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GUEST EDITOR

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From the Editor-in-Chief's Desk

I am happy and proud to announce the Volume 1, Special issue (December, 2023) on Agricultural Entomology. Agricultural entomology plays a pivotal role in agriculture by studying insect interactions within ecosystems, impacting crop health and productivity. It helps identify beneficial insects crucial for pollination and pest control, enabling sustainable farming practices. Through research and innovation, agricultural entomology develops effective pest management strategies, reducing crop losses and preserving yields. Understanding insect behaviour and biology assists in developing environmentally friendly approaches, minimizing the use of harmful pesticides. Overall, agricultural entomology is essential for ensuring food security, enhancing agricultural sustainability, and supporting global food production.

It gives me great pleasure to inform you that we have curated and finalized 11 articles for publication in this issue. I extend my heartfelt gratitude to Bontha Rajasekar for his contribution as Guest Editor in this Issue and also for the dedicated editorial team and the talented authors for their invaluable contributions in bringing this issue. Your efforts have played a pivotal role in making AgriTech Today Magazine a source of enlightenment and knowledge in the agricultural domain.

Editor-in-chief

EDITOR'S MESSAGE

Dear Readers,

It is very much delighted to act as Guest Editor for AgriTech Today Magazine special issue on Agricultural Entomology. This Magazine special issue provides basic ideas related to Entomology in the field of Agriculture. The magazine special issue consisting of 11 different popular articles on Integrated pest management, Biological control, Insect Taxonomy, Systemics, Ecology and Toxicology, New pest control approach, New Invasive Alien species, Beneficial insects and Biotechnology in insects contribute by scientists, professors, scholars of reputed universities and institutes throughout India.

I hope that this special issue will be helpful for the researchers in the development of future research studies. Any suggestions or inputs from Academicians and Researcher to improve the special issue will be highly solicited and will be a great contribution to the discipline of Agricultural Entomology Research. I am thankful to the authors for the contribution of scientific and technical popular articles in the magazine special issue. I extend my gratitude to AgriTech Today Magazine for the entire support and cooperation in bringing up the issue.

Happy reading!

Warm regards,

B. Rajasekar

(BONTHA RAJASEKAR)
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Role of Insects in Pollination and Crop production

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Abstract

Pollination is performed by mean of abiotic and biotic factors. Among the biotic factors, Insect pollinators (entomophily) play lead role in pollination. Contribution of insects in global food production ranges between 15% and 30%. Insect pollinators enhance both quality and quantity of crops and are associated with crops in ecosystem and visitations of these insects positively correlated with yield. Pollination is critical for food production and human livelihoods, and directly links wild ecosystems that many wild animals rely on for food and shelter with agricultural production systems. Without this service, many interconnected species inhabiting, and processes functioning within, an ecosystem would collapse. Therefore, this article includes the role of insects in pollination which ultimately leads to increase in quality and yield of the crops.

Introduction

Pollination brings fertilization by allowing the fusion of male gametes and female gametes. It helps in the production of foods and seeds. Pollination aids in the transmission of features and characteristics from both parents to the offspring. It is an essential part of plant reproduction. Pollen from a flower's anthers (the male part of the plant) rubs or drops onto another flower, where the pollen sticks to the stigma (the female part). The fertilized flower later yields fruit and seeds. Pollination affects crop quality and quantity. Some crops, such as field beans and mangoes, are self-pollinating but give better yields if pollinated by insects. Many, such as passion fruit, cowpea, sesame, litchi, mustard and cashew, give a substantially increased yield when pollinated by insects.

A pollinator is the biotic agent, animals or vector that moves pollen from anthers to stigma of a flower. Insects and other animal pollinators are vital for the production of healthy crops for food, fibers, edible oils, medicines, and other products. They are vitally important to agriculture, as well as our food system and ecosystems. They help thousands of flowering plants reproduce, from flowers to fruits and even some crops. Pollinator habitat can also provide benefits on the farm, such as preventing soil erosion and improving biodiversity. Both adaptions, along with their high frequency of flower visitations, make bees the most effective pollinators in the world. Although not as efficient as bees, other insect pollinators such as wasps, flies, beetles, moths and butterflies still play a critical part in plant pollination.

Role of Insects in Pollination and crop production

Insects aid in cross pollination in fruits, vegetables, ornamentals, cotton, tobacco, sunflower and many other crops. Insect pollination helps in uniform seed set, improvement in quality and increase in crop yield. Insects and other animal pollinators are vital to the production of healthy crops for food, fibers, edible oils, medicines, and other products. It is estimated that more than 1,300 types of plants are grown around the world for food, beverages, medicines, condiments, spices and even fabric. Of these, about 75% are pollinated by animals. More than one of every three bites of food we eat or beverages we drink are directly because of pollinators. In fact, pollinators such as bees, birds and bats affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide, as well as many plant-derived medicines (Klein *et al.* 2007). About 6 million acres were devoted to producing fruits, vegetables, and nuts- most of which are dependent upon insect pollination. These plants provide about 15 percent of our diet (Gregor, 1976). The commodities produced with the help of pollinators generate significant income for producers and those who benefit from a productive agricultural community. Pollination by bees therefore increases fruit production by 50% over that achieved by wind (Krishnnan *et al.*2012).

The use of pollinators (honey bees) and pollinizers in aonla orchards is necessary for increasing the fruit yield (Allemullah & Ram 1990). Smyrna and second crop San Pedro figs are pollinated exclusively by the hymenopterous fig wasp (*Blastophaga psenes* (L.), which overwinters in the caprifig fruit. The use of this wasp is the oldest form of man-manipulated insect pollination, a system referred to as caprification.

Bael is only about 5 % flowers are self-pollinated and 95 % animal pollinated. It is mostly pollinated fruit crop which has entomophilous flowers by various insect pollinators like honey bees (*Apis dorsata*, *A. mellifera*), hover flies, yellow wasp, carpenter bee, weevil, black ants, butterflies etc. (Haldhar *et al*. 2010). Cucumber crop requires insect pollination as an additional input for enhancing the yield (Shah et al. 2015). Ramanujam *et al*. (1964) reported 55.86% natural cross pollination in coriander, 70.05 to 77.83 % in ajwain and 82.20 to 91.4 % in fennel. Papaya plants are cross pollinated by insects and wind. Insect pollinators for papaya are honey bees, wasps, midges, thrips, syrphid flies, and butterflies (Crane, 2013).

High yield and high-quality crops are produced by the pollinators. Pollinating insects improve the yields of around three-quarters of crops.

Conclusion

In this article, we conclude great potential of insect pollinators in production of different agricultural crops. Hence, declining bee population poses a threat to global agriculture. Improving the health of bees and other pollinators is a necessity. Without pollinators, much of the food we eat and the natural habitats we enjoy would not exist. Taking action now to protect pollinators and reduce the usage of toxic pesticides is a positive step for our environment and economy. In the long run, if we don't find some answers, we could lose a lot of bees. A realistic way to ensure pollinator conservation is to promote and enhance its value to society.

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Evaluation of Suitable Management Strategy Against Melon Fruit Fly in the Terai Region of West Bengal

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Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae), the melon fruit fly, is found worldwide in temperate, tropical, and subtropical climates. It is a serious pest of cucurbitaceous vegetables, especially the bitter gourd (*Momordica charantia*), muskmelon (*Cucumis melo*), snap melon (*C. melo* var. *momordica*), and snake gourd (*Trichosanthes anguina*). It has been recorded to injure 81 host plants. (Dhillon *et al*, 2005). Depending on the season and the type of cucurbit, losses might range from 30% to 100%. On-farm testing was laid out at multilocational farmer's fields of different villages of Cooch Behar district of state West Bengal by Cooch Behar Krishi Vigyan Kendra to find out the suitable management strategy against melon fruit fly infesting bottle gourd (*Lagenaria siceraria*, family cucurbitaceae) during 2020-21 and 2021-22.

Materials and methods

For selection of farmers a group meeting was organized from where a few farmers (8 numbers) were selected considering the production system and farming situation. The 21 days old seedlings of hybrid variety of bottle gourd NS Kaveri by Namdhari Seeds were used during the study. The seeds were planted in raised heap method. 250 gms of Single super phosphate, 100 gms of urea and 80 gms of potash were applied during planting as basal dose. Another 100 gms of urea and 70 gm of potash were applied per plant as top dressing after 45 days after planting (DAP). Three technologies were tested viz. Technology option1 (To-I): Bait spraying (Spinosad 45 SC @ 0.3 ml L^{-1} + jiggery 10 gm L^{-1} + water) at the trunk region of the plants soon after flowering @ 20 spots Ha^{-1}, Technology option 2 (To-II): Placement of pheromone trap @ 25 Ha-1 soon after flowering + collection of all fallen/affected fruit in an air tight polythene pack followed by exposure to direct sunlight, Technology option 3 (To-III): Bagging of fruit with shed net (70%) just after fruit setting. The method of data observation was through calculation of post set damage, harvested damage percentage and total marketable yield as per method suggested by Sapkota *et al*. 2010.

Post-set damage (PSD): Just after set to immature fruits (<100 g) damaged by cucurbit fruit fly.

Harvested damage (HD): Unmarketable fruits (>100 g) damaged by cucurbit fruit fly recorded at harvest.

PSD = Number of PSD fruit fly damaged fruits/ Total number fruits set x 100

HD% = Number of harvested fruit fly damaged fruits/ Total number fruits set x 100

Results and Discussion

The results of the study conducted on assessment of suitable management strategy against melon fruit fly infesting bottle gourd indicated that (Table 1) (Graph-1) all the technologies provided significantly higher yield as compared to the farmer's practice. Among the technologies evaluated TO1 recorded highest yield of 23.68 quintal Ha-1 and lowest percentage of harvested damage 11.13%. The lowest post set damage (23.83 %) was recorded in TO2. The next best treatment was technology option 2 which recorded 21.54 quintal Ha^{-1} whereas in farmers practice the yield was 17.25 quintal Ha^{-1}. 32.17% post set damage obtained in TO2 was may be due to larger pore size space in 70% shade net from where female flies were able to puncture which resulted in fruit damage. Highest yield and control obtained in TO1 was may be due to use of Spinosad + jaggery solution that glued to the plant surface and flies were died after coming in contact with Spinosad when they were roaming around the plants before and after fruit set.

Sapkota *et al*. 2010 reported similar findings from Nepal where they observed that out of total set fruits, 26% post set damage and harvested damage of 14.04% by the cucurbit fruit fly in squash orchard. Chakraborty *et al*. 2019 reported that Pheromone traps @ 25 Ha^{-1} + gur based poison bait trap (50 ml Malathion 50 EC + 200g gur + 2 litre water) resulted mean percent fruit infestation by melon fruit fly to the tune of 13.92% in 2017 and 16.90% in 2018 in gherkins. The highest net return of Rs. 50110 Ha^{-1} was recorded in TO1 which resulted in lowest benefit cost ratio of 2.03 whereas in farmers practice only net return of Rs. 28780 Ha^{-1} was recorded (Table 2). It was clear from the study that frequent use of contact insecticides to manage melon fruit fly is of limited use. Similar findings were reported by Sapkota *et al*. 2010.

Conclusion

From the study it was concluded that all the management options evaluated are equally applicable to manage melon fruit fly. All the options may be considered to apply together like placement of pheromone trap @ 25 Ha^{-1}+ collection of all fallen/affected fruit in an air tight polythene back and exposure to direct sunlight + bagging of fruits + bait spraying (Spinosad 45 SC @ 0.3 ml L^{-1} + jaggery 10 gm L^{-1}) The efficacy of poly propylene bags are to be evaluated in place of shed net bags as percentage of post set damage was higher through shed net bags.

Table 1: Different yield components under different management options against melon fruit fly (mean of two years study 2020-21 and 2021-22)

Treatments	Post set damage (%)	Harvested damage (%)	Yield (quintal/ha)
Technology option1 (To-I): Bait spraying (Spinosad 45 SC @ 0.3 ml L^{-1} + jiggery 10 gm L^{-1} + water) at the trunk region of the plants soon after flowering @ 20 spots Ha^{-1}	25.44	11.13	2.03
Technology option 2 (To-II): Placement of pheromone trap @ 25 Ha^{-1} soon after flowering + collection of all fallen/affected fruit in an air tight polythene pack followed by exposure to direct sunlight	23.83	13.16	1.90
Technology option 3 (To-III): Bagging of fruit with shed net (70%) just after fruit setting	32.17	16.74	1.85
Farmers Practice: Frequent use of lamda cyhalothrin 5% EC @ 1 ml L^{-1}	38.61	22.54	1.71
CD at 5%			1.98

Table 2: Economics of different management options against melon fruit fly (mean of two years study 2020-21 and 2021-22)

Treatments	Gross Cost (Rs Ha^{-1})	Gross return (Rs Ha^{-1})	Net return (Rs Ha^{-1})	Benefit cost ratio (B:C)
Technology option 1 (To-I): Bait spraying (Spinosad 45 SC @ 0.3 ml L^{-1} + jiggery 10 gm L^{-1} + water) at the trunk region of the plants soon after flowering @ 20 spots Ha^{-1}	48610	98720	50110	1: 2.03
Technology option 2 (To-II): Placement of pheromone trap @ 25 Ha^{-1} soon after flowering + collection of all fallen/affected fruit in an air tight polythene pack followed by exposure to direct sunlight	45350	86140	40790	1: 1.90
Technology option 3 (To-III): Bagging of fruit with shed net (70%) just after fruit setting	42630	78920	36290	1: 1.85
Farmers Practice (FP): Frequent use of lamda cyhalothrin 5% EC @ 1 ml L^{-1}	40580	69360	28780	1: 1.71

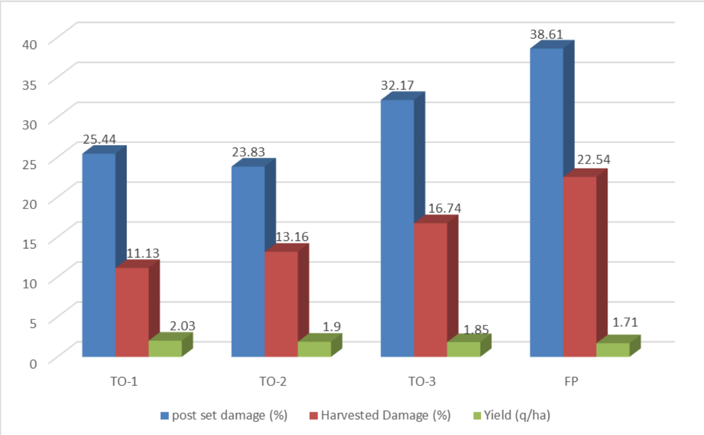

Fig 1: Graphical representation of Different yield components under different management options against melon fruit fly (mean of two years study 2020-21 and 2021-22).

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Breeding and Biotechnological Approaches for Biotic Stress Resistance in Vegetable Crops

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Abstract

Vegetables are often succulent, herbaceous plants. Since vegetable crops are naturally succulent, a wide range of pests can attack them. Because insects generate comparatively less economic damage than diseases did in the past, insect resistance has not been studied as extensively as disease resistance but vegetables are highly vulnerable to pest and insect attacks. Huge financial losses result from inadequate plant protection methods and a lack of resistant cultivars. Chemical pesticides are the mainstay of crop protection strategies. Pests have developed resistance as a result of repeated pesticide usage, and novel pest biotypes resistant to chemical pesticides have emerged. Additionally, pesticides pollute the environment and can endanger human health. As a result, it is imperative to switch from traditional chemical treatments to safer ones, such as the creation of resilient resistant cultivars. In addition to breeding approaches, selection with marker assistance decrease the amount of time and area required to screen resistant plants by increasing selection efficiency.

Introduction

Growing vegetables is a significant component of different agricultural economies of several developing countries (Srivastava et al. 2016). But massive occurrence of diseases and insect-pests is a problem of paramount importance in cultivation of vegetable crops. It is more difficult to reach the optimum yield potential of vegetable crops because of their increased vulnerability to diseases and insect pests. It is hazardous for human health and the environment to use pesticides indiscriminately to eradicate diseases, insect pests, and nematodes (Dhall, 2015). The establishment of pest and disease-resistant varieties and hybrids will always be more advantageous than chemical control since the resistant varieties limit outbreaks and preserve natural equilibrium. Selection for resistant plant types set in motion around the beginning of twentieth century (Painter, 1995). Since then, a huge number of insect-resistant cultivars have been developed all over the world (Panda et al. 1951). Despite of the fact that insect-pests are responsible for reducing about 40% yield in vegetables, the advancement in the development of insect resistance is very scanty. Host plant resistance is the economical method but the population pressure of pest resurgence affect the stability of the resistant host plants which ultimately aids in pest resurgence and resistance collapse (Dhall, 2015). In this article, important biotic stresses of major vegetable crops, sources of resistance, resistance breeding and biotechnological approaches are discussed.

Resistance Breeding for Biotic Stress:

Tomato fruit worm, beet armyworm, cotton bollworm, southern armyworm, soybean podworm, and egyptian cottonworm, colorado potato beetle and tobacco flea beetle, leaf miners, fruit fly, thrips, sinkbugs, and cutworms are some of the pests capable of causing severe losses in tomato crop. Tomato cultivars vary in levels of resistance as they produce plant peptide hormone system, systemin, after an insect attack (Srivastava et al. 2016). Large number of accessions of tomato have been screened and generally all cultivated varieties were found susceptible. Insect resistance has not been studied as much as disease resistance in tomato. However, two species namely *S. habrochaites* and *S. pennellii* are found to be possessing resistance against some major insect pests of tomato. S. *habrochaites* and *S. penelli* exhibits resistance against atleast 16 and 9 pest species respectively (Dhall, 2015). The three most serious brinjal diseases are wilt, small leaf, and phomopsis blight (Dhall, 2015). Resistance to Fusarium wilt was reported in S. Incanum. One of the major illnesses that affect brinjal in warm, humid climates is bacterial wilt. In wild species of Solanum, such as *S. torvum, S. xanthocarpum, S. nigrum*, and *S. sisymbriifolium*, resistance has been documented (Sugha et al. 2002). Previous workers observed that longer and denser hair on the leaves caused resistance to Jassids. Given the abundance of harmful pests that affect the crop, it is challenging to develop resistance types for particular pests. It makes sense to look for sources of resistance for many pests (Dhall, 2015). While *S. incanum* and *S. sisymbrifolium* species were resistant to minimal leaf disease, the wild species Solanum viarum did not exhibit any symptoms of infection and was immune (Anjaneyulu and Ramakrishnan, 1968, Chakrabarti and Choudhury, 1974). As, there are more harmful pests in the crop than there are resistant varieties, it is challenging to breed resistant varieties for each pest. It makes sense to look for sources that are resistant to multiple pests (Dhall, 2015). In case of chilli, Caleapin Red', 'Chamatkar', 'NP46A', x 1068, x 743, x 1047, 'BG-4', x 226, x 230, x 233 are the sources which have been found resistant against thrips (Tewari et al. 1985). Resistant sources against mites are LEC-1, 'Kalyanpur Red', x 1068, x 204, 'Goli Kalyanpur' -309- 1-1-15, 300-1-5-1, S-118 (Punjab Lal), 635, 565 (Tewari et al. 1985). LEC-28, LEC-30, LEC-34, 'Kalyanpur Red', x 1068 are the accessions possessing resistance against chilli aphid (Tewari et al. 1985).

Further, many insects infect cucurbits, but the two spotted spider mite and fruit fly are mainly responsible for huge losses. Resistance sources are usually observed in landraces and wild relatives. *C. callosus* has resistance against fruit fly. In the matter of cucumber, PI 220860, Hybrid Long Green Pickle are the resistant sources against two spotted spider mite (Robert, 1994).

Omics approaches for resistance against biotic stress

Candidate genes for aphid resistance in cucumber were discovered by using method of SLAF sequencing in conjuction with bulk segregant analysis (Liang et al. 2016). Four additive and two epistatic QTLs were found carrying genes for aphid resistance. The field of biotechnology is also concerned with transcriptomes, which are the total set of RNA transcripts produced in a cell or tissue by genetic code of an organism (Raza et al. 2021). 290 genes are found to be significant in case of viruliferous whitely in tomato (Richard et al. 2014). The plant metabolism can be analysed by performing qualitative and quantitative tests by the use of metabolomics (Dettmer et al. 2007). Proteinase inhibitors (PIs), the most studied defense-related proteins in plants, have been found to be elevated in tomato or pepper plants' responses to attack of different pests (War et al. 2018). Proteomics deals with the examination of proteins. Plant metabolic diversity and stress response are investigated through the application of the proteome approach (Ghosh et al. 2014 and Gong et al. 2015). In relation to thrips attack, it was identified that 52 proteins are present in different genotypes of sweet potatoes (Yang et al. 2013). It is anticipated that these developments will improve breeding efforts and help identify potential genotypes based on their breeding value. It not only creates new genotypes but also elucidates the intricate characteristics of plants in reaction to diseases, pests, and harsh environmental circumstances (Kumar et al. 2023). However, sample collection and analysis need to be done very carefully because transcriptome, proteome, and metabolome data are very inconsistent across time and environmental conditions.

Conclusion

One of the most effective methods to reduce the losses brought on by disease or pest incidence is to develop cultivars that are resistant or tolerant. To make the most use of the germplasm that is now accessible, a comprehensive research program must be implemented. It is anticipated that biotechnological methods would also improve breeding efforts and help determine which genotypes are suitable for breeding.

Declaration

The authors declare no conflict of interest

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Integrated Pest Management Strategies for Controlling Diamondback Moth (DBM) in Cruciferous Vegetables

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Cruciferous vegetables are vegetables of the family Brassicaceae (also called Cruciferae) which include economically important crops of different genus like cabbage, cauliflower, broccoli, radish, kale, mustard etc. They contain sulphur containing secondary metabolites, called glucosinolates, which have a wide range of beneficial effects. The major cruciferous vegetables grown in India are cabbage and cauliflower, and they are mostly grown during the winter (*Rabi*) season. The major pests that are associated with crucifers are diamond back moth (*Plutella xylostella*), cut worm (*Spodoptera litura*), cabbage butterfly (*Pieris brassicae*) etc. Among these, the lepidopteran pest, diamondback moth is found to be the most destructive of all.

Diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), is the most destructive pest of crucifers around the world causing about 90% economic loss in these crops. The young larvae feed voraciously on the tender parts of the leaves, decreasing the appeal and market value of the produce. Though it is a major key pest of crucifers, particularly in cabbage and cauliflower crops in India, the control of diamondback moth is difficult through chemicals as the pest has developed resistance to a majority of pesticides including DDT and synthetic parathion, and also to about 82 compounds belonging to different classes of insecticides over 17 countries. In addition, use of chemical pesticides results in environmental pollution and their persistence in the crops can cause serious health damage.

Morphology and lifecycle

The female moth lays its eggs singly or in groups of 2 to 10 on the underside of the leaves of the host plant. The most suitable host plants for laying eggs are cabbage and cauliflower. The females prefer the tough lower leaves of the plant for this purpose. The freshly laid eggs are pale yellow with a greenish tinge and oval in shape. The larvae initially, after hatching, are pale white in colour with a dark brown head. These first instar larvae often tunnel through the leaves and eventually undergo three moultings to form the final fourth instar larvae. The fourth instar larvae are green in colour and their body is covered with short spiny hairs. The entire larval period lasts for 7 to 11 days. The larvae finally make a beautiful transparent web-like cocoon which remains attached to the foliage. The pupal period varies from 3-5 days. The adults that emerge are small greyish brown in colour. Forewings have three white triangular spots along the inner-margin and when adult folds the wings the spots from opposite wings meet to form diamond shape. The incidence of the pest varied from season to season owing to difference in the climatic conditions.

Fig. 1a: Eggs

Fig. 1b: Larvae

Fig. 1c: Pupa

Fig. 1d: Adult

Plate 1: Lifecycle of diamondback moth (DBM)

Nature of damage

The insect lays eggs preferably on the fibrous lower leaves, but the larvae upon hatching move upwards to feed on the young soft upper leaves of the plant. The larvae colonise the areas around the growing buds, in the loose spaces between leaves and on the underside of the wrapper leaves. The larvae scrape the leaf epidermis often leaving whitish patches on the leaf surface. They may also bore into the growing buds causing disfigurement and destruction of the commercially important structures like the curd of cauliflower. This reduces the market value of the produce significantly, causing economic loss to the producers.

Fig. 2: Cauliflower curd damaged by DBM

Fig. 3: Cabbage plant damaged by DBM larvae

The older larvae bites into the leaves causing tiny feeding "windows" on the leaf surface. In case of heavy infestation, the larvae completely skeletonise the leaf, leaving only the leaf veins behind. It also eats the curd, thereby hampering its development.

Fig. 4: Heavy infestation of DBM larvae

Fig. 5: Completely skeletonised cauliflower plant

Integrated pest management strategies

Cultural practices

- Practising clean cultivation by removal and destruction of plant debris and residues after harvest.
- Pinching and pruning of affected plant parts to lower the pest population.
- Removal and destruction of weeds which may act as alternate host of the pest.
- Balanced application of fertilisers. Excessive application of nitrogenous fertilisers makes the plant more succulent and hence, more prone to pest attacks.
- Trap cropping by growing two rows of mustard after every 25 rows of cabbage reduces 80 to 90% of DBM population and other pests. One row of mustard is sown 15 days before transplanting of cabbage and the other row 25 days before. The first and last rows of the patch are also mustard. The mustard crops are sprayed with Dichlorovos 0.1% soon after germination. The DBM are attracted to the mustard crop and the cabbage crop is less affected.
- Inter cropping with tomato plants with one row of tomato between two rows of cabbage helps to bring down the pest population as the tomato plant acts as a repellent. The tomato intercrop is planted two weeks before transplanting of the main crop.
- The population of DBM decreases considerably during the rainy season as the eggs get washed away. The similar effect can be created by installation of sprinkler irrigation methods to reduce the pest population.
- Installation of pheromone traps @ 12 per hectare for mass trapping and monitoring.
- Growing of resistant cultivars, e.g., Pusa Drumhead and Golden Acre of cabbage, or moderately resistant cultivars, like Pusa Samandh, Pride of India and Selection-51.

Biological methods

- Spraying with Azardirachtin 0.3% EC @ 20 ml per 20 L water is effective in reducing the pest damage.
- Foliar application of Bio-Power® WP (*Beauveria bassiana* 1.15% at 1.0 × 10^8 CFUs/g) @ 100 g per 20 L water.
- Foliar application of DiPel® DF (*Bacillus thuringiensis* subsp. *kurstaki*, Strain ABTS-351, 54% w/w) @ 20 g per 20 L water.
- Use of botanical pesticides like chilli extracts and seaweed extracts helps in controlling the pest population. Chilli possesses insecticidal properties that effectively repel the pest. Seaweed extract, on the other hand, is absorbed by the plant through assimilation and the biostimulants present along with micronutrients enhance the physiological resistance of the plant.

Fig. 6: Installation of pheromone trap in cabbage field

Fig. 7: *Cotesia plutellae* wasp attacking a DBM larva

- Use of *Zingiber officinale* extracts @ 25% w/v serves a better alternative to chemical pesticides in controlling the DBM larvae. The larval population often shows resurgence after chemical application, but the extracts of *Z. officinale* brings down their population significantly.
- Release of natural predators, like *Chrysoperla carnea* (Chrysopidae: Neuroptera), which attack the egg and larval stages; parasitoids, like *Trichogramma chilonis* Ishii (Trichogrammatidae : Hymenoptera), which is an egg parasitoid; *Cotesia plutellae* (Braconidae : Hymenoptera), which is a larval parasitoid; to control the pest population significantly.

Chemical insecticides:

- Spinosad 45% SC, Indoxacarb 14.5% SC and Emamectin benzoate 5% SG are the most effective treatments against DBM larval population
- Spinosad 45% SC is the best insectide against DBM and also improves the production by having higher benefit-cost ratio.

Conclusion

Cruciferous crops like cabbage and cauliflower form an important part of the Indian vegetable market. So, effective control measure should be taken up to reduce losses and bring higher productivity. The lepidopteran pest diamondback moth, which has assumed status of an important pest, needs to be controlled with strategies that are economical to the farmers and sustainable to the environment.

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Revealing the Menace Posed by *Spodoptera Litura* (Fabricius) to Groundnut

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Groundnut (*Arachis hypogaea*, Linn) is an important Kharif oil seed crop of India cultivated on about 4.56 million hectares, with a total production of 6.77 million tonnes and average yield of 1486 kg/hectare. The area under groundnut constituted approximately 3.3 percent of the net sown area in India and contributed nearly 16 percent of groundnut production to the world during 2016. Groundnut is now in constant threat from polyphagous pests such as *Spodoptera litura* due to its resistance build up and voracious feeding habit, causing up to 47 per yield loss in India. The increase of global mean surface temperature by the end of the 21st century (2081–2100) relative to 1986–2005 is likely to be 0.3 °C–1.7 °C which will bring a large area under the threat of this pest.

Life cycle

Spodoptera litura (F.) belongs to the family Noctuidae and order Lepidoptera, also known as tobacco cutworm or cotton leaf worm is a nocturnal pest with 30-40 days life cycle. Adult is stout having wavey white markings on the brown forewings and white hind wings with a brown patch along its margin. Eggs are laid in groups and covered with hairs on the leaves. The egg period is 4-5 days. Larva is stout, cylindrical, pale brownish with dark markings. The body may have row of dark spots or transverse and longitudinal grey and yellow bands. When fully grown, measures about 35-40 mm in length. The larval period is 14-21 days. It pupates in earthen cells in soil for 15 days.

Damage symptom

First instar of *S. litura* scraps the surface of leaves whereas 2nd and 3rd instars larvae feed by making holes in the leaves. The later stage larvae voraciously feed on the leaves and the field appears as grazed by the cattle. Larvae hide under the plants, cracks and crevices during daytime as the pest is nocturnal in habit**.** Pest incidence can be diagnosed by the presence of faecal pellets on the leaves and on the ground which is the indicator of the pest incidence.

Fig 2: Damage symptom on groundnut leaf

Pesticide resistance

Spodoptera litura is one of the first insect pests of agricultural importance in India to develop resistance to insecticides. The resistance was observed against benzene hexachloride in Rajasthan in 1965 and by the early 1970s, resistance was noted in West Bengal and Haryana to endosulfan and carbaryl. In the early 1980s, populations from Andhra Pradesh and Tamil Nadu exhibited high resistance to various chemicals such as lindane, endosulfan, carbaryl, malathion and synthetic pyrethroids (Kranthi *et al.*, 2002).

Production loss

Field studies on groundnuts revealed the impact of *S. litura* infestation at different stages of plant growth. At the seedling stage, one larva devoured 54.7% of the leaf area per plant, resulting in a pod yield reduction of up to 25.8%. At the flowering stage, one larva per plant consumed 49.1% of the leaf area, causing a 19% reduction in pod yield. During pegging, one larva per plant consumed approximately 38.8% of the leaf area, leading to a yield loss of 5.7%. The hierarchy of ovipositional response of females on leaves followed are Sunflower> Mustard>

Groundnut> Maize when compared between these crops (Singh *et al.,* 2015).

Management

Cultural control is highly recommended to manage *S.litura* in the field. Deep summer ploughing, planting castor, sunflower and marigold as trap crops for egg laying and destroying these eggs helps in the reduction of pest incidence. Early sowing enables the crop to escape insect pest damage. Migration of caterpillars should be checked by digging trenches 30 cm depth and 25 cm wide with perpendicular sides around the infested field. Prolonged mid-season drought should be avoided by providing at least one irrigation. Resistant varieties should be cultivated namely Pratap Mugphali-1, Vasundhara (Dh 101), Co(GN)-5, ICGS-86, GG-14, M45, M28-2, NCAc343, ICGV 91180 (11, 12), ICGv86699, ICGV86031, ICg2271 and ICG1697(13). Among the mechanical control, 12 light traps/ha. can be installed for insect traps. Two hand held or mechanical weeding at 15-20 days after sowing is recommended. Pheromone traps (5 traps/ha) helps to monitor the moth population and subsequently release of biocontrol agents like *Telenomus remus* @50000/ha. four times (7-10 days intervals), *Trichogramma chilonis* @50000/ha. two times (7-10 days intervals), *Bracon hebetor* @5000/ha(two times at 7-10 days intervals) effectively checks the population of pests. The spray of insect pathogenic fungus *Nomuraea rileyi* @10^13 spores/ha proves useful for controlling early instars. Neem seed kernel can be effectively used on need basis. Application of insecticides is to be done only if the insect population crosses ETL. Application of Quinalphos 20%EC 750 ml/ha, Dichlorvos 76%WSC 750 ml/ha, Indoxacarb 14.5%SC 250 ml/ha, Spinosad 45%SC 125 ml/ha, Diflubenzuron 25%WP 300g/ha, Imidacloprid 17.8%SL 125ml/ha is recommended.

Conclusion

Excessive use of chemical insecticides to manage *S. litura* has rendered groundnut cultivation vulnerable to this pest due to the development of pesticide resistance. In this scenario susceptibility of *S. litura* to biocontrol agents has emerged as a boon to sustainable agriculture. In the event of a rise in surface average mean temperature chemical control measures may not seem effective in mitigating this damage and in such conditions, biocontrol can very well help in obtaining optimum plant population and yield.

Table 1: Biocontrol agents applicable in Indian condition

Biocontrol agents	Family	Selected reference
Egg parasites		
Chelonus helipae	Braconidae	Patel *et al.,* (1971)
Trichogramma chilonis	Trichogrammatidae	Joshi *et al.,* (1979)
Trichogramma dendrolini	Trichogrammatidae	Bhatnagar (1981)
Egg-larval parasites		
Telenomus remus Nixon	Seelionidae	Joshi *et al.,* (1979)
Chelonus formosanus	Braconidae	Patel *et al.,* (1971)
Larval parasites		
Apanteles prodeniae viereck	Braconidae	Sathe (1987)
Apanteles spp.	Braconidae	Joshi *et al.,* (1979)
Pupal		
Hybothoracini spp.	Chalcididae	Rao et al. (198I)
Sarcophaga albiceps Meigen	Sarcophagidae	Bhatnagar (1981)
Bacteria (Larval)		
Bacillus cereus	Bacillaceae	Kore and Bhide (1978)
Metarhizium anisopliae	Clavicipitaceae	Siddaramaiah *et al.,* (1986)
Micrococcus spp.	Micrococcaceae	Zaz and Kushwaha (1983)
Virus (Larval)		
Granulosis virus	Baculoviridae	Narayanan (1985)
Nuclear polyhedrosis virus	Baculoviridae	Ramakrishnan & Tiwari (1969)
Nematode (Larval)		
Hexamermis spp.	Mermithidae	Bhatnagar *et al.,* (1985)
Pentatomimermis spp.	Pentatomidae	Bhatnagar *et al.,*(1985)

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From Courtship Songs to Parallel Evolution: Decoding *Chrysoperla's* Secrets

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The *Chrysoperla* genus, encompassing a diverse array of lacewings within the Neuroptera order, is distinguished by its elegant members known for intricate wing patterns and distinctive features. These lacewings, particularly notable during their larval stage, exhibit a predatory nature, actively contributing to the biological control of garden pests. Among the species in this genus, *Chrysoperla carnea* takes centre stage as a green lacewing species with vibrant green colouration. Renowned for its significant role in natural pest control, *C. carnea* is a beneficial predator, especially effective against aphids and other soft-bodied pests. Its presence is a welcomed ally in agricultural ecosystems, aiding gardeners and farmers to balance pest management and environmental sustainability. In addition to their ecological significance, lacewings in the Chrysoperla genus are known for their unique courtship behaviour, often involving intricate courtship songs. This courtship song, a fascinating component of their reproductive behaviour, adds another layer to the intricate world of Chrysoperla lacewings, highlighting their complex and nuanced interactions within their ecosystems.

Green lacewings within the *Chrysoperla* genus, notably the 'carnea group,' were initially believed to constitute a single Holarctic species, *Chrysoperla carnea* (Stephens), based on similar adult specimens found across North America, Europe, northern Africa, and Asia (Tjeder, 1960). These cryptic species, identified by Duelli in 1996, engage in substrate-borne songs as part of their courtship behavior. Rather than striking the substrate, they utilize abdominal vibrations through a process termed tremulation (Michelsen *et al.*, 1982). These vibrations, travelling through the substrate, are picked up by subgenual organs in the tibiae of potential mates (Devetak *et al*. 1978).

The vibrational songs serve a discriminatory function at close range, aiding in mate selection. Both male and female lacewings partake in producing these songs, allowing individuals to synchronize their mating signals during a prolonged heterosexual duet as a prerequisite to copulation. Due to strict genetic control, the song phenotype contributes to reproductive isolation, as individuals with different songs fail to match up (Wells and Henry 1992). The songs of *Chrysoperla* green lacewings consist of volleys of low-frequency abdominal vibrations repeated regularly. Some species have relatively simple songs composed of single-volley SRUs repeated many times, while others produce more complex songs with longer, multi-volley SRUs, responding to similar songs from potential mates.

Fig 1: Adult of *Chrysoperla* sp.

Fig 2: Egg of *Chrysoperla* sp.

Song Evolution

In his 1993 experiment, Wells investigated hybridization in lacewings to explore genetic incompatibility. Courtship songs play a crucial role in reproductive barriers among lacewings in the genus *Chrysoperla*, as seen in *Chrysoperla plorabunda*. Heterotypic matings, involving different song morphs, are less likely than homotypic matings, contributing to postzygotic isolation. Experimental crosses between sympatric P1 and P3 morphs of *Chrysoperla plorabunda* reveal delayed egg laying and lower hatching success in heterotypic crosses compared to homotypic crosses. Backcrosses with P3 morph males or females are less successful, with delayed mating. These findings suggest behavioral isolation and provide genetic evidence supporting the idea that song morphs in the *C. plorabunda* complex represent distinct biological species. A striking example of parallel song evolution is demonstrated between the well-known European species, *Chrysoperla pallida*, and a recently identified vibrant-green North American species, *Chrysoperla calocedrii* sp. *nov*. Henry's study in 2012 delves into the parallel evolution of these two different lacewing species. To validate this parallelism, the research establishes that: (1) the songs of both species exhibit measurable similarities in multi-volley temporal and frequency structure; (2) the songs share a common genetic pathway; (3) each species fails to distinguish between its own and the other's song in playback trials, confirming acoustic niche overlap; (4) the two species readily engage in normal duets in the laboratory, leading to copulation and the production of robust hybrid offspring with an intermediate song phenotype; (5) they possess distinct morphologies in both adults and larvae, indicating different adaptive responses and independent evolutionary histories; and (6) they occupy relatively distant positions in a Bayesian phylogenetic analysis of 4630 bp of protein-coding mitochondrial DNA, dismissing the alternative hypothesis of similarity through recent common ancestry.

Conclusion

In summary, the *Chrysoperla* genus showcases intricate lacewing dynamics, with notable species like *Chrysoperla carnea* contributing significantly to natural pest control in agriculture. Their courtship rituals, marked by substrate-borne songs, reveal a complex interplay of genetics and behavioral isolation, influencing the distinct biological species within the *C. plorabunda* complex. Wells' 1993 study delves into hybridization, demonstrating how courtship songs contribute to reproductive barriers, influencing egg laying and hatching success. Meanwhile, Henry's 2012 research unveils a parallel song evolution between European species *Chrysoperla pallida* and North American species *Chrysoperla calocedrii* sp. nov., emphasizing their distinct evolutionary paths despite geographic separation. In essence, *Chrysoperla* lacewings exemplify a fascinating blend of ecological significance and intricate behaviors, underscoring the importance of understanding and preserving their role in maintaining ecosystem balance.

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Bee Vectoring in Vegetable Farming: An Agricultural Advancement

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Vegetable farming plays a crucial role in global food production, providing essential nutrients and sustenance to billions of people. However, the successful cultivation of vegetable crops is continuously threatened by diseases caused by bacteria, viruses and fungi. These diseases result in significant economic losses and can impact food security. Traditional methods of disease control often rely on chemical pesticides, which are not only expensive but also raise environmental and health concerns. In this context, the concept of "bee vectoring" has emerged as a sustainable and eco-friendly approach to disease management in vegetable farming.

Bee vectoring involves the use of bees to transport and disseminate biological control agents (BCAs) such as beneficial microorganisms and natural enemies of plant pathogens. By harnessing the natural foraging behaviour of bees, bee vectoring can effectively deliver BCAs directly to the flowers of the target crop, where disease-causing pathogens often enter the plant. This method has shown promise not only in reducing disease incidence but also in enhancing crop productivity by promoting pollination.

In this article, we will explore the scientific principles behind bee vectoring, its applications in vegetable farming, the advantages and challenges associated with this approach, and its future directions.

Principles of bee vectoring

Role of bees in vectoring

The idea of using bees as vectors for disease management and pollination is rooted in the natural behaviour of these insects. Bees are well-known pollinators, transferring pollen from the male reproductive organs (anthers) of a flower to the female reproductive organs (stigma) of another flower, promoting fertilisation and subsequent fruit and seed development. In the process, they visit numerous flowers, making them ideal candidates for delivering biological control agents.

Honeybees (*Apis mellifera*) and bumblebees (*Bombus* spp.) are among the most commonly used bee species in bee vectoring. Their foraging activities lead them to visit a wide range of flowers, including those of vegetable crops. As they collect nectar and pollen, they inadvertently distribute the biological control agents on these flowers. These agents can be microorganisms such as beneficial bacteria or fungi, which compete with or antagonise plant pathogens. The bee's body becomes coated with these BCAs, and as the bee moves from flower to flower, it transfers these agents to the stigma of the flowers. Bee vectoring works well in farms of all sizes, large and small, and can function in both fields and greenhouses.

Biological control agents (BCAs) in bee vectoring

The choice of biological control agents is a critical aspect of bee vectoring. BCAs used in this method are typically beneficial microorganisms that can protect plants from pathogens. These BCAs can include:

a) **Beneficial bacteria:** Certain bacterial strains, such as *Pseudomonas fluorescens* and *Bacillus* spp., are known for their ability to suppress pathogenic bacteria and fungi. They can colonise the plant surfaces and outcompete harmful microorganisms for nutrients and space.

b) **Antagonistic fungi:** Some fungal species, like *Trichoderma* spp., have antagonistic properties and can inhibit the growth and colonisation of pathogenic fungi. They achieve this through mechanisms such as mycoparasitism, competition for resources and the production of antifungal metabolites.

c) **Entomopathogenic fungi:** Fungi like *Beauveria bassiana* and *Metarhizium* spp. are commonly used in bee vectoring systems to control insect-pests, thus offering dual benefits. While their primary role is to manage pests, their presence on flowers can also deter or compete with plant pathogens.

Targeting pathogens at the flower level

One of the key advantages of bee vectoring is its ability to target pathogens at the flower level. Many plant pathogens, particularly bacteria and fungi, enter the plant through the flower and establish infections in reproductive structures. This is a critical entry point for pathogenic microorganisms because it can lead to the development of infected fruits and seeds. By applying BCAs directly to the flowers, bee vectoring provides a focused and preventive approach to disease management.

When bees collect nectar and pollen from flowers treated with BCAs, they transfer these agents to the stigma, which is a receptive surface for pollen grains and also the point of entry for pathogens. The BCAs can then establish themselves on the stigma and style, preventing the colonisation of pathogenic microorganisms. This is a valuable strategy for diseases such as bacterial speck on tomatoes (*Pseudomonas syringae*), where the pathogen enters the plant through the flower.

How does bee vectoring work?

Bees pick up small particles that contain biocontrol agents as they leave their hive and disseminate them to flowering crops. Essentially, it can be used with any flowering crop that uses bees for pollination. The concept of bee vectoring is very simple. Biocontrol agents are diluted in powder-based diluent and placed in dispensers in the hives. This powder sticks to the legs of the bees while they are moving inside the hive. Once they land, it gets brushed on to the flower, where it protects the blossom from pathogens, like *Botrytis* (grey mold). Other pollinators can then spread it further as they flit from flower to flower.

Bumblebees are the perfect workers for many reasons. They can carry their own body weight and nectar or pollen and can, therefore, deliver correct amount of BCAs. Unlike honeybees, they fly in cooler temperatures in damp weather. A single bumblebee hive contains as many as 300 bees. These bees can touch approximately 10 million flowers over the bloom period, and each bee can visit 10 or more flowers per minute.

Disease management in vegetable farming

Bee vectoring has gained attention as a promising method for managing diseases in vegetable farming. Several key vegetable crops are susceptible to various diseases, and by utilizing bee vectoring, these crops can benefit from enhanced disease control. Here are a few examples of vegetable crops where bee vectoring can be applied for disease management:

a) **Tomato (*Solanum lycopersicum*):** Tomatoes are susceptible to various diseases, including bacterial canker (*Pseudomonas syringae*), bacterial speck (*Pseudomonas syringae*), early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*). Bee vectoring has shown promise in reducing the incidence of these diseases. For instance, a study demonstrated that bee vectoring with *Pseudomonas fluorescens* led to reduction in bacterial canker severity in tomato plants.

b) **Cucumber (*Cucumis sativus*):** Cucumber crops are vulnerable to powdery mildew and downy mildew, both of which can affect the leaves, stems and fruit. Bee vectoring with antagonistic fungi like *Trichoderma* spp. has been explored as a strategy to combat these diseases. Research showed that bee vectoring with *Trichoderma* spp. reduced the severity of powdery mildew in cucumber plants.

c) **Squash (*Cucurbita* spp.):** Squash crops can be afflicted by various diseases, including powdery mildew and cucurbit downy mildew. These diseases can have a significant impact on fruit yield and quality. A study investigated the use of bee vectoring with *Ampelomyces quisqualis* to control powdery mildew on squash, and positive results were obtained.

Benefits of bee vectoring in vegetable farming

i. **Environmental sustainability:** One of the primary advantages of bee vectoring in vegetable farming is its environmental sustainability. Conventional disease management often relies on chemical pesticides, which can have detrimental effects on the environment. Pesticides can harm non-target organisms, contaminate soil and water, and lead to the development of pesticide-resistant pathogens. Bee vectoring relies on the application of natural and beneficial microorganisms, reducing the need for synthetic chemicals. This approach is compatible with organic farming practices and contributes to the preservation of beneficial insects, including bees, which are essential for crop pollination and biodiversity.

ii. **Reduced chemical residues:** By minimising the use of chemical pesticides, bee vectoring helps reduce chemical residues in vegetables. This is particularly important for crops like tomatoes and cucumbers, which are often consumed without peeling. Lower chemical residues mean safer and healthier food for consumers.

iii. **Cost-effective disease management:** While the initial setup of a bee vectoring system may involve some investment, the long-term costs are often lower compared to conventional disease management strategies. Once established, the system relies on the natural foraging behaviour of bees, reducing the need for frequent applications of chemical pesticides.

iv. **Increased crop yields:** Bee vectoring not only contributes to disease control but also enhances pollination, which can lead to increased crop yields. This dual functionality makes bee vectoring an attractive option for vegetable growers. Increased yields translate to higher profits for farmers and improved food security at a global level.

v. **Compatibility with integrated pest management (IPM):** Bee vectoring is compatible with the principles of integrated pest management (IPM). IPM emphasizes a holistic and sustainable approach to pest and disease control, incorporating various strategies to minimize the impact of pests and pathogens while safeguarding human health and the environment. Bee vectoring aligns with the IPM approach by using natural biological control agents to manage diseases.

Challenges and limitations

While bee vectoring holds great promise in vegetable farming, several challenges and limitations need to be addressed to maximise its effectiveness and adoption:

i. **Specificity of BCAs:** The effectiveness of bee vectoring relies on the specificity of the biological control agents. BCAs should target the desired pathogens while sparing beneficial microorganisms. Ensuring this specificity can be challenging and requires careful selection and testing of BCAs.

ii. **Bee health and safety:** The health and safety of bees are critical in bee vectoring. Honeybees and bumblebees are commonly used, and their well-being is essential for the success of the system. Factors such as exposure to pesticides, habitat loss and disease can impact bee populations. Efforts should be made to protect and support these pollinators.

iii. **Regulatory approval:** The use of bee vectoring in agriculture may require regulatory approval in some regions. This approval process can be time-consuming and costly, potentially slowing down the adoption of this technology.

iv. **Logistics and infrastructure:** Implementing a bee vectoring system involves setting up infrastructure for the application of BCAs to flowers. This requires a commitment of resources and training for farmers. Additionally, the successful implementation of bee vectoring may require changes in farm management practices, which can be a barrier to adoption.

v. **Weather and environmental factors:** Weather conditions and environmental factors, such as wind and rain, can influence the effectiveness of bee vectoring. Rain can wash away applied BCAs, and strong winds can hinder bee foraging activity. These factors need to be considered when implementing bee vectoring systems.

Future directions

Bee vectoring represents a sustainable and eco-friendly approach to disease management and pollination enhancement in vegetable farming. While the concept is promising and supported by scientific evidence, there is still room for further research and development in this field. Here are some future directions:

i. **Expansion to additional crops:** While the effectiveness of bee vectoring has been demonstrated in some vegetable crops, there is potential to expand its application to a broader range of crops. Research and trials can explore the use of bee vectoring in other vegetables susceptible to diseases, as well as in fruits and other horticultural crops.

ii. **Integration with precision agriculture:** The integration of bee vectoring with precision agriculture techniques, such as the use of drones and sensor technologies, can enhance the precision and efficiency of BCA application. This approach can optimise the timing and dosage of BCAs, ensuring better disease management and pollination.

iii. **Collaboration and knowledge sharing:** Collaboration between researchers, farmers and industry stakeholders is essential for the successful adoption of bee vectoring in vegetable farming. Knowledge sharing and capacity building can help overcome challenges and facilitate the widespread implementation of this technology.

Conclusion

In conclusion, bee vectoring has the potential to revolutionise disease management and pollination in vegetable farming. Its eco-friendly nature, reduced chemical residues and cost-effective disease control make it an attractive option for modern agriculture. While challenges and limitations exist, ongoing research and the development of best practices can address these issues. Bee vectoring aligns with the principles of sustainable agriculture and can contribute to increased food production and environmental conservation in a changing world.

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Integrated Pest Management on Mustard Crop

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Indian vegetable oil economy is the world's fourth largest after United States, China and Brazil. India is third largest rapeseed- mustard producer in the world after China and Canada with 12 per cent of world total production. Rapeseed-mustard ranks second after soybean among edible oilseeds in production and contributes to more than 30% of edible oil production in India. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout northern India in cooking and frying purposes. The oil cake is used as a cattle feed and manure. Green stems and leaves are a good source of green fodder for cattle. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in the diet. The oil content of the rapeseed and mustard ranges from 30 to 48 percent. Rapeseed-mustard group of crops comprise mustard / raya, toria, brown Sarson, Yellow Sarson, Gobhi Sarson, black mustard and taramira. Mustard (*Brassica juncea*), the major edible oilseed brassica crop in India, is extensively grown traditionally as a pure crop as well as intercrop (or mixed crop) in marginal and submarginal soils in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, Assam, Jharkhand, Gujarat, North Eastern States and Bihar. Cool moist climate of winter months is the major factor for the luxuriant growth and productivity of mustard in these states. These states account for 96% of the area and production of rapeseed-mustard and mustard is grown only as a mixed crop for seed being used for condiment purposes. Productivity of mustard is highest (1996 kg ha^{-1}) in the state of Gujrat and lowest (636 kg ha^{-1}) in Assam with an overall national average being of 1458 kg ha^{-1} which is the actually harvested yield and is commonly a fraction of the attainable yield of 2500-3000 kg ha^{-1} because the important factors causing low and fluctuating production of mustard in India are low or non-adoption of package of improved production technology, susceptibility of mustard varieties to pest and diseases and non-adoption of pest and diseases management practices.

Among several insect pests of mustard aphid (*Lipaphis erysimi*) is the key pest and five others viz, sawfly (*Athalia lugens proxima*), painted bug (*Bagrada hilaris*), leaf miner (*Chromatomyia horticola*), cabbage butterfly (*Pieris brassicae*) and Bihar hairy caterpillar (*Spilosoma obliqua*) are assumed to be of regional and sporadic importance (Kolte, 1985; Bakhetia *et al.*, 2002). Among diseases white rust (*Albugo candida*), Sclerotinia rot (*Sclerotinia sclerotiorum*), Alternaria blight (*Alternaria brassicae*) and powdery mildew (*Erysiphe cruciferum*) are the major diseases, which reduced the yield potential of rapeseed mustard substantially (Chattopadhyay *et al.*, 2015). The loss in yield may depend upon the nature of the pest and severity of attack. In India, mustard is predominately grown in which integrated pest management (IPM) is urgently required. ICAR-National Research Centre for Integrated Pest Management (NCIPM) has been working on synthesis and validation of IPM in mustard over few decades. Extensive surveys of mustard growing areas revealed that excessive and injudicious use of chemical pesticides and fertilizers have aggravated the pest menace, secondary pest outbreaks and caused environmental degradation. Recently a holoparasitic weed Broomrape (*Orobanche aegyptica*) has emerged as a serious pest in mustard.

Key Pests of **Mustard Aphid** (*Lipaphis erysimi*): This is a major pest of mustard. It causes loss to the crop from December to March. This insect can cause

loss from 25 to 40 per cent. Both nymphs and adults suck cell sap from leaves, stems, inflorescence and developing pods, as a result plants remain stunted, reduced pod and grain number, pod shrivel up and seed do not develop. Economic threshold level of this pest is when pest population reaches 20-25 aphids/ plant and when 30 per cent plants are infested.

Painted Bug (***Bagrada hilaris***, cruciferarum): This pest attacks the crop at two stages in the season *i.e.* at initial stage in October-November and crop maturity stage in March-April. The nymphs and

adults suck cell sap from leaves and pods, which eventually wilt and dry up. This insect also reduced the oil quantity by sucking pods, pods shrivel up and seed do not develop.

Alternaria blight: In mustard crops, this disease is mainly caused by Alternaria brassicae. However, other species of Alternaria that is, *A. brassicicola, A. raphani* and *A. alternata* have also been reported parasitizing these crops in India. This is widely distributed, more destructive and most

damaging disease under epiphytotic conditions, causing yield loss up to 70 per cent. Heavy losses in yield occurs if favorable conditions like an average

temperature of 18oC with relative humidity 80 percent or above and stormy weather prevail especially during flowering and pod development stages. The shrivelled and discoloured seeds fetch lower market price. The disease is characterized by formation of brown colour concentric rings on leaves, stems, siliquae and pods. *Alternaria brassicae* survives on diseased plant debris in the soil and many alternate cruciferous hosts like, cauliflower, cabbage, turnip, radish etc.

White rust: This is a common disease of mustard caused by fungus *Albugo candida* and attacks all the plant parts except roots. The disease appears as prominent white creamy scattered raised and roundish pustules on the under surface of lower leaves. Many pustules coalesce and form large patches which cover entire lower surface of the leaf. This disease when

appears on stag head phase distorts inflorescence, where it causes hypertrophy and hyperplasia causing 17-34 per cent loss in yield. White and creamy pustules also appear on the hypertrophied parts.

Sclerotinia rot: *Sclerotinia* rot caused by fungus *Sclerotinia sclerotiorum* is the major pest in mustard. Its infection at early stages of plant growth results in complete failure of the crop whereas late infection lowers the yield quantity and quality as well. Disease increases with mono-cropping of mustard. In individual affected plants some time no grain is formed. In recent years, *Sclerotinia* rot has emerged

as major pest in mustard in North India. The extent of damage is 40 - 80 per cent in Haryana and Punjab. The disease appears as elongated, buff to light brown water-soaked lesions, which later rot and are covered with white, cottony mycelial growth of the fungus. All the affected parts of the plants rot in cool and wet weather. The affected plants show stunting and premature ripening, shredding of stem, wilting and drying. A large number of black sclerotia appear in fungal growth around the rotted stem. The sclerotia survive in the soil for longer period.

Powdery mildew caused by *Erysiphe cruciferarum* is a disease of warmer and drier tracts, where mustard is grown. The disease is gradually

becoming common with shortening of winter and climate change. The disease usually arrives in later part of crop. However, it is also observed during vegetative stage, whereby the pathogen could cause significant loss to the crop.

Broomrape (*Orobanche aegyptica*): Mustard crop in Haryana over large area has been severely

infested with holoparasitic weed broom rape, which has threatened the cultivation in these areas. This parasitic weed grows on the roots of mustard plants in response to germination stimulants secreted by its roots and looks like a beautiful plant. As infestation of this weed starts after 7-10 days of sowing of oilseeds Brassica. So, control measures in early stages of crop growth should be applied.

IPM Interventions in mustard at different growth stages of the crop

IPM is a systems approach that combines a wide array of crop production and protection measures to minimize the economic losses caused by pest. Hence, use of low or judicious dose of pesticides, integrated with other means like growing pest tolerant cultivars, sanitation, crop rotation, use of bio-agents and plant extracts seems to be best method of pest management without environmental pollution. ICAR-National Research Centre for Integrated Pest Management, New Delhi conducted multilocational field trials of IPM technology of mustard in farmers' participatory mode in Haryana and Rajasthan. Based on which IPM interventions at different growth stages of the mustard crop were developed which are as follows:

Pre-sowing stage

- Deep summer ploughing the soil to expose the soil-borne pathogens and to destroy egg of painted bug in order to reduce the primary source of inoculum.
- Preparation of level and well drained field to ensure proper drainage of water.
- Follow appropriate crop rotation and balanced dose of fertilizers as per location specific recommendation.
- Sesbania green manuring along with soil incorporation of mustard waste @ 2.5 ton/ha in Kharif season.
- Removal of pest debris and residue of previous crop to reduce the soil-borne inoculum of diseases. Painted bug also thrives on crop residues and weed.

Sowing Stage

- Soil incorporation of Trichoderma based product @ 2.5 kg/ha pre-incubated in 50 kg of well rotten farm yard manure to reduce soil-borne inoculum of diseases.
- Sowing at proper time (01-31 October). It escapes the attack of aphid, painted bug and white rust.
- Use of disease resistant hybrids and varieties recommended for the region.

- Seed treatment with freshly prepared aqueous garlic bulb extract (1% w/v) or Trichoderma based product @10 g/kg.
- In case of downy mildew infection, the disease is brought under control by treating the seeds with metalaxyl-M 31.8% ES @ 6 ml/kg seed.
- Avoid narrow spacing/ heavy seed rate.

Seedling and Vegetative stage

- Maintain recommended spacing of plants by thinning of crop.
- Irrigation of crop at seeding stage to protect against painted bug.
- Maintenance of weed free crop by clean cultivation.
- Regular monitoring of crop and destroying of pest infested/ infected plants.
- Spray application of micronutrients like boron and zinc are also very useful practice in pest management.
- Judicious use of irrigation depending on soil type and rain fall. Irrigation after vegetative stages should preferably be avoided.
- Hand picking of aphid-infested twigs in the initial attack.
- Conservation of natural enemies of Aphids namely *Coccinella septempunctata*, *Chrysoperla carnea*, *Syrphid fly*, etc.
- Application of two drops of soybean oil per young shoot of *Orobanche* reduced the infestation.
- Removal of heavily diseased plants from the field and apply need-based spray of freshly prepared aqueous garlic bulb extract (2% w/v).

Flowering and Pod formation stage

- Regular monitoring of crop field.
- Foliar spray of freshly prepared aqueous garlic bulb extract @ 1% (w/v) at early bloom.
- If mustard crop is sown late and fertilized excessively with nitrogen, the crop tends to get affected more severely by diseases but can be protected from major diseases by spraying the crop at flowering-to-early pod formation stage with a mixture of metalaxyl 4 % and mancozeb 68%.

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Integrated Pest Management (IPM) for Sustainable Agriculture

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Integrated pest management (IPM) is not a new philosophy. The concept has been around since the 1920's when a cotton pest management program was developed. However, the development of inexpensive pesticides caused us to get on what is commonly referred to as the "Pesticide Treadmill". That is, because these new pesticides were extremely effective and inexpensive, we used them as the answer to all pest problems. The overuse of these pesticides causes specific problems like:

Insecticide resistance

Resistance to insecticide is a serious and growing problem in pest management. Worldwide, more than 600 species of pests have developed some level of pesticide resistance against different formulation of insecticides.

Secondary pest outbreak

By using a broad-spectrum insecticide to control a pest, it inadvertently kills beneficial insects which would normally keep another pest under the economic threshold. This "secondary" pest is then able to multiply rapidly and it then becomes a significant pest.

Biomagnification

Biomagnification, also known as bioamplification or biological magnification, is the increase in concentration of a substance, e.g a pesticide, in the tissues of organisms at successively higher levels in a food chain. Some pesticides started to bioaccumulate in nature. High levels could be found in fish, birds, and mammals (including humans). For example, DDT caused sharp population declines in predatory birds such as the bald eagle.

Insecticides are not the only solution for agricultural pest management. Although many ecofriendly methods are incorporated in to an IPM program.

There are so many definitions of IPM but according to FAO "Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms."

IPM is a philosophy. That is, we recognize that there are no cure-alls and/or cheap and easy methods to manage pests. Reliance on a single tactic will favor pests that are resistant to that practice. For example, relying on single group of insecticides to manage the sucking pests can results in development of resistant pest species against that particular group of insecticides.

Identify and correct the cause of the pest problem

Instead IPM stresses reliance on preventative management practices and balances the strengths of one practice against the weaknesses of another to provide a more complete or holistic pest management approach. Rescue (should rescue treatments be defined, or is it apparent?) treatments are used only if the preventative practices fail. For example, a preventative practice might be planting a okra leafhopper resistant variety. Only when leafhopper populations are extremely high will an insecticide treatment may be required. Hopefully, by planting the leafhopper resistant variety you might not spray for leafhoppers during the season. Another example is that proper weed control may create an environment which insect to not find attractive. Therefore, by controlling weeds within your fields you may also avoid some insects.

The eradication of a pest is seldom necessary or even desirable, and is generally not even possible. IPM realizes that some pest damage is acceptable. We must focus on economics before implementing any management techniques. We should only initiate management techniques when the cost of management is lesser than the amount of damage expected.

With IPM we can:

- Monitor pests to see when they are present and make sure control is cost-effective
- Trick and Avoid pests by planting or harvesting early or late
- Trick pests by using pheromones (attractant smells) to disrupt their mating or trap them
- Trap pests by planting attractive plants on the edge of the crop field—then destroy them
- Use special plants to attract parasites & predators to the crop field—so they kill pests
- Induce an 'immune response' in crop plants—so they repel or kill pests
- Apply special plant extracts, microbes and parasites—so they repel or kill pests

Pesticides vs IPM

IPM doesn't means that it can't include use of pesticides in management techniques. In some agro systems, they are a very important part. Some pests because of sheer numbers, continuous occurrence, low thresholds or because of food contamination issues dictate pesticide use. However, it can be used as a last resort, when all other management techniques, including preventative techniques, have failed or are no longer economical. Pesticides are to be used when there is no risk of environmental damage or when benefits outweigh the risks. Pesticides only used when other control practices aren't available or economical.

Monitoring of pest population

Prior to including any insecticides in pest management programme, fields must be monitored to make sure that:

- The pest is properly identified
- It is present in economical proportions, above the ETL (Economic threshold level)
- Is at a life stage that is susceptible to the pesticide
- Present at a crop stage when there is "preventable yield loss".

Generally, Pheromone trap, sweep net, square meter frame, water pan, Sticky trap, sphere trap, sieves and light traps are used for the monitoring of pest.

Important agronomic practices optimize growing conditions for the crop

- Deep summer ploughing to expose the hibernating pest in the soil and also increases the aeration in the soil.
- Application of fertilizers on the basis of recommendation that can give the crop a competitive edge over weeds
- Proper plant spacing (row to row and plant to plant) is also important. A dense crop canopy will shade the ground making emerged weeds less competitive and also preventing germination of more weeds and reduces weed seed production for subsequent years.
- Sowing/Planting time- Time of sowing/planting is very important. Early sowing of Indian mustard avoids attack of aphids.
- Selection of variety is necessary so that it can compete with the population of pest (germinate early and provide rapid early season growth).
- Use of trap crops to protect the main crop (In cotton trap cropping should be done with crops like okra, castor, marigold, *Nicotiana rustica* so the pest feeding on these, should be periodically removed or killed).
- Proper weeding and sanitation should be done, some pest prefer to lay eggs on grassy weeds, by removing these grassy weeds we can avoid problems of pest.

Natural control of pest to enhance the population of natural enemies

Natural enemies of insects play an important role in limiting the densities of potential pests. An example is to spray an insecticide for mustard aphid control only, when it is economically feasible and it is apparent that natural enemies will not control the aphids. Lady bird beetle and syrphid fly population was found in large number in mustard, in this case do not use insecticides to kill aphids. Once natural enemies are removed from the field, the pest may increase at a much faster rate

Biological Control of pests

Biological Control refers to the introduction of a predator, parasite or pathogen (disease) to control a pest. One of the most significant successful examples of classical biological control is the, control of papaya mealy bug *Paracoccus marginatus* through the introduction and field releases of exotic natural enemies. The indigenous natural enemies like *Spalgis epius, Cryptolaemus montrouzieri* and *Scymnus coccivora* could not keep the papaya mealy bug population under check. Three species of exotic parasitoids, *Acerophagus papayae*, *Pseudleptomastix mexicana* and *Anagyrus loecki*, which were known to effectively suppress the papaya mealy bug in its native range, were imported from USDA-APHIS in Puerto Rico.

Major Obstacles in IPM

- Low awareness and innovativeness of extension personnel and target groups
- IPM requires a higher degree of management, Making the decision not to use pesticides on a routine or regular basis requires advanced planning and higher degree of management. This planning includes history of pest problems, selection of variety and other agronomic practices plan.
- Inadequate interaction between research and extension agencies
- Problem of timely and adequate supply of quality inputs, including Bio-control agents and biopesticides.
- Complexity of IPM *vs* simplicity of chemical pesticides
- The dominant influence of pesticide industry
- Non-availability of location-specific IPM modules for many crops
- IPM adoption is influenced by the cost versus efficacy of products, need for sophisticated information for decision making, ability to integrate new products and techniques into existing farm management practices and managerial skills.

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Stingless Bees: Their Ecological and Economic Significance

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The stingless bees are closely related to carpenter bees, orchid bees, bumble bees, and real honeybees. They are members of the Apidae family. Stingless bee is the smallest (4.0 to 5.0 mm long) bee among all the bees under Apidae. On contrary to *Apis* honeybees, the sting in stingless bees is atrophied in size and does not sting, but they defend themselves by biting when their nest is disturbed. Meliponiculture is the name given to the centuries-old practise of beekeeping using stingless bees that is carried out around the world. In India, Sri Lanka, and Nepal, stingless bees have also been kept for millennia despite little research in these countries (Crane, 1999; Kumar *et al.*, 2012).

Geographical distribution

Most tropical and subtropical areas of the world, including Australia, Africa, Southeast Asia, and tropical America, are said to be home to stingless bees. They are active all year round, however they are less active in the cooler months. In the Neoptropics upto 60 stingless bee species can be found in a single forest thus showing high local and regional diversity (Roubik, 1989). *Trigona iridipennis* is the widespread stingless bee species in the Indian subcontinent and used for meliponiculture, where colonies have been kept in tree logs, wooden boxes, and clay pots for harvesting small quantities of highly prized medicinal honey, and other hive products like wax and propolis which are used for therapeutic and household uses (Crane, 1999).

Diversity of stingless bees

Stingless bees are a large group of bees (approximately 600 species) comprising the tribe Meliponini. Stingless bees (Sub family Meliponinae) are divided into two tribes: Meliponini and Trigonini which have a large number of genera and sub-genera (Sommeijer, 1999). The tribe Meliponini comprises 23 genera and 18 sub-genera, which consist of 374 recognized species (Michener, 2000). The tribe *Trigonini* includes all species of Asian and African stingless bees. The *Trigona*, *Plebeia*, *Tetragona*, and *Nanotrigona* genera are among those in this group. *Trigona*, which has 130 species and 10 subgenera, is the largest and most widespread genus. Around 40 species of medium to large-sized bees in the genus Melipona are found exclusively in the Neotropics (Camargo *et al.*, 1988). *Trigona* has been split up into nine smaller genera and *Trigona* bees have all been placed in a genus called *Tetragonula* (Patricia *et al.*, 2013). Approximate numbers of species so far identified were 50 species in Africa, 300 species in the Americas, 60 species in Asia, 12 species in Australia and 4 species in Madagascar (Bradbear, 2009). Local and regional diversities are high in the Neotropics, where up to 60 meliponine species can be found locally in a single forest (Roubik, 1989). Stingless bees native to Brazil are represented by more than 200 species (Silveira *et al.*, 2002).

Nesting structure

They are social insects that live in colonies, much like honeybees. With hundreds or thousands of workers, the stingless bee colonies are perennial in nature. They build their nests in dark areas like hollow logs, tree trunk cavities, cracks in old walls, etc., where the nest entrance typically projects as an external tube. They prefer enclosed structures over open ones for nesting. The nest of stingless bees consists of entrance, cerumen, batumen, involucrum, storage pots and brood cells. Cerumen is a resin material mixed with wax. The wax of the stingless bee has a higher melting point compared to the wax of honey bees (*A. mellifera*) In a higher concentration of the wax than resin, the texture of the nest becomes harder. The waxy nest can furthermore be hardened by mud to make batumen, which provides excellent insulation especially with the exposed nests (Michener, 2007). Batumen and cerumen are used to protect the inner part of the hive. While involucrum is cerumen layer located around the brood cells to protect the nest from predators and parasites. Nests in large trunks or in underground dwelling inside soils are particularly well insulated (Michener 2007). The production of a new individual begins with cell construction. In cases where there are cell clusters, more brood cells are added to the edge of the nest or the edge of the comb. The brood cells are

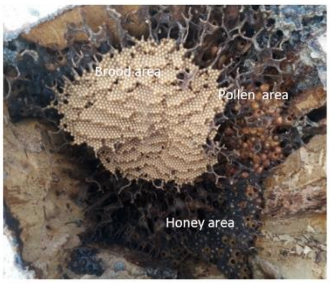

Fig.1 Stingless bee colony inside traditional log hive

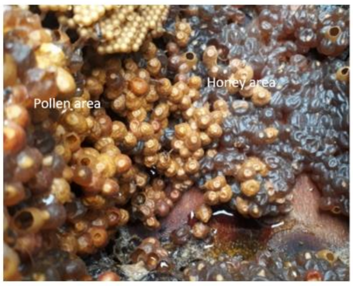

Fig.2. Close up view of honey and pollen pots

Fig.3. Nest entrance to hives

Fig. 4. Stingless bees pollinating cucumber flowers

Fig. 5. Rearing of stingless bees, *Tetragonal iridipennis* in traditional log hives in Jalukie, Nagaland (PC: R.Ch. Sangma)

spherical and organized in horizontal combs surrounded by the involucrum, a covering of waxy sheets that acts as insulation (Sakagami, 1984, Danaraddi *et al*. 2009; Chauhan and Singh, 2019). The involucrum is externally connected with the cavity wall by means of short pillars. There is no interaction between the adult population and the growing larvae in stingless bees. To feed the growing larva of stingless bees, mass provisioning is used, whereas the same are fed progressively with royal jelly and bee bread in case of *Apis* spp (Heard, 1999). The larval broods are darker and larger and pupal broods are smaller and paler in colour. The brownish workers and males were produced in similar cells and both are found in the same combs. Queen cells are elliptical and mostly positioned at the margin of combs. Stingless bees, unlike honeybees of the species *Apis*, store their honey and pollen in separate, spherical containers made of a substance called "cerumen" that is a combination of wax, resin/propolis, and mud. The food storage pots are constructed one over the other or side by side and usually found both at the top and bottom of the nest. The honey pots and pollen pots are larger in size, spherical or oval; and the walls soft, thin and dark-brown. The pollen pots in general are found closer to the brood but at times these are often intermixed. Food pots are sealed when they are filled. The nesting behavior of underground dwelling species. *Lophotrigona canifrons* found in Indian subcontinent are subterranean in nature, located within the bushy forests prevalent at sloppy places engulfing shade, small trees and shrubs preventing light. The entrance tube was found to be made of a mixture of soil, secondary roots and cerumen leading to the nest. The internal nest architecture was found to be covered with scutellum.

Hive products

Honey: Bees gather flower nectar, a mixture of sugars and other minor ingredients, which they concentrate into honey. It is a viscous, delicious fluid that honeybees make. It is gathered as nectar from nectarines at the base of flowers and plant parts other than flowers known as extra floral nectaries. Stingless bees only produce certain species-specific types of honey. Stingless bees store their aromatic honey and pollen in clusters of small spherical resin pots separately, prepared by using a mixture of wax, resin/propolis and mud called as “cerumen” near the extremities of the nest. That’s why their honey is also known as pot honey. A unique blend of sweet and sour with a hint of fruit characterizes the taste of stingless bee honey. The taste, which is derived from plant resins that bees use to construct their hives and honey pots, fluctuates throughout the year depending on the flowers and trees visited. The honey of stingless bees has darker color, more acidic taste and contains higher phenolic compounds (Kek *et al*. 2014). Antioxidant flavanoids are abundant in the honey of *T. iridipennis*. Approximately 600–700 grams of honey are produced per year, which is a little amount. Researchers from the University of Queensland discovered in 2020 that certain stingless bee species in Australia, Malaysia, and Brazil produce honey with trehalulose, a sugar with an unusually low glycaemic index (GI) in comparison to glucose and fructose, the two main sugars that make up conventional honey. Humans benefit from such low glycemic index honey because it does not raise blood sugar levels, which would otherwise prompt the body to produce more insulin. This type of honey is scientifically supported as providing therapeutic value to humans as well.

Propolis: Propolis is used by honey bees to construct their hives as well as to sterilize and disinfect the cavity that contains the colony. Propolis production by stingless bees is higher than that of honey bees. Propolis from *Tetragonula iridipennis* exhibits remarkable pharmacological qualities. *T. iridipennis* collects propolis to strengthen its nest, but humans have harvested it and found it to have a wide range of medicinal properties. Propolis exhibits notable antibacterial and antiviral properties.

Stingless bees in pollination of crops

The majority of eusocial bee species, including honeybees, stingless bees, and bumble bees, visit flowering plants and are important pollinators of crops (McGregor, 1976; Roubik, 1995). The honeybee, *Apis mellifera* L., is regarded as the primary pollinator of numerous crops due to a number of significant characteristics, including the high number of individuals per colony and its capacity to recruit numerous workers to visit rich resources. However, in tropical areas, stingless bees (Meliponini) are significant pollinating agents of numerous native plant species (Roubik, 1995). Their small size allows them to have access to many kinds of flowers whose openings are too narrow to permit penetration by other bees and they are common visitors to flowering plants in the tropics (Heard, 1999). Stingless bees gather pollen and nectar from a variety of plants since they are true generalists. Up to 100 plant species may annually provide floral rewards to a single species. Recent research shows that stingless bees are an efficient substitute for honeybees for the pollination of many greenhouse plants of considerable economic and social importance, such as strawberries (Malagodi-Braga and Kleinert, 2004), capsicum (Occhiuzzi, P. 2000), tomatoes (Macias *et al*., 2001), watermelons (Chauhan and Singh, 2021) etc. Stingless bee pollination produced greater fruit set and healthy fruits than other methods.

Conclusion

Thus, from the above we can see that Stingless bee keeping, also known as meliponiculture, is a sustainable activity that does not harm the environment, provides valuable products, such as honey, propolis, pollens etc. which has high economic value. This activity generates great benefits to the environment through pollination, which is a service provided by these insects, in a way that contributes to the regeneration of forests and increased biodiversity. Pollination has high economic value, as it is fundamental for the increase productivity of agricultural crops. Meliponiculture is a viable activity and should be popularized among the people of the country especially in rural areas for income generation and increasing yield of their crops through pollination services.

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Cuckoo Bees: Nature's Clever Nest Invaders

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Cuckoo bees, also known as cleptoparasitic bees, that exhibit a unique and intriguing behavior within the world of bees. Unlike typical bees they construct and provision their own nests and take a different approach by parasitizing the nests of other bee species. They are part of the subfamily Nomadinae, within the family Apidae which includes several genera of cuckoo bees. These Cleptoparasitic bees exhibit distinct morphological features, characterized by the absence of structures for pollen collection, as they neither construct nests nor gather pollen for nesting purposes. Their morphology typically includes fewer hairs and a more robust exoskeleton, serving as protective armor during nest invasions. This adaptation helps safeguard cleptoparasitic bees as they infiltrate the nests of other bees, reflecting their specialized lifestyle and unique strategies for survival.

Parasitic Behavior

Cuckoo bees do not build their own nests or collect food for their larvae. Instead, they lay their eggs in the nests of other bees. The cuckoo bee female locates the nest of a host bee species and waits for an opportunity to enter the nest when the host bee is away.

Host Species

Cuckoo bees typically target solitary bee species, such as mining bees or mason bees, as hosts. They are often adapted to the specific host species they parasitize, ensuring that their eggs are laid in a suitable environment for the development of their larvae.

Egg-Laying

After entering inside the host nest, the cuckoo bee female lays her eggs in the cells where the host bee has laid its eggs. The cuckoo bee eggs usually hatch earlier than the host bee eggs, and the cuckoo bee larvae consume the provisions left by the host bee for their own development.

Ecological Significance

The cuckoo bee's parasitic behavior plays a crucial role in the ecosystem by influencing the dynamics of host bee populations. This interaction between cuckoo bees and their hosts contributes to the balance of bee communities, shaping the distribution and abundance of various species.

Mimicry

Some cuckoo bee species exhibit mimicry, resembling the appearance of their host species. This mimicry can help them infiltrate host nests more effectively.

Short Adult Lifespan

Adult cuckoo bees typically have a shorter lifespan compared to other bee species, as they do not engage in foraging activities.

Life cycle

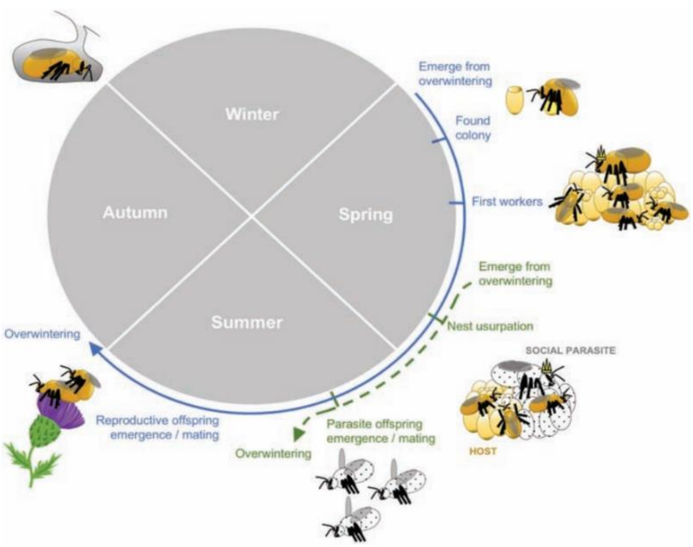

Fig 1: The life cycle of social (solid line) and cuckoo bees (dashed line)

Social bee queens undergo a solitary phase, emerging alone from hibernation in early spring. Upon finding a nest, they provision their initial worker brood. Once these workers emerge in mid- or late spring, they assume the responsibilities of nursing and foraging for subsequent worker generations. By the end of summer, the colonies shift focus to producing reproductive males and females (gynes). These solitary gynes leave the nest, mate, and enter hibernation in early autumn. Cuckoo bumble bee females have a later spring emergence and typically take over nests once the first batch of host workers is produced. Their life cycle is considerably shorter, primarily involving the production of reproductive males and females from early to mid-summer. Similar to their host counterparts, these solitary gynes leave the nest, mate, and hibernate.

Conclusion

Cuckoo bees play a unique role in the ecosystem by taking advantage of the nesting efforts of other bee species. While they may seem parasitic, they are an interesting aspect of the diverse strategies employed by different bee species for reproduction and survival.

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