistant, susceptible, $F_1$ and backcross progeny showed the minimum number of independently segregating genes as 0.387, indicating Cry1Ac resistance a single gene trait. Fitness costs in term of larval weight were associated with resistance when resistant and susceptible parents were reared on diet without toxin. However, none other traits like larval and pupal periods, % pupation and % adult emergence showed differences between the resistant and susceptible parents or the progeny of the $F_1$ back-crosses with resistant or susceptible parents, as expected. Fitness costs do not appear to be important and hence, may not contribute to the resistance management.

# Inheritance of Cry1Ac Resistance in Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* (Guenée)

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Brinjal (*Solanum melongena* L.) is an economically important vegetable crop cultivated across the world. India is second leading brinjal producer in the world. Brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenée) is the key pest of brinjal, causing an annual yield loss of >60%. Brinjal shoot and fruit borer larvae feed and grow inside fruits and stem of brinjal crop. In India, 29 different insecticides formulations are registered to control brinjal shoot and fruit borer outbreaks. Despite the extensive application of insecticides (15-40 applications per crop season), the annual losses are high. The nature of damage by brinjal shoot and fruit borer impairs all control measures and has led to secondary pest outbreak, environmental pollution, health hazards and resistance development. In India, transgenic brinjal expressing Cry1Ac toxin derived from *Bacillus thuringiensis* (Bt), was developed during EE1 event and successfully tested under fields conditions. In 2014, Bt brinjal is commercialized in Bangladesh and is likely to be cultivated in India in near future as well. Therefore, reports about genetic basis of Cry1Ac resistance in brinjal shoot and fruit borer are vital in designing resistance management strategies. In the present study, brinjal shoot and fruit borer larvae evolved resistance to Cry1Ac after over 8 generation of selection, under laboratory conditions (over 2.3 fold increase in selection dose). The Cry1Ac inheritance studies in brinjal shoot and fruit borer was done by crossing adults of DEL39-Bt resistant strain (386-fold Cry1Ac resistant) with the adults of ODI-S susceptible strain (never selected), and found out to be recessive and autosomal in nature. The degree of Dominance (D) varied from -0.27 and -0.39 with dominance (*h*) value at 0.36 and 0.31. Hence, the study shows sustainability of insect protective Bt-transgenic technology and helpful in devising proactive resistance management strategies.

# Studies on Occurrence and Insecticide Resistance Monitoring Against Brown Planthopper *Nilaparvata lugens* (Stal.) in Chhattisgarh Plains

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Rice is one of the most domesticated cereals, and insect pests like brown planthopper (BPH) *Nilaparvata lugens* (Stal.) causes serious damage to this crop globally. Changing climate is more favorable for BPH menace. Recently in India severe outbreaks of this pest were noticed in Haveri, Shimoga, Mandya, Mysore and Chamarajanagar districts of Karnataka. Similarly outbreaks have been noticed in several parts of world and the year 2009 was the worst year for BPH outbreaks. Keeping in view the severity of the pest, present studies were conducted in two BPH prone districts of Chhattisgarh plains during 2013-14. In each district two blocks were selected and in each block three fields were observed for BPH occurrence. It was found that the BPH population was varied at each location. In general Dhamatari region showed maximum number of BPH followed by Kurud region. Maximum BPH was observed in second fortnight of October. The BPH population ranged from 0.06 to 5.11 insects/plant in Arang and 0.01 to 5.81 in Abhanpur of Raipur district, while it ranged from 1.03 to 7.97 in Kurud and 0.23 to 11.73 in Dhamatari region of Dhamatari district. Among different insecticides tested, Dinotefuran 20SG (150 gm/ha) was found to be most effective against all the populations collected from four blocks. The insects developed resistance against imidacloprid many fold as compared to lab population. In future, survey at multiple locations can be conducted to know the district wise occurrence status of BPH in Chhattisgarh state, and the data thus obtained can be amalgamated for decision making and effective management of this pest.

# Genotyping of Phosphine Resistance in North Indian Populations of Lesser Grain Borer *Rhyzopertha dominica* (F.)

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Phosphine is the primary fumigant used to protect the majority of world's grain and a variety of other stored commodities from insect pests. Phosphine plays an important role in the protection of commodities for two primary reasons. Firstly, use of the alternative fumigant, methyl bromide, has been sharply curtailed and is tightly regulated due to its role in ozone depletion, and secondly, consumers are becoming increasingly intolerant of contact pesticides. The lesser grain borer, *Rhyzopertha dominica* (F.) is the most destructive insect pest of stored grain. These pests have been controlled successfully by fumigation with phosphine for the last several decades, though strong resistance to phosphine in many countries has raised concern about the long term usefulness of this control method. In order to understand the evolution of phosphine resistance and to isolate the responsible genes the insects were collected from different FCI and CWC Godowns in North India. The resistance in field populations to phosphine was detected by exposing the insects to a discriminating dose phosphine fumigant under controlled conditions. Genotyping of phosphine resistance levels in lesser grain borer populations was done by using the marker for phosphine resistance gene, *rph2*. Genotyping analysis using PCR RFLP test using markers for *rph2* gene revealed the existence of very high levels resistance in lesser grain borer populations collected from Punjab, Haryana, Uttar Pradesh and Rajasthan. This study suggests that a single sequence of genetic changes is responsible for the development of resistance in this insect. The significance of this finding is that the mechanisms for phosphine resistance are likely to be the same across all major grain storage regions. This means that resistance management strategies that address the mechanisms of resistance should be effective in all regions where phosphine resistance occurs.

# Monitoring of Phosphine Resistance in Red Flour Beetle, *Tribolium castaneum* (Herbst) Infesting Wheat

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An essential component of safe storage of food grains is the management of insects and other pests, for which fumigant gases are heavily relied upon. Phosphine is the only fumigant used to protect grains in storage against insect pests. A consequence of the heavy use of phosphine is the development of resistance in *Tribolium castaneum* in many regions of the world. Resistance screening tests on populations of *T. castaneum* in India revealed that phosphine resistance was common in the field populations and the frequency of the resistance was as high as 100%. The present studies were carried out to assess the level of phosphine resistance in *T. castaneum* in three selected locations of Uttar Pradesh. Three populations of *T. castaneum* infesting wheat were collected from FCI Godowns of Pratapur, Naini and Jhansi along with the information of their storage methods, dose, length of exposure period, number of fumigations, length of storage period and sealing methods. Insects were reared in laboratory and adults of *T. castaneum* were bioassayed with phosphine to study their susceptibility. Phosphine bioassay was carried out according to FAO standards. The insects were subjected to two discriminating concentrations, 0.03 mg/l and 0.25 mg/l, over 20 h exposure period and mortality was assessed after a recovery period of 7 days. The results revealed that resistance to phosphine was common in all the collected populations of *T. castaneum*. Jhansi population showed the lowest level of mortality ranging between 5 to 8% at both doses 0.03 and 0.25 mg/l. With lower discriminating dose, tolerance was 89.33% in Pratapur population, 88.33% in Naini population, and 94.66% in Jhansi population. The higher discriminating dose of phosphine showed survival level as 86.66%, 85.0% and 91.66% in Pratapur, Naini and Jhansi populations, respectively. Significant difference in mortality could not be observed at both these doses.

# Neonicotinoid Resistance in *Bemisia tabaci* (Gennadius) Populations From India

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Whiteflies belong to the family Aleyrodidae, and include a large insect group with more than 1200 species, some of which are notorious agricultural pests. The sweet potato whitefly, *Bemisia tabaci* (Gennadius) is one among the most widely distributed agricultural pests worldwide. Due to its severe damage, *B. tabaci* has been controlled predominantly with chemical insecticides. However, as a result of extensive application of synthetic insecticides high degree of resistance has been developed to a wide range of conventional insecticides including carbamates, organophosphates, pyrethroids, etc. Now neonicotinoids are widely used for its management. The present study was conducted to evaluate the status of neonicotinoid (Imidacloprid, Acetamiprid and thiamethoxam) resistance in whitefly populations from India. Five different population of *B. tabaci* were collected from cotton growing regions *viz.*, Sriganganagar (RJ), Ludhiana (PJ), Indore (MP), Amravati (MH) and Delhi. Various populations of whitefly were maintained separately in insect proof climate control chamber in the Division of Entomology. Adults of *B. tabaci* were bioassayed through leaf dip method according to insecticide resistance action committee (IRAC) susceptibility test methods series method no 12a, 2009. It was observed that compared to Delhi population all other populations of *B. tabaci* showed lesser susceptibility against the three neonicotinoids tested. Delhi population showed $LC_{50}$ values of 279, 342 and 382 mg/lit for imidacloprid, acetamiprid and thiamethoxam, respectively. The LC50 values for Sriganganagar, Ludhiana, Amravati and Indore populations ranged from 783 to 1462 mg/lit for imidacloprid, 717 to 1540 mg/lit for acetamiprid, and 1012 to 1874 mg/lit for thiamethoxam technical grade insecticides.

# Glimpses of the IPM Symposium











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