## Ninth International Conference on

# Management of the Diamondback Moth

## and Other Crucifer Insect Pests

**May 2-5, 2023**
**Phnom Penh, Cambodia**

Sowing seeds, meeting needs
World Vegetable Center
1973-2023

TACTRI

The IX International Conference on

**Management of the Diamondback Moth and other Crucifer Insect Pests**

2-5 May 2023

Phnom Penh, Cambodia

# Book of Abstracts

## Editors

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**S. Yule**


Sowing seeds, meeting needs

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1973-2023

The World Vegetable Center is an international nonprofit research and development institute committed to healthier lives and more resilient livelihoods through the increased production and consumption of nutritious, diverse, and health-promoting vegetables.

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## ORGANIZERS

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**Royal University of Agriculture (RUA), Cambodia**

Taiwan Agricultural Chemicals and Toxic Substances Research Institute, Council of Agriculture, Executive Yuan

## SPONSORS

**Council of Agriculture, Executive Yuan, Taiwan**

# Meeting Information

**The IX International Conference on Management of the Diamondback Moth and other Crucifer Insect Pests**

2-5 May 2023

Phnom Penh, Cambodia

## Meeting Venue

The IX International Conference on Management of the Diamondback Moth and other Crucifer Insect Pests will be held at Himawari Hotel in Phnom Penh, Cambodia (https://www.himawarihotel.com/).

## Guideline for Oral Presenters

PC and projectors are provided for the meeting rooms. Presentation files should be uploaded to the laptops before the beginning of the sessions. There are 30 minutes for each speaker; 20-25 minutes for oral presentation (in person and online participants) and 5-10 minutes for discussion.

## Guideline for Poster Presenter

The posters can be mounted during the respective scientific session. Authors should stand close to their boards to answer questions and facilitate discussions on their work.

# Scientific Committee

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**Dr. Francisco Ruben Badenes Perez**
Institute of Agricultural Sciences, Spain

# Schedule

## Tuesday, 2 May 2023

**Venue:** Himawari Hotel Conference area

| | |
|---|---|
| 08:30-09:30 | Registration |
| 09:30-10:00 | Coffee Break (Coffee Lounge) |
| **10:00-12:00** | **Inaugural session** |
| 10:00-10:20 | Welcome address and Introduction to the Conference (Dr. Srinivasan Ramasamy, World Vegetable Center) |
| 10:20-10:35 | Inaugural address by Dr. Marco Wopereis, Director General, World Vegetable Center |
| 10:35-10:50 | Inaugural address by Dr. Yann-rong Lin, Deputy Director General – Partnerships, World Vegetable Center |
| 10:50-11:05 | Special address by Dr. Bunthan Ngo, Rector, Royal University of Agriculture, Cambodia |
| 11:05-11:20 | Special address by Dr. Ker Monthivuth, Director, Department of Plant Protection, Sanitary and Phytosanitary, General Directorate of Agriculture, Cambodia |
| 11:20-11:25 | Group Photo |

| | |
|---|---|
| **Session 1** | **Insect Plant Interactions, Host Plant Resistance and Chemical Ecology of Crucifer Pests and Their Natural Enemies** |
| 11:30-12:00 | **The Effect of Herbivory on Diamondback Moth Host-Plant Selection: Implications for Trap Cropping ……**……1<br>Tannner, E.R. and Furlong, M. J. |
| 12:00-13:00 | Lunch |
| 13:00-13:30 | **Ecosystem services within the vegetable integrated push-pull (VIPPT) protects Brassicas against diamond back moth with improved yield and quality**. ……2<br>Chidawanyika, F.; Pittchar, J.; Subramanian, S.; Khan, Z. R. |
| 13:30-14:00 | **Diamondback Moth (*Plutella xylostella*) and Aphids (*Brevicoryne brassicae* and *Lipaphis pseudobrassicae*) Control in Cabbage Production Using Vegetable Push-Pull Technology ……**……3<br>Boni, S. B. et al. |

## Wednesday, 3 May 2023

| | |
|---|---|
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| 08:30-09:00 | **A Pilot 'Green' Initiative with Integrated Pest Management (IPM) for a Cauliflower-based System in Myanmar ...**<br>Sivapragasam, A. et al. |
| 09:00-09:30 | **Promoting Integrated Pest Management for Climate-Resilient Market-Led Cruciferous Vegetable Production in Assam, India**<br>Ravishankar, M. et al. |
| 09:30-10:00 | **Scaling of IPM Technologies for Off-Season Production of Leafy Brassicas in Cambodia**<br>Sotelo-Cardona, P. et al. |
| 10:00-10:30 | Coffee break / Poster |
| | **Poster session**<br>**Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of Pesticide Use in Chinese Cabbage Production in Taiwan**<br>Huang, L. H. et al. |
| 10:30-11:00 | **Agronomic Performance of Kales (*Brassica oleracea*) and Swiss Chard (*Beta vulgaris*) Grown on Soil Amended with Black Soldier Fly Frass Fertilizer Under Wonder Multistorey Gardening System**<br>Abiya, A. A. and Niassy, S. |
| 11:00-11:30 | **Management of Diamondback Moth in Florida and Georgia, USA**<br>Furuya, A. M. et al. |
| 11:30-12:00 | **How do *Bacillus thuringiensis* Biopesticides Reduce Flea Beetle Damage on Leafy Brassicas?**<br>Adhikari, P. et al. |
| 12:00-13:00 | Lunch |
| **Session 3** | **Insecticide Resistance and Management in Crucifer Pests: The on-going Challenge** |
| 13:00-13:30 | **Bacterial Survey in the Gut of Philippine Population of The Diamondback Moth, *Plutella xylostella* L.** |

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| 09:00-09:30 | **Developing Vegetable Hummingbird Formulation to Manage Diamondback Moth, *Plutella xylostella* (Linnaeus) Infesting Crucifers** .....33<br>Shanthi, M. et al. |
| 09:30-10:00 | **Promoting natural enemy activity in brassica crops: multi-scalar effects** .....34<br>Gurr, G.M. et al. |
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| 11:30-12:00 | **Biological Control of Diamondback Moth and other Crucifer Insect Pests by Microbial Entomopathogenic Fungi** .....38<br>Ahmmed, A. N. F |
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| 13:30-14:00 | **Production Breaks, Cropping Patterns and Biological Control: Towards A Better Management System for Diamondback Moth, *Plutella xylostella*** .....40<br>Li, Z. et al. |
| 14:00-14:30 | **Enhancing Virulence of *Beauveria bassiana* against Diamondback Moth, *Plutella xylostella*** .....41<br>Nithya, P.R. and Manimegalai, S. |

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| | |
|---|---|
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| 09:00-09:30 | **The Plasticity of Learning in The Specialist Diamondback Moth Parasitoid, *Diadegma semiclausum* (Hellén)** ……49<br>Weng, S.H. et al. |
| **Session 5** | **Genetic Approaches to Manage Crucifer Pests: Transgenic Plants, CRISPR, RNAi, and Genetic Pest Management** |
| 09:30-10:00 | **Genome, Host Genome Integration, and Gene Expression in *Diadegma fenestrale* Ichnovirus** ……50<br>Kim, J. |
| 10:00-10:30 | **Identification of Two Diamondback Moth Parasitoids, Using LAMP for Application in Biological Control** ……51<br>Kim, J. |
| 10:30-11:00 | Coffee break |
| 11:00-11:30 | **Application of Genome Editing in Insect Pest Management with Special Reference to Crucifers** ……52<br>Asokan, R. et al. |
| 11:30-12:00 | **Conference Conclusion and Wrap-up (including the next Conference)** |
| 12:00-13:30 | Lunch |
| 13:30-17:00 | Networking/Free meetings |

## Additional Poster

| | |
|---|---|
| **Session 3** | **Insecticide Resistance and Management in Crucifer Pests: The on-going Challenge** |
| **Thursday, 4 May 2023** | **Screening for the presence of Diamondback moth (*Plutella xylostella* L.) Resistance to Commonly Used Insecticides in Cambodia ……53**<br>Satya Ouk et al. |

## Saturday, 6 May 2023

| |
|---|
| Departure of participants |

# Session 1: Insect Plant Interactions, Host Plant Resistance and Chemical Ecology of Crucifer Pests and Their Natural Enemies

## The Effect of Herbivory on Diamondback Moth Host-Plant Selection: Implications for Trap Cropping

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## ABSTRACT

Diamondback moth (DBM) (*Plutella xylostella*) host plant selection is mediated by physical, visual and chemical cues. The effect of herbivory on DBM discrimination between the highly attractive, 'dead- end' trap crops *Barbarea vulgaris* and *Barbarea verna* and cabbage (*Brassica oleracea* cv sugarloaf) was investigated in laboratory studies. Two-choice oviposition tests showed that intact *B. vulgaris* and *B. verna* plants were more attractive to ovipositing moths than *B. oleracea* plants. However, following herbivory by conspecific larvae, damaged *B. oleracea* plants were more attractive to ovipositing moths than either *B. vulgaris* or *B. verna*. In contrast, treatment of *B. oleracea* with salicylic acid (to simulate the effects of feeding by sucking pests) resulted in *B. vulgaris* remaining more attractive to ovipositing *P. xylostella*. Mechanical damage of *B. vulgaris* and *B. verna* did not affect *P. xylostella* oviposition. *Plutella xylostella* preferentially oviposited on the middle leaves of *B. vulgaris* and middle-upper leaves of *B. verna*, where neonates also preferred to mine. Larval survival on *B. verna* (42% of cohort) was higher than expected. On *B. vulgaris* < 1% of test larvae survived; larvae feeding on the lower, oldest leaves survived for longer than larvae feeding on younger, upper leaves. Bouts of feeding by second instar larvae on *B. vulgaris*, showed that feeding repellency was greatest on the youngest leaves, but when larvae were re-introduced to *B. oleracea* they were able to recover and complete development. The study shows that that herbivory is likely to impact oviposition preferences of DBM and this could compromise the effectiveness of *Barbarea sp* as trap crops to manage the pest in cabbage crops.

## Keywords

*Barbarea vulgaris*, *Barbarea verna*, *Brassica oleracea*, herbivory, trap-cropping

# Ecosystem Services Within the Vegetable Integrated Push-Pull (VIPPT) Protects Brassicas against Diamond Back Moth with Improved Yield and Quality

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## ABSTRACT

Diamondback moth (DBM), *Plutella xylostella* is a key pest of cruciferous vegetables in the tropics including sub-Saharan Africa. Recognizing the need for sustainable intensification of cropping systems to boost food production and nutritional diversity, we recently integrated kales, *Brassica oleracea*, a high value vegetable preferred by the farmers into the cereal push-pull technology to form the VIPPT. The VIPPT involves intercropping maize and vegetables with *Desmodium* companion plants, with *Brachiaria* grasses as border crop around the plot. The semiochemicals produced by the *Desmodium* and *Brachiaria* companion plants are known to be important for controlling key lepidopteran pest of maize including the fall armyworm *Spodoptera frugiperda* through stimulo-deterrent diversion strategy. To test a similar stimulo-deterrent mechanism of VIPPT on DBM, we conducted on-station full-factorial trials with different spatial/agronomic arrangements of the VIPPT and assessed the population of DBM on kales. We also assessed the percentage of kales damaged, total yield and quantity of spoiled yield that was not fit for consumption for each plot. We also assessed the impact of VIPPT on DBM with 50 farmers randomly selected from a pool practicing VIPPT in western Kenya in the short rain and long rain seasons from 2021 to 2022. Our results showed DBM infestations reduced by over 60% in kales within the VIPPT both on-station and in the farmer's fields. This was followed by yield increase of 35% and limited losses due to crop damage. Further standard oviposition choice tests under greenhouse conditions showed non-preference by DBM for kales paired with *Desmodium* compared to the sole ones. Interestingly, our olfactometry assays also revealed higher attraction for the DBM larval parasitoid, *Cotesia vestalis* to Desmodium. We therefore conclude that kales benefit from the pest control ecosystem services provided by the companion plants leading to improved productivity.

## Keywords

Stimulo-deterrent, *Plutella xylostella*, *Cotesia vestalis*, Cropping system

# Diamondback Moth (*Plutella xylostella*) and Aphids (*Brevicoryne brassicae* and *Lipaphis pseudobrassicae*) Control in Cabbage Production Using Vegetable Push-Pull Technology

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## ABSTRACT

The push-pull technology used in the control of pests of cereal crops has not been commonly used in vegetable cropping systems. A study to evaluate the effectiveness of various plants on their capacity to deter (push) or attract (pull) diamondback moth (DBM) and aphids in cabbage crop is being conducted at World Vegetable Center (WorldVeg) research station in Arusha, Tanzania in collaboration with International Centre of Insect Physiology and Ecology (icipe), Kenya. Based on field experiences, baseline survey and some information obtained from the literature, the following crops were selected as having push or pull characteristics on DBM and cabbage aphids. The potential push-pull crops are: spider plant as a pull crop for both DBM and aphids, onion and marigold as push crops for both DBM and aphids, and French bean sprayed with kale extract as pull crops for DBM. Nine treatments/combinations were evaluated

including a control. The trial was set between October 2022 and January 2023, with all the treatments arranged in Randomized Complete Block Design with three replications. Data on plant growth (number of leaves per plant and plant width), plant damage severity caused by DBM and aphids on both main and push-pull crops were collected. Cabbage yield was also determined. The on-station trial is being repeated in 2023 in order to collect more data on the performance of the push-pull crops in controlling the target pests before the technology is taken for on-farm assessment prior to its scaling among cabbage producers. This paper presents and discusses the preliminary results of the first season trial based on the incidence and severity of damage by both pest species on cabbage, cabbage growth parameters and yield (fresh weight, head size and marketable versus non-marketable products) of the various treatments. It is expected that this technology would provide more ecologically-friendlier vegetable production system than the conventional pest control methods commonly used worldwide. The approach may contribute knowledge to the global efforts to safeguard and generally improve the quality of environment, and safe vegetable consumption while controlling sustainably target pests effectively.

## Keywords

Cabbage, agroecology, pest control, push-pull technology

## Integrating Cabbage into the Push-Pull Farming System Can Enhance Productivity

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## ABSTRACT

The push-pull technology has been widely promoted in many parts of sub-Saharan Africa, exclusively in cereal cropping systems; however, little is known about the possibility of integrating vegetable crops such as crucifers. We, therefore, investigated the performance of cabbage under a push-pull system assuming increased yield and reduced pest infestation. Cabbage under push-pull (PPT) was compared with a control treatment (cabbage without push-pull) in two seasons in a completely randomized design and replicated three times. In addition, we investigated the spatial spread of the pests within a Push-pull setup to establish effective control mechanisms. Pest infestation level on cabbage plants differed between the seasons and was mainly caused by aphids. However, the damage was significantly reduced in in the treatment plot (2.3000, p=0.00402, 95 C.I, vs 4.52963) as compared to the control plot. This attest to the effectiveness of Push-pull technology in controlling aphids for improved food security. In both seasons, the proportion of infested plants was significantly lower in cabbage under push-pull treatment setup. Cabbage plants under PPT plots produced more leaves per plant than in control. Cabbage heads under push-pull were heavier (Season 1: 2.45kg vs 2.23 kg; Season 2: 2.03kg vs 1.13kg) and larger (season 1:15.88cm vs 15.43cm); season 2: 15.29 cm vs 15.43 cm) than those under control plots. Simple experiments suggest water-soluble chemical components associated with *Desmodium intortum* root exudates that may be responsible for the rapid growth of cabbage. The enhanced performance of cabbage under PPT could be attributed to a reduction in pest infestation and soil improvement effects by *D. intortum*. This is the first study to demonstrate the possibility of integrating a vegetable crop into the push-pull system.

## Keywords

Vegetable, Push-Pull system, *Desmodium intortum*, intercropping, soil fertility, pest control, plant health, semiochemicals

# The Larvae of *Phyllotreta striolata* Share the Same Olfactory Cues for Locating Brassicaceae Plant as Conspecific Adults

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## ABSTRACT

The sophisticated olfactory system of insects plays crucial roles in host plant location. In comparison with comprehensive studies on the molecular mechanisms of olfactory cue detection in lepidopteran moths, little is known about how coleopteran beetles detect host plant cues. The striped flea beetle, *Phyllotreta striolata*, is a devastating coleopteran insect pest of Brassicaceae crops whose larvae feed on roots underground, while its adults destroy leaves aboveground. In this study, we focus on the molecular basis of olfactory cue detection in *P. striolata* and attempt to determine whether *P. striolata* larvae share the same specific olfactory cues for host plant location as conspecific adults and whether the detection mechanism is conserved. A two-choice behavioral bioassay was conducted to examine the behavioral responses of *P. striolata* to different types of isothiocyanates, which are the characteristic volatiles of Brassicaceae crops. The results showed that both *P. striolata* adults and larvae were attracted by allyl isothiocyanates, although adults showed a broader behavioral response range. The transcriptome sequencing of *P. striolata* adults and larvae was performed, and 157 chemosensory genes were identified, among which 6 OBPs were found to be preferentially expressed in both *P. striolata* adults and larvae. Functional studies of PstrOBP9, PstrOBP13 and PstrOBP17, three of the six OBPs that were highly expressed in both adults and larvae, revealed that PstrOBP9 strongly bound allyl isothiocyanates and eight other isothiocyanates. Taken together, these findings demonstrated that *P. striolata* larvae and adults could employ the same olfactory proteins to detect specific plant volatiles for host location, which provides a new perspective on the development of environmentally friendly pest management targeting both *P. striolata* adults and larvae.

## Keywords

*Phyllotreta Striolata*; Isothiocyanates; Odorant-Binding Proteins; Host Plant Location

# The Study and Development of Mass Trapping System for Sex Pheromone of *Plutella xylostella* (Lepidoptera: Plutellidae) in Taiwan

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## ABSTRACT

Diamondback moth (DBM), *Plutella xylostella*, is an important pest of Brassicaceae in Taiwan. The insecticide resistance of DBM is a serious issue. The aim of this study is to develop a mass trapping system for the sex pheromone of DBM. We used synthetic sex pheromone of DBM to develop the best formulation of sex pheromone lure, and the optimal number for mass trapping is 120 traps/ha in this study. There was a lower density of DBMs and a lower infested rate of DBMs on the cauliflowers. Thereafter, we designed various dry traps for DBM sex pheromone. The "2-layer lepidopteran flies up plastic trap" with ventilation holes in the lower layer is as effective as a wing sticky trap in the higher density of DBMs. We hope this system can be introduced into IPM programs for controlling DBMs. The components and mixture ratio of synthetic sex pheromone for DBM in Taiwan have been authorized by technology to a pesticide manufacturer for commercialization and sale.

## Keywords

diamondback moth (DBM), *Plutella xylostella*, sex pheromone lure, dry trap

# A Nanomatrix for Controlled Release of Diamondback Moth *Plutella xylostella* (L.) (Plutellidae: Lepidoptera) Pheromone

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## Abstract

The diamondback moth (DBM) is a destructive pest of brassica crops throughout the world. Indiscriminate use of insecticides has resulted in the development of resistance and the buildup of residue in harvested commodities. Exploiting the potential of semiochemical is an eco-friendly approach to manage DBM, considering its compatibility with biocontrol agents of the pest. The female sex pheromone of *P. xylostella* comprises Z-11-hexadecenal and Z-11-hexadecenyl acetate. Currently, pheromone loaded in rubber septa dispensers is being used @ 10 per ac for mass trapping adult males. The rubber septa have a high release rate of pheromone and this warrants the replacement of the lure twice or thrice during the cropping period making it expensive for the farmers to adopt. Meso and microporous materials are novel carriers/dispensers for the volatile signaling molecules with controlled spatiotemporal release rates. A delivery matrix made of micro/mesoporous sieves with pore channels was developed for loading the *P. xylostella* pheromone. Nanomatrix characterization by Field Scanning Electron Microscopy (FESEM) and X-ray Diffraction (XRD) confirmed the ordered structure of the pores on the matrix. Pheromone when loaded in nanomatrix showed delayed dissipation as compared to pheromone alone when assayed by Thermal gravity analysis (TGA). The release rate of pheromone loaded in the nanomatrix revealed the controlled release of pheromone as compared to release from rubber septa. The physiological and behavioral response of the male moths to the pheromone released from nanomatrix was ascertained. Field test of pheromone loaded in nanomatrix captured more moths than unbaited traps. The nanomatrix developed for delivery of *P. xylostella* pheromone scaled down the cost of mass trapping of moths.

## Keywords

Nanomatrix, mass trapping, *Plutella xylostella*

# Mating Disruption for the management of diamondback moth *Plutella xylostella* (L.) (Plutellidae: Lepidoptera) using Nano Matrix Controlled Release Pheromone Dispenser

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## Abstract
The Diamondback Moth has developed resistance to nearly all synthetic insecticides used against it in the field. Because of this pest, pesticides recommendations constantly change as new compounds come into market and others become ineffective. This has led to Cole crops produce having heavy residues. The larvae feed on the growing tips of crucifers causing stunting and distortions that makes heads unmarketable. To manage the pest effectively by semiochemicals, ATGC has developed in collaboration with JNCASR and ICAR-NBAIR a new nano matrix delivery system consisting Z-11-hexadecenal and Z-11-hexadecenyl acetate the female sex pheromone of *P. xylostella* to disrupt mating effectively. We were able to have a season long control with our novel delivery system using these nano matrix materials. The technology allows control release of pheromone for the entire season disrupting mating in every brood. This technology is formulated in different formulations like CREMIT P Glue dispensers, CREMIT T Solid dispensers and CREMIT SM. We have demonstrated that using the above-mentioned delivery system mating disruption can be achieved above 92% in small farm holdings. The treated plots had less than 5% damage to the heads against 35% in farmer practice. The treated plots were applied with only 2 insecticide sprays for managing secondary pests against farmer practice where 12 insecticide applications were made, 9 specifically for managing diamond back moth. Mating disruption tool will be an effective tool in IPM for management of *P. xylostella*.

## Keywords

Pheromone, CREMIT P Glue dispensers, CREMIT T Solid dispensers, CREMIT SM

# Plant Glucosinolates Content and Susceptibility to the Diamondback Moth and the Small Cabbage White Butterfly

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## ABSTRACT

The diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) and the cabbage white butterfly, *Pieris rapae* L. (Lepidoptera: Pieridae) are specialized on using glucosinolate-containing Brassicacea as host-plants. This research indicates that there seems to be an association between plant glucosinolate content and host-plant preference and suitability in these two specialist insects. The results of this research will be discussed with regards to host-plant resistance and trap cropping.

## Keywords

host-plant preference, host-plant resistance, larval survival, oviposition, Pieris rapae, *Plutella xylostella*

# Session 2: Constraints and Opportunities to the Sustained Adoption of Integrated Pest Management (IPM) For the Management of DBM and Other Crucifer Pests

## Promoting Biocontrol and Biopesticide Products as Part of an IPM Plan to Fight Crop Pests and Diseases Sustainably

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## ABSTRACT

Farmers encounter perennial crop losses due to high pests and diseases pressure in their crops, and efforts to manage them in most cases results in overusing chemical pesticides. It is increasingly evident that broad-spectrum chemical pesticides used in agriculture are causing serious human health and environmental concerns. Conversely, the use of biocontrol and biopesticide products contribute towards more sustainable solutions as part of an Integrated Pest Management (IPM) plan, meet export and market standards requirements and reduce pesticide load pressure on the environment. The CABI-led Plantwise programme was advocated in more than 30 countries worldwide as a framework for managing their plant health challenges to complement the national extension system and targeting plant health issues such as that of indiscriminate and misuse of pesticide on various crops, including brassicas. Essentially, Plantwise provided smallholder farmers with better access to IPM-based advisory support and information - essentially mitigating crop loss, and thus save more of what they grow, due to pests and diseases and other plant health problems. More recently, to augment the Plantwise programme, CABI's bioprotection resource, i.e., the CABI BioProtection Portal, has been developed. The Portal is a knowledge repository that contains information about biocontrol and biopesticide products from several countries. More than 3,935 authorized products are featured on the Portal, available in 32 countries and in nine languages. The Portal is an open access tool to provide

information on what biocontrol and biopesticide products to use against crop pests. For example, for the management of the diamondback moth, there are more than 100 registered bioproducts available in the USA. Pertaining to CABI's commitment towards biopesticides, the paper also reported the findings from the CABI and AgBiTech collaborative research on efficacy of Lepigen, AcMNPV against diamondback moth in cabbage in Malaysia.

## Keywords

Biocontrol, biopesticide, integrated pest management, plantwise, bioprotection portal

# A Pilot 'Green' Initiative with Integrated Pest Management (IPM) for a Cauliflower-Based System in Myanmar

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## ABSTRACT

A pilot study was conducted to evaluate a 'green-based' integrated pest management (IPM) approach versus the conventional indiscriminate use of pesticides against insect pests of cauliflower in farmer fields in Thekawgyi Village, Lewe Township, Myanmar. In the IPM plot, a total of six components which was made of five (5) 'green' components and one insecticide component were used. The latter included use of trap crop, crude tobacco extract, neem insecticide, neem cake powder and yellow sticky trap. In the non IPM (NIPM) plot, there were two components which was made of one 'green' component (i.e., trap crop) and one insecticide component. The key insect pests recorded in both the IPM and non IPM plots were the diamondback moth (*Plutella xylostella*), aphid (*Myzus persicae*), flea beetle (*Phyllotreta cruciferae*) and white fly (*Bemisia tabaci*). Generally, higher populations of insects were seen for each key pest in the NIPM plot compared to the IPM plot. No parasitoids were recorded in this trial in both the IPM and NIPM plots. Overall, the IPM plot had lesser insecticide sprays, i.e., 2 times against 5 times in the NIPM plot. The IPM plot also gave better results compared to the NIPM plot in terms of the % pest control costs over total production costs (i.e., 8.2% versus 19.1%, respectively) and in terms of overall profit (i.e., USD168.0 versus USD33.8, respectively). Further, negligible residues were seen in the harvested produce in the IPM cauliflower compared to the NIPM cauliflower which exceeded (i.e., 0.75ppm) the Maximum Residue Limit (MRL) allowed for cypermethrin (i.e., 0.5 ppm). The study suggested the potential feasibility for a 'green'-based' IPM approach in managing insect pests on cauliflower. However, there are several challenges that need to addressed towards the adoption and scaling-up of this approach by Myanmar farmers.

## Keywords

Integrated pest management, brassicas, Myanmar, adoption, challenges

## Promoting Integrated Pest Management for Climate-Resilient Market-Led Cruciferous Vegetable Production in Assam, India

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### ABSTRACT

Farmers in Assam, India predominantly grows rice, but crop diversification with vegetables can improve production, productivity, and income, as well as human nutrition. However, the indiscriminate use of chemical pesticides not only adversely affect producers through increased production costs and health risks, but also the environment and consumers. To address this issue, the World Vegetable Center developed IPM packages which includes seedling production, use of sticky and pheromone traps, biopesticides, and the use of selective chemical pesticides in later stages of the crop. Farmers participatory field trials were conducted for two years (2020-21 and 2021-22) during the winter season in 208 farmers' fields (112 for cabbage and 96 for cauliflower). Farmers were trained on the GAP practices with the IPM inputs. The results showed a significant yield increase and reduction in chemical pesticide use compared to the control plots for both crops in both years. The mean yield increase in cabbage ranged from 24.4-27.7%, and the pesticide reduction was 45.4-52.8%. In cauliflower, the mean yield increase ranged from 24.4-38.4%, and the pesticide reduction was

43.9-54.6%. The benefit cost ratio (B:C) for cabbage increased from 2.24 to 3.20, resulting in an additional benefit of 0.96, while the B:C ratio for cauliflower increased from 2.05 to 2.96, resulting in an additional benefit of 0.90. Thus, IPM technologies were well received by the beneficiary farmers, contributing to reduced agro-chemical usage in pest management, while contributing to yield increase, quality improvement of produce, and more economic returns per unit area and can improve the economic viability of cabbage and cauliflower cultivation. The promotion of IPM technologies among a larger number of farmers and the strengthening of input value chains to ensure the availability of quality IPM products at affordable prices within the reach of the farmers in Assam should be encouraged.

## Keywords

Crop diversification, Good Agricultural Practices, yield increase, pesticide reduction, sustainable agriculture

# Scaling of IPM Technologies for Off-Season Production of Leafy Brassicas in Cambodia

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## ABSTRACT

Smallholder farmers in Cambodia cultivate leafy brassicas as they play a significant role in income generation and in improving nutrition. In addition, growing leafy brassicas during the off-season means that farmers can produce when the general supply is low and prices are high, generating higher availability and income during this period. However, the production of leafy brassicas is constrained by a plethora of pests and diseases. Therefore, the objective of this study was to pilot and scale-out IPM technologies through farmer participatory approaches for the off-season production of leafy brassicas in seven provinces (Tboung Khmum, Kampot, Kampong Cham, Kandal, Prey Veng, Svey Rieng, and Takeo) in Cambodia. A majority of the farmers cultivated choy sum (caisim) (62%), followed by pak choi (23%), and mustard green (13%). The IPM package consisted of a neem-based product, and microbial-based biopesticides, together with the use of other technologies such as colored sticky traps, and pheromone traps. Our results showed that although major insect pests were present in the demonstration plots, the level of damage (1-5 damage score scale) recorded was

low to intermediate (score 1-2) in the case of aphid, armyworms, and cabbage loopers, whereas diamondback moth and flea beetles had a slightly higher damage score (score 3-4) on choy sum and pak-choi crops. An obvious reduction in the use of chemical pesticides was recorded in 80% of the demonstration plots. Choysum, Chinese cabbage, mustard green, and pak-choi registered an average reduction of about 35%, and with up to 57% reduction in pak-choi. The economic benefit due to the adoption of IPM was higher in Kandal, Prey Veng and Svey Rieng provinces, receiving up to USD 1.25 per m2. The benefit: cost ratio was higher in Kampot province (10.52), followed by Kampong Cham (5.16), and Tboung Khmum (4.25). The lowest benefit: cost ratio was observed by the brassica producers in Prey Veng province (1.82). Thus, the adoption of IPM reduces the pest incidence and thus the reliance on chemical pesticides, while increasing the income of the farmers substantially.

## Keywords

Biopesticides, IPM, safe and off-season production, leafy brassicas

# Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of pesticide use in Chinese Cabbage Production in Taiwan

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## ABSTRACT

In conventional agriculture involving Chinese cabbage production in Taiwan, insecticides are inevitably used to control various insect pests, especially *Plutella xylostella* (diamondback moth, DBM), *Pieris rapae* (imported cabbageworm), and *Phyllotreta striolata* (stripped flea beetle). To reduce pesticide use, we introduced an integrated pest management program (IPM) to Chinese cabbage growers, including the sex pheromone of DBM for monitoring and mass trapping, insecticide Cartap GR and diatomaceous earth for controlling stripped flea beetle larvae in soil, and Bacillus thuringiensis to control Lepidoptera larvae. We designed scouting record sheets for different insect pests to teach growers how to record situations of pest occurrence so that they could launch different control strategies according to the amount of insect population. Furthermore, the environmental impact quotient (EIQ) was used to evaluate the potential impact of pesticides on human health and environment as a decision support tool in IPM decisions. Field use of EIQ can improve the selection and use of pesticides in IPM decisions to reduce the risk of hazards and can also be a useful indicator for impact assessment of IPM programs.

## Keywords

Integrated pest management, Environmental Impact Quotient (EIQ), Chinese cabbage

# Agronomic Performance of Kales (*Brassica oleracea*) and Swiss Chard (*Beta vulgaris*) Grown on Soil Amended with Black Soldier Fly Frass Fertilizer under Wonder Multistorey Gardening System

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## ABSTRACT

The wonder multistorey garden (WMSG) is an innovative vertical farming system tailored for urban settings. We evaluated the effects of applying NPK fertilizer and black soldier fly frass fertilizer (BSFFF) under different irrigation regimes on kales (Brassica oleracea) and Swiss chard (Beta vulgaris). The fertilizers were applied at rates equivalent to 371 kg of N ha−1. For each crop, the BSFFF or NPK was applied to supply 100% of the N required (100% BSFFF), and then a combination of BSFFF and NPK, so that each fertilizer supplied 50% of the N required (50% BSFFF + 50% NPK). Three irrigation regimes were applied: daily, after two days, and after three days. The results revealed that the irrigation regime significantly affected leaf production of both vegetables. Irrigation regimes significantly influenced kale plant height, where plants provided with water daily achieved the highest average heights of 20 cm, 46 cm and 54 cm, at 14, 28, and 42 days after transplanting (DAT), respectively. Furthermore, the application of 100% BSFFF produced kales with significantly higher plant heights (55 cm) and number of leaves (9.9 leaves) at 42 DAT, compared to other treatments. Fertilizer application significantly affected pest population, with the lowest pest infestation being recorded from kales and Swiss chard grown in soil amended with BSFFF. The application of 100% BSFFF or NPK, together with daily irrigation, significantly increased the fresh shoot weight and leaf dry matter of kales and Swiss chard, as compared with the control. Our study has demonstrated the high potential of single (100% BSFFF) or combined applications of BSFFF (50% BSFFF + 50% NPK) with daily irrigation regime to im-prove the growth, yield and pest management in Swiss chard and kales under vertical farming. Our study advocates for the scaling of WMSG and BSFFF for sustainable food systems in urban settings.

## Keywords

Vertical farming innovation, Urban agriculture, Organic vegetable, Insect frass fertilizer, Irrigation scheduling, Food security

## Management of Diamondback Moth in Florida and Georgia, USA

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### ABSTRACT

Cole crops in the state of Georgia, USA are grown on approximately 20,000 acres annually and have a farmgate value of about $100 million each year. About 9,000 acres of cabbage are grown annually in Florida at a value of over $45 million. The diamondback moth larva is the most important pest of the cropping system, primarily due to its propensity to become resistant to most insecticides used extensively for its control. The response in Florida and Georgia has been to quantify the resistance problem on a field-by-field basis through bioassays and detection of known genetic factors associated with insecticide resistance, recommend effective chemical insecticide rotations to mitigate resistance, explore biorational control options. Recent initiatives in Georgia have focused on potential sources of host plant resistance, while research in Florida has compared infestation levels and percentage parasitism among different cole crops. The presentation summarizes the most important research findings from the last several years.

### Keywords

Resistance monitoring, insecticide efficacy, host plant resistance, parasitoids

## How do *Bacillus thuringiensis* Biopesticides Reduce Flea Beetle Damage on Leafy Brassicas?

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**ABSTRACT**

Striped flea beetle, *Phyllotreta striolata* Fab. (Chrysomelidae: Coleoptera) is one of the most important pests of leafy brassicas in South- and Southeast Asia. The damage of this pest, especially in the early crop stages can lead to complete crop failure. Hence, the farmers rely on indiscriminate use of chemical pesticides to control this pest. However, control failures are reported due to the rapid development of resistance to chemical pesticides. In earlier studies in Cambodia assessing the effectiveness of bio-pesticides including *Bacillus thuringiensis* formulations, it was found that the *B. thuringiensis* treatments reduced the incidence and damage of *P. striolata*. Since *B. thuringiensis* formulations have primarily been used to manage the lepidopteran pests, their role in controlling *P. striolata* beetles needed further validation. An experiment was conducted in the laboratory condition at World Vegetable Center, Taiwan following a completely randomized design. Two commercially available biopesticide formulations based on *Bacillus thuringiensis*, E-911® *(B. thuringiensis* subsp. *kurstaki)* and Xentari® (*B. thuringiensis* subsp. *aizawai*) were used for assessment. There were six treatments: (i) pak-choi plants infested with diamondback moth (DBM), (ii) pak-choi plants infested with DBM and sprayed with Xentari®, (iii) pak-choi plants infested with DBM and sprayed with E-911®, (iv) pak-choi plants infested with DBM and sprayed with spinetoram, (v) pak-choi plants mechanically damaged, and (vi) pak-choi plants with no infestation. Five DBM (second instar) larvae were released on to each plant. After one hour, the bio- or chemical pesticides were sprayed in T2, T3, and T4 treatments and kept for 2 h. The treated plants were moved to the cages (75-cm X 75-cm X 115-cm) and kept for 72 h. Then, 60 *P. striolata* beetles were released into each treatment, which was replicated nine times. After five days, the data on the feeding damage (total number of the shot hole) by *P. striolata* was recorded. *P. striolata* damage was significantly less where DBM larvae were managed with *B. thuringiensis* biopesticides and the chemical pesticide, as compared to untreated control, mechanically damaged plant and the plant infested with DBM larvae ($F=10.39$, $P<0.0001$). The mean number of shot-holes per plant in the Xentari®, E-911®, and spinetoram treated plants was on par (276-348), compared to the untreated control, mechanically damaged plant and the plant infested with DBM larvae (491-561). Reduction of mechanical plant damage or the damage due to other phytophagous insects seems to reduce the production and release of glucosinolates-based hydrolyzed products

that act as attractants for the *P. striolata* beetles. Thus, application of bio-pesticides targeting caterpillar pests can also reduce the incidence and damage by *P. striolata* as a spill-over effect.

**Keywords**

Leafy brassicas, *Phyllotreta striolata*, biopesticides, glucosinolates, spillover effects

# Session 3: Insecticide Resistance and Management in Crucifer Pests: the on-going Challenge

## Bacterial Survey in the Gut of Philippine Population of the Diamondback Moth, *Plutella xylostella* L.

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## ABSTRACT

The insect gut microbiota has been implicated to function, among other distinctive roles, in the detoxification of plant defense, the provision of necessary vitamins and metabolites to the host, and the facilitation of insecticide resistance. Studies have shown that the gut microbiota also plays key roles in insecticide resistance of the diamondback moth (DBM), *Plutella xylostella*. Knowledge on DBM microbiota may therefore provide an important variable in the augmentation of available IPM strategies against this insect pest. In this study the gut microbial profiles of Philippine *P. xylostella* from Illumina MiSeq 16S rDNA-based amplicon metagenomic datasets were analyzed using QIIME 2. A transgenerational shift in the predominant taxa; from the genus *Sanguibacter* in the first generation to a combination of *Glutamicibacter*, *Enterobacteriaceae*, *Carnobacterium*, and *Serratia* in the fourth generation was noted, with possible association to insecticide resistance as determined *in silico*. Further functional exploration into this possibility is, however, warranted. The observed bacterial composition was further supported by a PCR-based detection method.

## Keywords

16S rRNA amplicon sequencing, QIIME2 analysis, DBM gut microbiota, insecticide resistance, metagenomics

## Mode of Resistance in Spinosad-resistant Diamondback Moth

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## ABSTRACT

Mounting evidences from previous studies showed that there is diverse mode of inheritance in resistant insects. Albeit within the same insect species, there are differences of inheritance mode that have been recorded. The present finding focused to investigate the mode of inheritance in spinosad-resistant diamondback moth (DBM). The DBM strain originated from an organic farm in Semenyih, Selangor, Malaysia was selected with spinosad until generation 15 (G15), producing spinosad-selected (Spi-Sel) strain. Study on mode of inheritance revealed an overlapping fiducial limit between F1 and F1' suggested there was no influence of maternal effect, thus, autosomal inheritance was concluded. The recessiveness of the resistance was represented by the value of degree of dominance ($D_{LC}$) of F1 and F1', -0.6062 and 0.0311 respectively. The $LC_{50}$ value and position of regression lines of both F1 and F1'on the log-dose mortality graph are closer to the susceptible parent further confirmed recessive inheritance of the resistance. Meanwhile, the effective dominance concluded that the resistance was completely dominant ($D_{ML}$ = 1) at the lowest spinosad concentration (18.75 ppm) and incompletely recessive ($D_{ML}$ = 0.31) at the highest concentration (300 ppm). No significant deviation (P>0.05) between the expected and observed mortality of the backcross (BC2) population implied monofactorial resistance. It is concluded that spinosad inheritance in this study was governed by a single autosomal factor that is incomplete recessively inherited, implying that the resistance took some times to develop, nevertheless, since it is monofactorial, it should not be underestimated as the effect can be more severe compared to polyfactorial-resistance-inherited effect and the resistance can reside longer and evolve faster in the real field.

## Keywords

Diamondback moth, resistance, spinosad, inheritance

# Analysis of Diamide Resistance in Field Population of Diamondback Moth *Plutella xylostella* and its Synergistic Mitigation

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## Abstract

Diamides, a new insecticide class, have been used globally for more than 15 years. The severe incidence of diamondback moth (DBM), *Plutella xylostella* L., on cabbage/cauliflower drew intensive applications of diamides in India. The field populations collected from cauliflower and cabbage in Tamil Nadu, India were tested for the resistance of two widely used diamides, *viz.,* flubendiamide and chlorantraniliprole. The insect mortality was assessed after 72 h of diamides treatment. All field populations exhibited high resistance with a maximum of 98.32 and 54.52 mg/L for flubendiamide and chlorantraniliprole, respectively, in the Krishnagiri population (KRI). The resistance folds to flubendiamide (121.38) and chlorantraniliprole (227.16) got multi-folded when matched against the reference susceptible population. The cause of diamide resistance was determined by assessing the activity of detoxifying enzymes and the presence of target site mutation at the ryanodine receptor (Ryr). Detoxifying enzyme analysis (MFO, GST, and CarE) in highly resistant DBM populations in response to sublethal diamide exposures revealed that GST was only over-expressed for up to 24 hours. The maximum of 5.84 and 5.74 µmol mg of protein$^{-1}$min$^{-1}$ were recorded with the most resistant KRI population after exposure to flubendiamide and chlorantraniliprole at 24 h after treatment. Further, the results of target site mutation indicate the G4946E point mutation, where the replacement of glycine with glutamic acid occurs in all the tested filed populations. The activity of five synergists (PBO, DEM, TPP, rosemary oil, and thyme oil) evaluated indicated that DEM had the highest synergistic activity of 5.15 and 2.30, respectively, to flubendiamide and chlorantraniliprole in the KRI population. Thus, the detoxifying enzymes, coupled with target site mutation is responsible for diamide resistance, could be managed by applying synergists and rotating insecticides with a different mode of action to prevent the development of resistance.

## Keywords

Diamondback moth, Diamides, Resistance, Detoxifying enzymes, Target site mutation, Synergists

# Response of Field Populations of *Plutella xylostella* and *Spodoptera litura* to Cyantraniliprole

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## Abstract

Cyantraniliprole, a newer insecticide under diamide, was introduced a decade ago and is widely used to manage several lepidopteran insect pests. Because of its fast mode of action and high efficiency in managing insect pests, it has been sustained in the hands of farmers, especially the cole crop producers. This study was conducted to analyze the status of cyantraniliprole in managing the two key pests of cole crops, such as *P. xylostella* and
*S. litura,* from various cole crop-growing regions of Tamil Nadu, India. All the seven field populations of *P. xylostella* collected from cabbage or cauliflower were found to express high median lethal concentration ($LC_{50}$) (19.81 - 5.20 µg/ml) to cyantraniliprole and thus express a high ratio of resistance (2828.57 - 742.86) implied that all the field populations were highly resistant. In the case of *S. litura*, the maximum and minimum $LC_{50}$ of 0.20 (RR=1.89) and 0.11 (RR=1.09) µg/ml were recorded, indicating the susceptibility of all the field populations. Further, the enzyme analysis revealed the overexpression of GST up to 24 hours after exposure and MFO up to 48 h after exposure to cyantraniliprole in *P. xylostella*. In contrast, detoxifying enzymes differed irrespective of the time of insecticide exposure in the case of *S. litura*, indicating that they have no role against cyantraniliprole. The synergist study indicated that DEM (Diethyl maleate) and PBO (Piperonyl butoxide) had the highest synergistic ratio of 5.17 and 2.87 in the tested population of *P. xylostella.* The target site mutation study in *P. xylostella* and *S. litura* revealed that a single point mutation (glycine to glutamic acid change) predicted earlier in diamide-resistant lepidopteran insects has occurred in the tested populations of *P. xylostella* but not in the populations of *S. litura.* Thus cyantraniliprole-resistant *P. xylostella* can be managed by applying synergists DEM and PBO along with the rotation of insecticides with a different mode of action, but this is not necessary for managing *S. litura.*

## Keywords

Diamondback moth, Cyantraniliprole, Resistance, Detoxifying enzymes, Target site mutation, Synergists

# Managing Diamondback Moth Resistance to Insecticides in Fiji: A Flexible Insecticide Resistance Management (IRM) Strategy and the Importance of Community Engagement

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## ABSTRACT
In Fiji, management of the diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutellidae), has been constrained by resistance to broad-spectrum insecticides and access to selective products. Since 2013, the susceptibility of DBM field populations to a range of insecticides has been monitored and new selective products have been sequentially introduced and incorporated into an insecticide resistance management (IRM) strategy. The strategy is based on the "window" principle promoted by the Insecticide Resistance Action Committee (IRAC). It relies on the limited use of insecticides with different modes of action in discrete temporal windows that equate to the duration of the life cycle of the pest (≈18 days in Fiji) to minimize exposure of successive generations to similarly acting insecticides. Constrained by the insecticides available to farmers, the original strategy, developed in 2014, included indoxacarb, lufenuron, abamectin, AgChem-Bt (aizawai) and chlorantraniliprole. The strategy, which was initially supported by community meetings to engage farmers, worked well through to 2017 and the susceptibility of field populations to the recommended insecticides remained high. In 2018 of high levels of DBM field resistance to indoxacarb, chlorantraniliprole and deltamethrin were detected, indicating that the IRM strategy was either no longer effective or not being adopted. Efforts to increase the range of selective insecticides available were increased and AgChem Bt (kurstaki) and spinosad were introduced to the market in collaboration with a local pesticide reseller. The IRM strategy was revised to include these new products and it was promoted in farming communities by information sessions. Between 2019 and 2022 resistance of DBM field populations to the original recommended selective products declined and susceptibility to spinosad and both AgChem Bt products remined high. The importance of continued community engagement for successful IRM and IPM adoption and sustainable insecticide use will be discussed.

## Keywords
Bt, abamectin, chlorantraniliprole, spinosad, selective insecticides, insecticide resistance management

# Session 4: Biological and Non-Chemical Methods of Management of Crucifer Pests (Including Organic Agriculture)

## Chitosan and their Derivatives: Potential Applications in *Plutella xylostella* L. Management

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### Abstract

Diamondback moth *Plutella xylostella* L. is an invasive and economically important pest of crucifers. Chitosan from crustaceans is a versatile and promising biopolymer with the potential for plant protection application. This study aimed to synthesize eco-friendly bioproducts from crude chitosan and study its insecticidal and antifeedant effect against *P. xylostella.* Chitosan, a putative dsRNA carrier, showed improved pest management effectiveness upon synthesis. Chitosan loaded with neem seed extract as nanocapsules proved an effective insecticide delivery agent. The colloidal chitosan synthesized from crude chitosan flakes showed improvements in its properties *viz.,* Solubility (36.2 to 87 %), Degree of Deacetylation (56 to 85.3 %), Water Binding Capacity (0.64 to 6.24$gg^{-1}$), Fat Binding Capacity (0.47 to 5.76 $gg^{-1}$), Viscosity (92 to 452 cP), Moisture (0.43 to 0.24 %), Nitrogen (5.24 to 2.79 %), Protein content (32.75 to 17.43 g/kg), Ash (1.87 to 0.66 % ), Antioxidant activity ( 0.31 to 1.64 %), Whiteness index (41.49 to 64.68 %) and Bulk density (0.52 to 0.24 g/ml). The chitosan and colloidal chitosan were characterized by Fourier-transform infrared (FTIR) spectroscopy to identify the presence of reactive functional groups. The synthesized colloidal chitosan was evaluated for its toxicity and antifeedant effect against second instar larvae of *Plutella xylostella* by leaf dip method with different concentrations, *viz*., 3000, 6000, 8000, and 10000 ppm, in comparison to solvent alone (Glacial Acetic acid 1%), adjuvant alone (Tween 80 0.05 %), standard check (Azadirachtin 1 EC @ 2 ml/lit), and untreated check, each treatment replicated thrice. It was found that colloidal chitosan at 10000 ppm had caused the highest mortality (76.60 %)

and antifeedant activity (92.77 %) after 72 hours of treatment. The $LC_{50}$ and $LT_{50}$ values were 8609.81 ppm and 45.70 h, respectively. It is concluded that the role of colloidal chitosan in pest management needs further exploration.

**Keywords**

*Plutella xylostella,* Colloidal Chitosan, Standardization, Characterization, Toxicity, Antifeedant

# Neem Biopesticide Proves to Be a Cost-Effective and Potent Option Against Diamondback Moth *Plutella xylostella* L. (Lepidoptera: Plutellidae) and the Cabbage Webworm *Hellula undalis* F. (Lepidoptera: Crambidae) Compared to Conventional Pesticides

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## ABSTRACT

Cabbage is an important cash crop to the resource-poor farmers in sub-Saharan Africa and offers a good source of vitamins and minerals. The diamondback moth (DBM), *Plutella xylostella* L. and the cabbage webworm, *Hellula undalis* F. are major pests causing significant losses to brassica crops worldwide. At the University of Ghana, an experiment was undertaken during the major and minor seasons of 2015 to establish the effect of some pesticides (synthetic insecticides-chlorpyrifos and lambda-cyhalothrin, botanicals - hot pepper fruit extract, aqueous neem seed extract, local insecticidal soap - 'alata samina' and water as control) in managing diamondback moth and *H. undalis* populations on cabbage. The results revealed that the highest population of diamondback moth was recorded in the insecticides sprayed plots, with neem recording the least number of diamondback moth and cabbage webworm. The highest marketable yield was recorded for the neem sprayed plots, followed by alata samina and pepper extract for both seasons. The current finding has revealed aqueous neem seed extract as the most cost-effective option for managing diamondback moth/webworm and other pest on cabbage.

## Keywords

Food safety, *Plutella xylostella, Hellula undalis*, neem seed extract, cost benefit analysis

# Biological Control of Diamondback Moth—Increased Efficacy with Mixtures of *Beauveria* Fungi

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## ABSTRACT

Brassica vegetables are one of the world's most-consumed crops due to their health benefits and economic importance for small-scale producers. The production of brassica crops is vulnerable to damage by many invertebrate pests, which cause yield and financial losses. Diamondback moth (DBM) is an important horticultural pest worldwide, which causes a financial loss between $4-5 billion and leads farmers to spray broad-spectrum insecticides across the globe. These practices bring about many consequences including environmental damage, public health, biodiversity degradation, and pest resistance. As DBM has developed resistance to more than 100 classes of synthetic insecticides, new biological control options are urgently required. *Beauveria* species are entomopathogenic fungi recognized as the most important fungal genus for controlling a wide range of agricultural, forestry, and veterinary arthropod pests. Previous research, aimed at developing new *Beauveria*-based biopesticides for DBM, has focused on screening single isolates of *Beauveria bassiana*. However, these fungal isolates have individual requirements, which may limit their effectiveness in some environments. This current study separately assessed 14 *Beauveria* isolates, from a range of habitats and aligned to four different species (*Beauveria bassiana, B. caledonica, B. malawiensis,* and *B. pseudobassiana*), to determine the most effective isolate for the control of DBM. Further assays then assessed whether selected combinations of these fungal isolates could increase the overall efficacy against DBM. Six *Beauveria* isolates (three *B. bassiana* and three *B. pseudobassiana*) achieved high DBM mortality at a low application rate with the first documented report of *B. pseudobassiana* able to kill 100% of DBM larvae. Further research determined that applications of low-virulent *Beauveria* isolates improved the control of DBM compared to mixtures containing high-virulent isolates. This novel approach increased the DBM pest mortality and shortened the time to kill.

## Keywords

Biopesticide; biocontrol combinations; medium lethal concentration ($LC_{50}$); medium lethal time ($LT_{50}$); virulence

## Modified Chitosan as a Bioactive Principle in Diamondback Moth Management

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### Abstract
Diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is a global insect pest of cruciferous crops, leading to a decline in cruciferous productivity and quality. Chitosan O Arginine (CS O Arg) was synthesized from chitosan, a naturally occurring biopolymer, and tested for its efficacy against *P. xylostella* for its insecticidal effects, anti-nutritional and growth-inhibiting potential. It was tested at different concentrations with Tween 80 0.05% as an adjuvant and Azadirachtin 1 EC @ 2 ml/lit as a standard check, compared with untreated check, in three replicates. The larval mortality, leaf quantity consumed, the weight of larva and feces, developmental period, adult emergence, etc., were recorded. CS O Arg 1000 ppm caused the highest larval mortality (100%) after the fourth day. Weight gain of treated life stages was the lowest at 500 ppm (0.76 mg larva, 1.00 mg pupa, 1.05 mg adult) with malformations in the surviving larva (13.33%), pupa (6.66%) and adult (10.00%). At 100 ppm, the larval period was prolonged by two days (13.66 days). The CS O Arg 1000 ppm significantly affected the consumption index (2.01%) with a lower consumption rate of 0.19% and approximate digestibility of 8.44%, compared to untreated check (14.95%, 7.77%, and 79.41%, respectively). It also affected the relative growth rate (0.00%), the efficiency of conversion of ingested food, and the efficiency of conversion of digested food. A significant decline in the activity of digestive enzymes, viz. chitinase, invertase, amylase, protease, and trypsin, was recorded. The histological studies of CS O Arg on the larval midgut showed characteristic elongation, disorganization, and thickening of cells, the disintegration of the epithelial cells, and lesions in the epithelial cell lining of the midgut. This study is the first to document the insecticidal effects of the CS O Arg as a bioinsecticide interacting in the midgut of *P. xylostella* larvae.

### Keywords
Chitosan O Arginine, Diamondback moth, nutritional parameters, growth and development, Histology.

# Developing Vegetable Hummingbird Formulation to Manage Diamondback Moth, *Plutella xylostella* (Linnaeus) Infesting Crucifers

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## Abstract
Diamondback moth (DBM), *Plutella xylostella* L. (Plutellidae: Lepidoptera), is the most nefarious and oligophagous pest of cruciferous vegetables, which has resisted all registered insecticides available in the market and also may potentially resist future molecules. The marketable yield loss of 50 to 80% was recorded due to *P. xylostella*. The inexhaustible source of environmentally safe bioactive compounds is an alternative to harmful pesticides. The *S. grandiflora* methanolic extract (5%) displayed excellent growth inhibition activity against DBM, showing minimum larval weight gain (0.47 mg) and maximum total larval mortality with LC50, and LT50 of 2.23% and 37.76 hours, respectively. Phytochemical analysis of the extract by GCMS revealed the greatest concentration of n-hexadecanoic/ palmitic acid (21.22%), and the same was recorded in fraction 8c of the 36 fractions obtained in the Flash Extraction Chromatography study of purified extract. Fraction 8 recorded the highest antifeedant index, hence, *S. grandiflora* 40 SL was formulated by mixing the active ingredient (40%), DMSO (50%), and Nonyl Phenyl Ethoxylate (10%) using a magnetic stirrer, ultrasonicator, and homogenizer. It had succeeded in tests, *viz.,* cold, heat, and standard hard water stability tests, revealing no separation, including creaming at the top and sedimentation at the bottom. The pH, particle size, and zeta potential of *S. grandiflora* 40 SL were measured as 6.24, 276.5 nm, and 43.8 mV, respectively. In laboratory bioassay, *S. grandiflora* 40 SL formulation (3%) showed high mortality (83.33%), antifeedant index (90.47%), oviposition deterrence (100%), and ovicidal effect (66.67%) with the $LC_{50}$ and $LT_{50}$ reported as 1.23% and 33.14 hours, respectively.

## Keywords
*Plutella xylostella*, *Sesbania grandiflora*, $LC_{50}$, GCMS, and Flash Extraction Chromatography

## Promoting natural enemy activity in brassica crops: multi-scalar effects

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**ABSTRACT**

Conservation biological control of crop pests has relied primarily on in-field manipulations such as flower strips or groundcovers, but larger scale effects are also important. The significance of field-adjacent land use is likely to be especially important as donor habitat for natural enemies or pests but knowledge of such effects is patchy. To develop more comprehensive understanding of these and related effects and formulate evidence-based recommendations, we surveyed brassica crop fields spread across Australia to assess the effect of adjacent land-use types, as well as wider landscape properties, on the abundance of pest and beneficial arthropods. Riparian vegetation significantly increased overall numbers of beneficial arthropods in the adjacent areas of crops compared with the densities in the crop centre. Similarly, roadways reduced overall number of pests and increased numbers of multiple beneficial taxa in adjacent areas of crops, reflective of the frequent presence of woody vegetation in these linear habitats. For the wider landscape, the presence of woodland promoted in-crop abundance of aphids and influenced the beneficial impact of in-crop habitat manipulation using flowering plant strips. Interactions among these multi-scalar effects warrant further research to guide growers on which crops are most at risk of pest attack and potential interventions to promote biological control.

**Keywords**

Diamondback moth, biological control, pest management, habitat manipulation, landscape.

# Impacts of Increasing Global Temperatures on *Diadegma semiclausum*, an Important Parasitoid of the Diamondback Moth

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## ABSTRACT

The parasitoid *Diadegma semiclausum* has been widely adopted as a biological control agent for diamondback moth over the last 80 years. Understanding the thermal dynamics of this host-parasitoid interaction is crucial to predicting how the utility of *D. semiclausum* might be affected by geographic locations and climate change. We compared performance traits of the host and this solitary endo-larval parasitoid, over a range (10-30°C) of constant rearing temperatures. Parasitoids reared at 30°C experienced reductions in pupation rate, pupal mass, egg load and adult life span when compared with those reared at lower temperatures. Our analyses of the fate of parasitized hosts indicated that the causes leading to the failure of parasitoids to complete development were different at different temperatures. The intergenerational population growth of the unparasitized host and the parasitoid demonstrated clear divergent population outcomes under different temperature conditions. Based on the experimental data, the modelling package CLIMEX was used to investigate the suitability of current climates for the host and the parasitoid and the effects on their potential global geographical distributions. The study was then extended to investigate possible changes to these distributions that might result under different climate change scenarios that can be anticipated by 2080. The models predict that the global distributions of both the host and parasitoid will be reduced. These changes will not be proportionate and many areas in tropical, sub-tropical and temperate regions that are currently suitable for the parasitoid are predicted to be no longer suitable, while retaining suitability for diamondback moth. The seasonal dynamics of both the host and parasitoid are also predicted to be significantly reshaped under climate change. The present study demonstrates the constraints on the efficacy of *D. semiclausum* for controlling diamondback moth under likely future climates.

## Keywords

Host-parasitoid interaction, CLIMEX, Global warming, biological control

## Potential of Entomopathogenic Nematodes and Biopesticides Against Flea Beetles (*Phyllotreta striolata* and *P. chotanica*) on Choy Sum in Hot, Wet and Dry Seasons in Thailand

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### ABSTRACT

Flea beetles (*Phyllotreta striolata* and *P. chotanica*) cause serious damage on brassica crops and lead to dramatic yield losses. Flea beetle population are increasing continuously due to year-round production of brassica crops in Southeast Asia, especially short-cycle leafy brassicas such as choy sum (*Brassica rapa* and *B. chinensis*). Since insecticides are not very effective to manage the flea beetles, we evaluated the alternatives such as entomopathogenic nematodes (EPN) [*Steinernema siamkayai* and *Steinernema carpocapsae*], biopesticides (neem extract, *Beauveria bassiana*, *Metarhizium anisopliae,* and a combination of *Beauveria* plus *Metarhizium*) and insecticides (carbaryl, abamectin, fipronil and tolfenpyrad) on choy sum under the controlled and field conditions. Under controlled condition, susceptibility of the third instar larvae and adults of flea beetles were assessed. The bioassay was conducted using half of the recommended dose, the recommend dose and twice of the recommend dose of the EPNs, bio-pesticides and chemical pesticides in comparison with an untreated control. The results revealed that increased concentration of EPNs and bio-pesticides caused higher larval mortality. The highest mortality of 63% and 50% was obtained with the twice the recommended dose of *S. carpocapsae* and *Beauveria* plus *Metarhizium*, respectively, which were on par with Fipronil (80%). Likewise, *S. carpocapsae* also caused 60% adult mortality at 6 days after treatment similar to Fipronil (100%) at twice the recommend dose at 3 days after treatment. Field trials were conducted at World Vegetable Center, Nakhon Pathom, Thailand during hot, wet and dry seasons (April-December) of 2021. The biopesticides and insecticides were applied individually in a sequence at weekly intervals. The study found that biopesticides reduced feeding damages of flea beetles (2.72 damaged holes/ 4 $cm^2$ and performed equally as insecticides (2.89 damaged holes/ 4 $cm^2$) in wet season while the leaf damage did not differ significantly among the treatments in hot and dry seasons The marketable yield did not differ significantly among the treatments in all the seasons. Of the total harvest, the proportion of marketable

yields of EPN (*S. siamkayai*), biopesticides and insecticide treated plots was 55-84%, 53-61%, 46-49% in hot, wet and dry seasons, respectively. Whereas it was 67%, 46% and 52% in the untreated control plots. Our study revealed that combining EPNs and entomopathogenic fungi (EPF) can be effective alternative for flea beetle management.

**Keywords**

*Phyllotreta* spp., Biopesticides, Entomopathogenic nematodes, *Steinernema siamkayai*, *Steinernema carpocapsae*

# Biological Control of Diamondback Moth and other Crucifer Insect Pests by Microbial Entomopathogenic Fungi

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## ABSTRACT

Among the vegetables, Crucifers are important winter crop consist of cabbage, cauliflower, mustard, broccoli, radish etc. Major insect pests of crucifers are *Pieris brassicae* L. (Lepidoptera: Pieridae), *Plutella xylostella* L. (Lepidoptera: Plutellidae), *Brevicoryne brassicae* L. (Hemiptera: Aphididae) and *Trichoplusia ni. Hübner* (Lepidoptera: Noctuidae). Among them diamondback moth (DBM), *Plutella xylostella* (L.) is a noxious pest of cruciferous crops all over the world causing up to 80% crop losses globally. In certain parts of the world, economical production of crucifers has become almost impossible due to insecticidal control failures. It was the first crop insect reported to be resistant to DDT and now, in many crucifer producing regions, it has shown significant resistance to almost every synthetic insecticide applied in the field. Management of insect pest generally depends on chemical control. As DBM has developed resistance to more than 100 classes of synthetic insecticides, therefore, exploration of eco-friendly management strategies to cope with resistant DBM population is inevitable. Alternatively, entomopathogenic fungi (EPF), like *Beauveria bassiana* (Balsamo-Crivelli), Vuillemin (Ascomycota: Hypocreales), *Metarhizium anisopliae* (Metschn.), Sorokin (Hypocreales: Clavicipitaceae), *Isaria fumosorosea* Wize (Hypocreales: Cordyciptaceae), *Verticillium lecanii* (Zimm.) (Deuteromycotina: Hyphomycetes), and *Nomuraea rileyi* (Farl.), have been found to be promising tools for controlling several agricultural insect pests. The most efficient and well-studied EPF are the soil-borne fungi mainly *B. bassiana* and *M. anisopliae* that have a wide range of insect hosts. These two fungi are compatible with each other and showed significant results against lepidopteran insect pests. During the last century, about 750 species of EPF were reported to infect insects or mites. EPF are generally characterized by having a wide range of hosts which made them the perfect candidate for biological control missions. They are existing in abundance in the environment and involved in plenty of environmental interactions. They have prestigious enzymatic machinery and toxins that contribute as killing tools. Moreover, after penetrating the insect, the expanded vegetative growth of hyphal bodies enabling the invasion of the fungi throughout the entire tissues of host insect cause physic, histolytic, and pathologic changes ultimately leading to the death of the host insect.

## Keywords

Biocontrol; Microbial; Biopesticides; *Plutella xylostella*

# Current Approaches in Exploiting Biocontrol Potential of Endophytic *Beauveria bassiana* against Diamondback Moth in Crucifer Crops

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## ABSTRACT

Worldwide, production of Crucifer vegetables is estimated to contribute US$26 billion to the global economy. Crucifer crops are exposed to numerous insect pests that decrease productivity. The diamondback moth (DBM), *Plutella xylostella* is a prominent pest of crucifer crops which is well known for reducing global crop yield by an extent estimated of 30 to 50% annually. Control of diamondback moth is achieved mostly through the use of broad-spectrum synthetic insecticides. Field populations of *P. xylostella* now have shown resistant to most recommended insecticides across the world. The cost of DBM control combined with crop yield losses can reach US$2.7 billion annually. Despite years of research, the range of available products used in biological control of diamondback moth is still limited. The entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin has been used for many years as environmental safety biological control agents by traditional methods to protect a great variety of crops against pest insects, but in the direct use, its propagules are exposed to the harmful UV radiation, fluctuating humidity, and temperature, reducing its effectiveness. Therefore, endophytic establishment in the plant provides an acceptable approach for avoiding the problem in field application and opens up new horizons for biological pest control. Several studies have demonstrated the plant-mediated effects of endophytic colonization by *B. bassiana* with capacity to limit the development of pests and diseases, contributing to the reduction of chemical inputs use in several crops. In recent investigations, *B. bassiana* has been reported to be endophytically colonizes crucifer crops and may be an alternative to chemical pest control. This paper is intended to highlight the current approaches and nuances in strain selection, mass production technology, formulation development, delivery methods, thereby paving the way towards more effective use of *B. bassiana* in biological control of diamondback moth and other crucifer insect pests.

## Keywords

Entophytic *Beauveria bassiana,* diamondback moth, biological control, crucifer crops.

## Production Breaks, Cropping Patterns and Biological Control: Towards a Better Management System for Diamondback Moth, *Plutella xylostella*

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## ABSTRACT

*Plutella xylostella* (L.) (Lepidoptera: Plutellidae), the diamondback moth (DBM), is the most destructive and costly pest of *Brassica* vegetable and oilseed crops worldwide. With widespread, large-scale application of chemical insecticides to vegetable crops, the pest status of DBM appears to have increased as the species has evolved resistance to every class of insecticide used against it. Yet DBM has been successfully managed in many regions by classical biological control, most notably with the introduction of a hymenopteran parasitoids including the larval-pupal parasitoid, *Diadegma semiclausum* (Hellén). Here we use a DYMEX meta-population model with four demes, each equivalent to a cropping cycle, to investigate the interaction of cropping pattern (with and without a seasonal production break), different intensities of harvest and days to replanting or residue hygiene, variable spray thresholds for spray decision making, with and without biological control and if present, with added parasitoids. Unsurprisingly, the response surface of DBM pest pressure and sprays is complex but there are some clear conclusions. Production breaks greatly reduce pest pressure, and additional biological control can greatly reduce the required number of insecticide sprays. We discuss the difficulties of implementing such management tactics.

## Keywords

Real IPM, Cropping pattern, demes, modelling, parasitoids

# Enhancing Virulence of *Beauveria bassiana* against Diamondback Moth, *Plutella xylostella*

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## ABSTRACT

The diamondback moth *Plutella xylostella* is a significant pest of crucifers globally. Entomopathogenic fungi (EPF), *Beauveria bassiana* is nowadays recommended as an alternative to conventional pesticides to manage this serious pest due to self-propagation and ecofriendly nature. The present study aimed to enhance the virulence of three strains of *B. bassiana* by supplementing the Potato Dextrose Broth media with chitin, chitosan, and yeast. The results showed that the addition of yeast improved the performance of all three strains of *B. bassiana* TM (MH590235), BR (MK918495) and BbI8 (KX263275). Among the strains, TM performed the best, with yeast supplementation leading to a significant increase in biomass (3.33 g) and spore production (10.84 x $10^9$ spores $ml^{-1}$) compared to the control (1.57 g and 0.89 x $10^9$ spores $ml^{-1}$, respectively). Addition of yeast and chitosan to the media resulted in 100% mortality of *P. xylostella* larvae within five days of treatment with TM strain of *B. bassiana*. The study revealed that supplementing the media with chitosan and yeast enhanced the virulence of *B. bassiana* against *P. xylostella* larvae. The study highlights the potential of *B. bassiana* as an alternative to conventional pesticides in managing diamondback moth. Management of *P. xylostella* with *B. bassiana* could help in reducing the reliance on conventional pesticides and mitigate their harmful effects on the environment.

## Keywords

*Plutella xylostella, Beauveria bassiana*, chitin, chitosan, yeast

# Lethality of Eco-friendly Farm Prepared Natural Formulations Against Eggs and Larvae of *Plutella xylostella* (Linnaeus)

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**ABSTRACT**

Four natural plant protection formulations (*Agniastra*, *Brahmastra, Darekastra* and *Dashparni*) were prepared from locally available herbs like neem (*Azadirachta indica*), darek (*Melia azedarach*), wild marigold (*Tagetes sp.*) custard apple, castor, papaya, guava, wild datura (*Datura* sp.), *Ipomea, Polygonum, Eupatorium* etc. along with green chillies, garlic bulbs, ginger rhizomes, asfoetida, urine and dung of indigenous breeds of cow. These formulations were evaluated at different concentrations for lethal activity against diamondback moth, *Plutella xylostella* (Linnaeus) under laboratory conditions. Besides eggs, 2nd, 3rd and 4th instar larvae of *P. xylostella* were exposed to five concentrations (5, 10, 20, 40 and 80%) of these formulations. Simultaneously, exposure of test stages to water served as check. The results revealed that these formulations were moderately lethal to eggs and larvae of *P. xylostella*. However, more mortality occurred at higher concentrations and longer periods after exposures. The egg hatchability got reduced by 24.0 – 50.0, 16.0 – 57.69, 15.0 – 53.85 and 16.0 – 42.31 per cent over check after exposure to *Agniastra, Brahmastra, Darekastra* and *Dashparni* at different concentrations, respectively. Similarly, the mortalities of 2nd, 3rd and 4th instars varied from 6.67 – 44.44, 8.89 – 44.44, 7.78 – 38.89in *Agniastra* and from 7.78 – 51.11, 7.78 – 40.0, 7.78 – 41.11in *Brahmastra* treatment. Likewise, *Darekastra* and *Dashparni* caused 11.11 – 51.11, 12.22 – 46.67, 14.44 – 47.78 and 3.33 – 43.33, 6.67 – 37.80, 5.56 – 36.67 per cent mortalities of 2nd, 3rd and 4th instars, respectively. On the other hand, mortalities of 2nd, 3rd and 4th instars in check varied between 0.0 – 2.22, 1.11 – 2.22 and 1.11 – 3.33 per cent at all concentrations, respectively.

## Keywords

*Agniastra, Brahmastra, Darekastra, Dashparni,* DBM mortality

## Acknowledgement

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## Effects of Agro-Ecological Approaches on Diamondback Moth (DBM) And Other Key Insect Pests of Collards in The Highlands of Kenya

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**Abstract**

Diamondback moth is the most important insect pest of collards, one of the most important leafy vegetables in Kenya. The pest has been known to cause total yield losses during dry spells. The crop is mainly produced in the highlands where rampant use of inorganic chemicals has been recorded. To reduce the negative impacts of the excessive usage of synthetic chemicals on human, environment and soil health, selected agroecological approaches were piloted on collards in Murang'a sub-county, Kenya during 2021-2022. The research was done in a farmer participatory approach where selected agroecological practices were compared with farmers' conventional practices, which is primarily the calendar-based application of synthetic pesticides. These two treatments were compared on side-by-side plots measuring 6-m X 12-m. The trials were carried out over two seasons (dry and rainy) in the lower and higher production zones in the highlands. A generalized pest damage scale (for DBM and other defoliators, cutworms, aphids, whiteflies, and thrips) was developed and used to collect comparative data on pests' infestation (prevalence and incidence)

fortnightly for a period of twelve weeks from the two treatments. Effect of the pests on quantity and quality of harvests was also evaluated. Results for the dry season showed that agroecological practices reduced the pest infestations significantly compared to the farmers' practice plots ($p<0.0001$). The marketable yield from the agroecological plot was higher than that of farmers' practice plot but there was no significant difference in the unmarketable yield. During the rainy season, the higher zone agroecological plot had lower pest infestation than the farmers' practice plot ($p=0.0395$) but there were no significant differences on the marketable ($p=0.1218$) and unmarketable yield ($p=1.000$) between the two treatments. In the lower zone, there were no significant differences on pest incidence ($p=0.1902$) and quantity of unmarketable yield ($p=0.165$) between the treatments. The marketable yield was however higher in the agroecological plot than in farmers' practices plot ($p<0.0001$). Further trials are being done to confirm if there are any clear patterns on pests' infestations due to the production practices, seasonality, and production zone on collards.

**Key words**

Collards, insect pests, agroecology

## The Effectiveness of Two Subspecies of *Bacillus thuringiensis* Collected from Taiwan against *Plutella xylostella* (Linnaeus)

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**ABSTRACT**
*Bacillus thuringiensis* (BT) is a well-known bio-insecticide that has been used for over 50 years to control caterpillars on cruciferous vegetables worldwide, including *Plutella xylostella* (Linnaeus) (diamondback moth, DBM), and noctuid moths. BT is a spore-forming bacterium naturally found in soil and on plant leaves, providing a good choice for eco-friendly agriculture. Two local *B. thuringiensis* subspecies were collected by the Taiwan Agriculture Chemical and Toxic Substance Research Institute (TACTRI) from barns and *Semecarpus longifolius* Blume leaves in Taiwan. One is *B. thuringiensis* subsp. *kurstaki* E-911 from a barn in Taiwan, and the other is *B. thuringiensis* subsp. *aizawai* Ab12 from a plant leaf. Both subspecies were separately transferred through technology to Fwusow Industry of Taiwan in 2005 and 2014 for commercialization and sale. The strains E-911 and Ab12 have been registered in Taiwan in 2011 and 2023, respectively. The commercialized products of *B. thuringiensis* subsp. *kurstaki* strain E-911 and *B. thuringiensis* subsp. *aizawai* strain Ab12 are 60% wettable powder. We used E-911 and Ab12 with artificial diet to feed second-instar DBM. After 72 hours, the mortality of DBM was 96.7% for strain E-911 at 30 ppm and for strain Ab12 at 60 ppm. In the field trial result, 60% wettable powder formulation of strain E-911 and strain Ab12 was recommended to be sprayed twice and three times on fields with DBM infestations. And then, the treatment group with the E-911 and Ab12 powder diluted 1000 times had a 65.6-89.9% and 53.4-58.7% control rate. In Taiwan, most strains of BT come from abroad. The commercial products of E-911 and Ab12 are both new localized BT products in Taiwan. It also provides Taiwanese farmers with more options for effectively controlling the diamondback moth.

**Keywords**
diamondback moth (DBM), *Plutella xylostella*, B*acillus thuringiensis*, E-911, Ab12, Taiwan

# Validation of Bio-pesticides for the Pests of Kale (Brassica *oleracea var acephala*) in Ethiopia

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## ABSTRACT

Kale (Aka Sukumawiki) is the major vegetable crop in terms of production and consumption in Ethiopia. However, its production is known to be affected by a lack of improved cultivars and pests such as cutworms, aphids, and diamondback moths (DBM). Furthermore, it suffers from the injudicious use of chemical pesticides. This study aimed to evaluate the effectiveness of different biopesticides on insect pests of kale including diamondback moth. In the 2021/22 rainy season, an on-station trial comprising five biopesticide treatments, one untreated control, and one chemical control was conducted. Treatments were arranged using a randomized complete block design and spraying was done every seven days from the date of transplanting to the fourth harvest. Data on yield, agronomic parameters, and pest incidence/severity were collected and analyzed. The analysis of variance revealed a significant difference ($p<0.05$) in marketable and total yield but not in unmarketable yield. The highest (70.38 t/ha) and the lowest (48.17 t/ha) marketable yields were obtained from the *Trichoderma + Metarhizium anisopliae* and *Trichoderma + Neem extract* treatments respectively. Regarding pests, there was no difference between treatments for African ball worm, diamondback moth, and flea beetles but significant differences were observed for aphid and leaf miners. Although the result is from a one-season and location experiment, as the first of its kind in the country, it sheds light on the prospects of bio-pesticides for the control of destructive pests of vegetables in a human and environmentally friendly manner.

## Keywords

Kale, biopesticide, pesticides

# Evaluation of Biopesticides for Kale (*Brassica oleracea*) in Kenya

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## ABSTRACT

Kale production is limited by insect pests that cause yield losses and reduce quality of produce. The indiscriminate use of synthetic pesticides to control these pests has been associated with increased pest resistance, and human and environmental health concerns. Biopesticides offer a natural, safe and effective alternative in controlling insect pests. Therefore, this study sought to evaluate the efficacy of commercially available biopesticides for controlling insect pests in kale, African nightshade and amaranth. Five biopesticide treatments (*Bacillus thuringiensis*, *Metarhizium anisopliae*, *Beauveria bassiana*, azadirachtin 0.03%), one synthetic pesticide treatment (Lambda cyhalothrin) and Control (no treatment) were applied to each crop. Each treatment had three replicates in a randomized complete block design. Treatment plots measured 2 m x 2 m with 1 m separating them. The pesticides were applied two weeks after transplanting and application continued at weekly intervals for 8 weeks. Weekly data on aphids and whiteflies incidence and leaf area damage caused by diamond back moth was collected over the same period and analyzed using analysis of variance and post hoc Tukey test. All pesticide treatments showed no significant difference in aphid and whitefly population. Leaf area damage was also similar in all treatments. The findings indicate that biopesticide are effective enough in controlling insect pests in TAVs.

## Keywords

Biopesticides, synthetic pesticide, insect pests

# Impact of cultural seasons, Biological and Chemical fertilizers on Major Pests of Cabbage (*Brassica Oleracea* L.), theirs Natural Enemies and yields In Dschang, West Region of Cameroon

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## ABSTRACT

A study on the impact of probiotics, Light Matrix Organic (LMO) and poultry manure (P) on cabbage (*Brassica oleracea* L.) pest was conducted during the dry and the rainy season in Dschang subdivision to ameliorate cabbage productivity. The complete randomized block design with three replications and one variety *Green Coronet* was used. The bio fertilizers treatments were, LMO1 (1L/ha), LMO2 (1.5L/ha), LMO1+P, LMO2+P, poultry manure (P) applied at 10 t/ha. This was compared to chemical fertilizer (positive control) NPK 20-10-10 (300kg/ha) and a control (no fertilizer). Direct counting of aphids, diamondback moth, snail and natural enemies started fourteen Days After Transplantation (DAT) and continued once a week till harvest. The results obtained showed that *Brevicoryne brassicae, Lipaphis pseudobrassicae, Plutella xylostella and Helix aspersa* were pests while *Hogna lenta* and *Lasius niger* were natural enemies. The infestation peaks of *Brevicoryne brassicae* ranged from 42DAT to 49DAT and 42DAT for *L. pseudobrassicae,* 28DAT to 35DAT for *P. xylostella*. *H. lenta* has irregular peaks. Pests were more abundant in the dry season than rainy season. Natural enemies were more observed in the rainy season (snail) and dry season (ants). Treatments in both seasons were not significantly different (P=0.05) in terms of pest abundance, but yields were different. The best yields were recorded in the rainy season with P and LMO1+P compared to the dry season with LMO1+P and LMO2+P. From these results, the combination of LMO and poultry manure during the two seasons can therefore be recommended to farmers to improve cabbage productivity.

## Keywords

Probiotics, Poultry manure, planting date, cabbage pests, Natural enemies.

## The Plasticity of Learning in The Specialist Diamondback Moth Parasitoid, *Diadegma semiclausum* (Hellén)

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## ABSTRACT

In insects, different learning experiences lead to different forms of memory formation. We investigated behavioral changes in the diamondback moth (DBM) parasitoid *Diadegma semiclausum* (Hellén), in response to different learning experiences. Naïve female *D. semiclausum* demonstrated innate preference for the herbivore induced plant volatiles (HIPVs) produced by DBM-induced Chinese cabbage plants over those produced by DBM-induced common cabbage plants, but this was overridden by associative learning if parasitoids previously parasitized hosts on common cabbage plants. Examination of memory formation in *D. semiclausum* under different "conditioned stimulus" regimes showed that single oviposition and massed oviposition events resulted in memory retention ≤12 hours, while time-spaced conditioning resulted in memory retention ≤24 hours. Responses to learned HIPVs waned after 24h, suggesting that long-term memory was not consolidated under any learning regime. Naïve *D. semiclausum* didn't discriminate between HIPVs produced by *Myzus persicae*-induced and DBM-induced common cabbage plants, but experienced parasitoids were more attracted to HIPVs from DBM-induced plants. Naïve and experienced parasitoids were more attracted to plants induced by DBM alone than to plants induced by both herbivores. Parasitoids experienced by attacking DBM larvae on co-infested plants discriminated between the HIPVs that they experienced from the HIPVs emitted by plants induced by *M. persicae* alone. This suggests that experiencing DBM-host-associated HIPVs is crucial for effective associative learning by *D. semiclausum*. Feeding by DBM and *M. persicae* induced expression of jasmonic acid and salicylic acid pathway marker genes in plants, but dual infestation didn't significantly enhance gene expression related to either pathway, suggesting that pathway crosstalk affects gene expression, and hence the HIPV profiles of dually infested plants. Such subtle differences may result in volatile profiles from dually infested plants that are indistinguishable from those of host-only infested plants. The study provides insight into understanding learning in *D. semiclausum* and in parasitoids more generally.

## Keywords
*Myzus persicae,* associative learning, olfactory learning, host-induced plant volatiles, long-term memory

# Session 5 Genetic Approaches to Manage Crucifer Pests: Transgenic Plants, CRISPR, RNAi, and Genetic Pest Management

## Genome, Host Genome Integration, and Gene Expression in *Diadegma fenestrale* Ichnovirus

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## ABSTRACT

Polydnaviruses (PDVs) exhibit species-specific mutualistic relationships with endoparasitoid wasps. PDVs can be categorized into bracoviruses and ichnoviruses, which have independent evolutionary origins. In our previous study, we identified an ichnovirus of the endoparasitoid *Diadegma fenestrale* and named it DfIV. Here, DfIV virions from the ovarian calyx of gravid female wasps were characterized. DfIV virion particles were ellipsoidal with a double-layered envelope. Next generation sequencing of the DfIV genome revealed 62 non-overlapping circular DNA segments. The aggregate genome size was approximately 240 kb, and the GC content (43.3%) was similar to that of other IVs (41–43%). A total of 123 open reading frames were predicted and included typical IV gene families. Neuromodulin N was found to be unique to DfIV, along with 45 hypothetical genes. Among the 62 segments, 54 showed high (76–98%) sequence similarities to the genome of Diadegma semiclausum ichnovirus (DsIV). Three segments contained lepidopteran host genome integration motifs with homologous regions of about 36–46 bp between them (DfIV and lepidopteran host, *Plutella xylostella*). Most of the DfIV genes were expressed in the hymenopteran host, and some in the lepidopteran host (*P. xylostella*), parasitized by *D. fenestrale*. Five segments were differentially expressed at different developmental stages of the parasitized *P. xylostella*, and two segments were highly expressed in the ovaries of *D. fenestrale*. Comparative analysis between DfIV and DsIV revealed that the genomes differed in number of segments, composition of sequences, and internal sequence homologies, reflecting differences in life strategy between the general parasitoid *D. fenestrale* and specialized *D. semiclausum*. DfIV maintained a co-evolution process in diverse hosts because additional viral genes acceding to the range of hosts and their expression were adjusted to the development of hosts.

## Keywords

Polydnavirus, koinobiont, Campopleginae, coevolution

# Identification of Two Diamondback Moth Parasitoids, Using LAMP for Application in Biological Control

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## ABSTRACT

The diamondback moth is a lepidopteran pest that damages various vegetable plants belonging to the genus Brassica worldwide. Various biological controls, such as parasitoid wasps, have been used to control this pest. Among these, *Diadegma semiclausum* and *Diadegma fenestrale* are widely used globally. In field-based biological control research, the investigation of the population dynamics of parasitoids and the rate of parasitism within the pest population is very important. However, achieving profundity in research is difficult when morphologically similar species coexist in the field. The morphological characteristics of *D. semiclausum* and *D. fenestrale* are very similar, and they both parasitize *P. xylostella* larvae. Therefore, to accurately identify these species, in this study, we developed a molecular diagnostic method by using loop-mediated isothermal amplification (LAMP). The mitochondrial genome of *D. fenestrale* and partial nucleotide sequences, including the ITS region of *D. semiclausum*, were analyzed for use as species diagnosis markers. The results showed that the homology of *D. fenestrale* to *D. semiclausum* was 94%. *D. fenestrale* species-specific primers for LAMP were designed based on the region encoding COX3, and the optimal diagnostic reaction condition for the four primers was 63 °C for 35 min. A species-specific primer capable of classifying *D. semiclausum* was developed based on the ITS2 region, and the optimal reaction condition for diagnosis was 63 °C for 40 min. Therefore, the developed LAMP diagnostic method can be used in a variety of ways to determine whether *P. xylostella* has been parasitized in the process of field research and mass breeding, and to accurately distinguish the species that are parasitic to *P. xylostella larvae*. This LAMP-based diagnostic method can be applied to identify various parasitoids that are used for the biological control of *P. xylostella*.

## Keywords

*Plutella Xylostella*, *Diadegma Semiclausum*, *Diadegma Fenestrale*, Lamp, Diagnostic Method

## Application of Genome Editing in Insect Pest Management with Special Reference to Crucifers

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**ABSTRACT**

Insect pests are the major limiting-factor in crop production, costing farmers billions of dollars in loss annually. The recent developments in arthropod genomics and bioinformatics facilitate identification of novel gene targets for various tools like RNAi, genome editing etc. Genome engineering by zinc finger nucleases (ZFN), transcription activator-like effector nucleases (TALEN) and recently the clustered regularly interspersed short palindromic repeats and associated proteins (CRISPR/Cas9) essentially generate target-specific mutations for various purposes. In this regard CRISPR/Cas9, an RNA guided DNA cleavage system causes a double stranded DNA break (DSB) and introduces random mutation at the target locus due to the error-prone mechanism called non-homologous end joining (NHEJ) affecting gene function. Currently, in addition to Cas9 other classes of Cas proteins such as Cas12A, Cas13A, Cas3 and other innovations like base editing and prime editing have increased propensity in insect pest management. In this regard, Cole crops are globally important that provide substantial nutritional and economic return to the growers. However, insect pests pose a very serious threat to the cultivation and genome editing has a lot of scope in managing them. Genome editing studies on *P. xylostella* have been taken up for the loss-of-function of genes including *abdominal-A* (Huang et al., 2016), *vitellogenin* (Zou et al., 2020), *vitellogenin receptors* (Peng et al., 2020), *yellow* (Wang et al., 2021), *period* (Wang et al., 2022). Recently, utility of CRISPR/Cas9 mediated gene drive for the management of *P. xylostella* has been demonstrated (Asad et al., 2022; Xu et al., 2022). Genome editing greatly helps in developing precision guided sterile insect technique (pgSIT) where it reduces requirement of infrastructural costs and sex separation at the pupal stage as required in normal course. For obtaining sterile males, the Cas9 and gRNA lines are crossed to generate sterile males for environmental release for population suppression.

**Keywords**
Genome editing, CRISPR/Cas9, Crucifers, Pest Management

# Session 3: Insecticide Resistance and Management in Crucifer Pests: the on-going Challenge

## Screening for the presence of Diamondback moth (*Plutella xylostella* L.) Resistance to Commonly Used Insecticides in Cambodia

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**ABSTRACT**
One of the most essential and popular vegetables in Cambodia is cruciferous vegetables. Crops in this family are sensitive to insect's pest devastation, starting from seedling to harvesting stages. At least 22 insect pests have been reported on the crop in Cambodia and among those, diamondback moth is considered as the main insect pests. It is classified as the major pest as it is hard to control or in other word, it is highly likely that they are resistant to commonly used insecticides. As resistant population in Cambodia is still unknown, in this study, 10 populations of diamondback moth from two major cruciferous production provinces, namely Siem Reap and Mondulkiri provinces have been collected and tested with commonly used insecticides in the laboratory experimentation.

**Keywords**
Insecticide Resistance, Siem Reap, Mondulkiri, Cambodia