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A REVIEW

Bioecology and management strategy of diamond back moth (*Plutella xylostella* L.)

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ABSTRACT

Cauliflower crop suffers heavy damage caused by numerous insect pests such as crucifer Leaf webber, leaf caterpillar, diamondback moth, borer, semi-looper, flea beetle and tobacco caterpillar etc., which are of economic concern. Among these, DBM is the most serious pest of the cauliflower and cabbage in this area and in most parts of the world. This insect is known to vary to a great extent in respect of habitat and mode of feeding. Hence, the selection of an insecticide and mode of their application to control DBM larvae on different host crops also vary. Efficaey of various chemicals in controlling DBM on different host crops has been widely discussed by many workers in the past. The synthetic chemicals that were initially effective against DBM were found to fail after few continuous applications. Indiscriminate use of every synthetic insecticide for controlling DBM has led to development of resistance in this pest. It is because of this, it built physiological dominance of detoxifying the xenobiotics and the DBM has attained worldwide importance. Therefore, judicious use of these promising bio-rational insecticides as a component of DBM management strategy on various host crops will be of paramount significance.

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INTRODUCTION

Vegetables are the important source of proteins, carbohydrates, vitamins and minerals contributing a significant role in nutritionally balanced diet of predominantly vegetarian population of our country. Their importance as protective food and as suppliers of adequate quantities of most essential life saving materials like vitamins, dietary fibre and drugs is well known throughout the world. Besides their greater potential to enhance the nutrition, large scale farming of vegetables also increase the income of rural and urban population and provide greater employment opportunities. There is universal recognition that vegetable production, processing and marketing have significant contributions to one's national income.

India is second largest producer of vegetables in the world next only to China. The daily per capita consumption of vegetables in India is only 135 g which is much less than the requirement of about 285 g for a balanced diet (Majeed and Nage Gowda, 1992).

Productivity of cruciferous crop :

More than 50 varieties of vegetable crops are grown in India of which cruciferous group of vegetable crops are most important in terms of nutritional and economic significance. Some of the important and extensively cultivated botanicals of this group in our country are, cabbage (*Brassica oleracea* L. *var. capitata*), cauliflower (*Brassica oleracea* L.var. *botrytis*), turnip (*Brassica rapa* L.), carrot (*Daccus carota* L.) and mustard (*Brassica campestris* L. var. *toria* and *Brassica campestris* L. var. *sarson*). Among all these cruciferous crops, the cabbage and cauliflower occupy the first position in terms of yield and export orientation and the availability of time has been considerably extended with the development of tropical hybrid varieties. However, the yield potential of cabbage is very low in our country as compared to other countries. Out of these, cauliflower is one of the most important winter vegetables in India.

Losses due to diamond back moth :

One of the major constraints for not attaining higher yields in crucifers is the damage caused by insect pests that attack at various growth stages of the crop. It is believed that more than 40 per cent yield loss is caused due to direct pests attack in different vegetables and also make most of the left over crop produces as unfit for human consumption. Among all, the insect pests that attack crucifer vegetable crops, the diamondback moth (Lepidoptera: Plutellidae) is one of the major constraints in the profitable cultivation of cole crops. The pest occurs in endemic form with high population densities on early and late sown cauliflower. In case of severe infestation, the growing hearts are also damaged, affecting the production of marketable curds (Arora, 2003). The annual cost for managing this pest is estimated to be U.S. $ 1 billion (Talekar, 1992). In India, DBM was first recorded in 1914 on crucifer vegetables (Fletcher, 1914). It is now found to be the most devasting pest in major cole crops growing areas of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, Maharashtra, Tamil Nadu and Karnataka. Among several cultivated vegetable crucifers, cabbage and cauliflower are the most preferred host plants for DBM and introduction of early and late maturing varieties for intensive cultivation of both involving more number of crops in sequence during a year, provide a continuous food supply to DBM thereby increasing the pest incidence. The loss in yield caused by the pest varies from 31–100% (Lingappa *et al.*, 2006). It was estimated that at least 52 per cent loss in marketable yield was due to DBM attack alone and loss could be more if the attack was severe (Chelliah and Srinivasan, 1986).

Insect management :

The control of *P. xylostella* has been depended primarily and extensively on the use of insecticides recommended for the last over forty years. However, the promiscuous use of a number of commercial insecticides led to the development of resistance in this pest in most countries of Southeast Asia (Georghiou, 1990). Many factors like pronounced cultivation of early and late varieties of cauliflower, intensive use of conventional insecticides, and prospects of the higher value of the crop during off-season have been outlined for its extraordinary propensity to develop resistance to all classes of compounds.

There are three main reasons for intensive use of insecticides on cruciferous crops.

– Firstly, in many countries synthetic insecticides are used to control DBM, which often eliminate natural enemies. This, in turn, can lead to continued intensive use of insecticides in the absence of natural enemies that cause eventual insecticide resistance and control failure (Sayyed *et al.*, 2002).

– Secondly, DBM is highly migratory (Chapman *et al.*, 2002) and may attain a pest status in a region where its biological control agents (BCAs) are naturally absent and farmers have to rely on insecticides for its control.

– Thirdly, consumer pressure, *i.e.* pest damaged/ contaminated produce is not acceptable in the market and farmers attempt to grow pest-free vegetables with the use of conventional insecticides.

In certain intensive vegetable growing parts of Asia including Malaysia, Indonesia and Thailand, cabbage and cauliflower growers commonly apply insecticides after every 3–5 days with a total of 12–16 applications in a crop growing season of 80–85 days. It is also common practice to produce at least four sequential crucifer crops, resulting in 60 or more insecticide applications on *P. xylostella* in a calendar year (Samsudin *et al.*, 2004). Indiscriminate use of various pesticides has resulted in the evolution of resistance in more than 500 species of insects in the last 100 years (Mota-Sanchez *et al.,* 2002).

Utilization of conventional synthetic insecticides posed certain problems such as adverse effects on natural enemies, development of resistance in target pests and pest resurgence. Hazardous implications of these pesticides and their residue at various trophic levels have also caused incalculable damage to every aspect of environment, globally. As a result, efforts are on to replace those hazardous chemicals with the compounds of relatively safe to non-target organisms and easily degradable in the environment causing no ecological imbalances. In search of alternate strategies for chemical pest control the importance of natural compounds of plant origin was realized and the present day emphasis on "treck back to nature", low input sustainable agriculture and pesticide free organic farming has brought the botanicals once more in the frontline, which were abandoned in the later part of 1930's largely due to the discovery of synthetic organic insecticides.

Mechanism of resistance :

Diamondback moth (*Plutella xylostella* L.) has become the most destructive insect- pest of cruciferous plants. Such as cabbage, cauliflower, knol-khol, radish, turnip, beet-root and mustard that contain mustard oil and their glycosides and are mostly attractive to this pest for feeding and reproduction (Hillyer and Thorsteinson, 1971). The glycosides sinigrin, sinalbin and glucocheriolin act as specific feeding stimulants whereas sulphur containing glucosinolates such as allyl-iso thiocynates act as oviposition stimulants (Reed *et al.,* 1989). Among several crucifer crops that contain these stimulants, the pest exhibit a marked preference to cabbage and cauliflower probably due to the fact that they possess fleshy and succulent leaves coupled with olfactory and gustatory stimuli for successful host selections and development as compared to rest of the crucifer crops (Singh and Singh, 1982).

The females of diamondback moth start laying eggs soon after the mating, normally at dusk of the same day of emergence, preferably in cancavities of leaves rather than on smooth surface. Neonates soon after emergence start feeding on foliage. The first instar larvae mine in spongy mesophyll tissues, whereas the older larvae feed from the lower leaf surface and usually consume all the tissues except the wax layer on the upper surface.

Chemical control

A high degree of resistance to pyrethroids, organophosphorus, insect growth regulators and newer molecular insecticides has been reported in this pest from various parts of the world. In earlier days, the susceptibility of diamondback moth to above group of insecticides was good but later on over use or continuous use of these insecticides, the pest become tolerance or resistance it has been observed by various workers in all over the world.

The resistance ratios for the synthetic pyrethroids tested were highest compared to organophosphorous and carbamate insecticides. The field strain showed very high degree of resistance 27,848 and 2,814 folds to both fenvalerate and deltamethrin (Chawla and Joia, 1992). Saxena *et al.* (1989) recorded resistance levels of 144-fold against cypermethrin at Panipat (Haryana), 178-fold against fenvalerate at Ranchi (Bihar), 191-fold and 115-fold against deltamethrin at Delhi and Bangalore (Karnataka), respectively in DBM larvae whereas Joia *et al.* (2005) reported higher level of resistance *i.e.* 2986, 3516, 3050 folds in cypermethrin, fenvalerate, deltamethrin, respectively. Since truly susceptible populations of the insects were not available, the resistance ratios of different populations have been calculated through employing experimentally determined LC_{99} values with the recommended doses of insecticides used in the field. However, resistance to permethrin was studied about the exposure of 3rd instar larvae of *P. xylostella* to discrete deposits of uniformly sized spray droplets. The result showed that the resistance levels of larvae of DBM to deltamethrin and methamidophos was 4-47 and 2-9 folds compared to a susceptible laboratory strain, respectively. However, no resistance to cartap was detected (Branco and Gatehouse, 1997). Organophosphorous insecticides are known to induce varying levels of resistance in DBM because of their highly diverse molecular structure.

A laboratory selection of a susceptible strain of diamondback moth, *Plutella xylostella* L, with methyl parathion resulted in > 2,600–fold resistance to this insecticide and nearly 500-fold cross resistance to parathion. Significantly higher glutathione S-transferase activity towards 1,2-dichloro-4-nitrobenzene was detected in the strain selected with methyl parathion. The increase of microsomal oxidase activity towards 7-methoxyresorufin in the parathion- selected strain was significant as compared with that in the susceptible strain. Nevertheless, in view of the extents of resistance, increase of these two detoxifying enzyme activites was quite limited and did not appear to account for the observed resistance (Kao *et al.*, 1989). Whereas, resistance levels to six insecticides of organophosphorus was tested by using leaf residue bioassay methods. Among the insecticides *viz.,* endosulfan, monocrotophos, malathion, acephate, carbaryl and cartap hydrochloride tested, high resistance was recorded in monocrotophos (Sannaveerappanavar and Virktamath, 2006). However, 19.9 and 15.1 folds of resistance were observed to malathi on and endosulfan, respectively (Lal and Kumar, 2004). Joia *et al.* (2005) observed the resistance level of diamondback moth to quinalphos and chlorpyriphos was 218 and 38 folds, respectively. However, moderate resistance levels were observed in chlorphyriphos, triazophos, profenofos and dichlorvos against DBM larvae (Sannaveerappanavar and Virktamath, 2006).

The resistance mechanism of diamondback moth to insect growth regulators like teflubenzuron, chlorfluazuron etc., has also been observed in various parts of the world. The resistance mechanism was observed in a laboratory and field selection larvae of DBM with chitin synthesis inhibitors. The larvae of 20 generations or more resulted in only 8-12-fold resistance to teflubenzuron, a benzoylphenylurea (BPU) that interferes with chitin synthesis. Selection of larvae with teflubenzuron caused the diamondback moth to develop considerable resistance to the ovicidal effect of this compound. Piperonyl butoxide, an inhibitor of microsomal oxidases, restored the effectiveness of teflubenxouron against larvae and eggs of the selected strains, indicating that microsomal oxidation was the major resistance mechanism.

In last decade various newer molecules were identified to control diamondback moth, *Plutella xylostella* L. in all over the world. Initially they have given good control over DBM larvae, later on those chemicals also showed lower efficacy to laboratory and field populations. Among the newer molecular insecticides, acetamiprid is the primary insecticide for DBM control from 1999–2001. Ninsin and Miyata (2003) recorded a slight resistance in diamondback moth (DBM) *Plutella xylostella* L. from cabbage fields in Japan. However, it may increase the resistance levels in future. To retard the progress of acetamiprid resistance, growers rotate acetamiprid with other insecticides. Thus, we, evaluated the efficacy of five other insecticides to identify efficacious products to be used with acetamiprid. Results indicated that the population was moderately resistant to fenvalerate and phenthoate, and tolerant to cartap.

The field collected strain of diamondback moth, *P. xylostella* was taken for monitoring the resistance to spinosad. After 26 generations 22.4 fold of resistance was observed when compared with susceptible strain.

The recent investigation showed that the larvae of DBM developed 1078 –fold of resistance to analogs of avermentins, ivermentins and emamectin benzoate. It had more than 1000 times greater resistance when compared with the avermectin-susceptible strain (Hu *et al.*, 2008)

Alternate strategy to overcome the insecticidal resistance in *Plutella xylostella* (L.) :

The various works have been done by researchers of all over the world in insecticides resistance management strategy. Using bio-rational insecticides to control the DBM populations is one of the alternate strategies to over come the synthetic insecticide resistance.

The *Bacillus thuringiensis* treatments along with tolerant cultivar give better control over the DBM larvae (Creighton *et al.*, 1981) whereas better control was achieved when Dipel was sprayed in combination with chloridimiform, both at 0.25 kg a.i/ha. (Krishnaiah *et al.,* 1981). Garcia (1991) viewed that *Bt*.var.*kurstaki* and deltamethrin gave the better results than diazinon on controlling DBM larvae. The efficacy of the Pyrethroids and Carbamates against DBM was poor probably due to insecticide resistance. Whereas, Sharma *et al.* (2000) conducted field trials in india to determine the efficacy of three formulations of *Bt*. subsp. *kurstaki*, (Bioasp and Biolep, each at 1.0, and 2.0 kg/ha) and Halt at 1.0 kg/ha against DBM on cauliflower. Efficacy was compared with that of cartap hydrochloride 50 WP, Dichlorovos 75 WSC and Malathion 50 EC. Biolep and Bioasp at 2 kg/ha gave the highest larval morality, which was statistically similar to that was obtained with Cartap hydrochloride 50 WP at 1 kg/ha. Applying *Bt* also helped to conserve predatory coccinellids. However Ali and Bakshi (1994) evaluated the different management strategies for *P. xylostella* on early and late crops of cabbage and concluded that the fortnightly sprays of Thuricide at 1 ml/litre reduced the pest populations. Whereas, Krnjajic *et al.* (1997) evaluated the efficacy of combination of three biological control agents (*Bt*., NPV and *Trichogramma evanescens*) for controlling various pests including DBM on cabbage crop, and found that the biological control practices tested by *Bt*. was more effective than NPV against *P. xylostella*. It was also concluded that *T. evanescens* alone could not control cabbage pests and that it gave better results in combination with *Bt.* subsp. *kurstaki*. Nagesh and Shashi (1997) determined that the sequential spraying with *Bt.* formulations and Azardiractin can be recommended to solve the problem of development of resistance in the DBM.

Fagoonee *et al*. (1987) found that the efficacy of neem seek kernel extract (NSKE) against the Yponomeutid *P. xylostella* was satisfactory on the Chinese cabbage field trials. The use of neem extract alternatively with the insecticide gave the best protection against DBM. Good control of DBM was also achieved with neem seed kernel powder and aqueous extracts of neem cake by Dreyer *et al.* (1991). The biorationals like *Bt.* and NSKE treated leaves recorded lesser feeding time and consequently lesser quantities of fresh food of cabbage and cauliflower leaves. Larvae preferentially fed on cauliflower than on cabbage under untreated conditions (Selkar *et al*., 2004). However Soluneem, Econeem plus, Vijayneem, Neemark, Indoxecarb 0.0075 per cent and Fipronil (0.01%) and neem seed kernel extract 4 per cent were evaluated for their efficacy against DBM. Among the treatments Indoxecarb, Fibronil and NSKE were found to be effective in reducing the DBM population and recorded significantly higher marketable cabbage heads followed by Soluneem, Econeem plus, Vijayneem, Neemark (Murthy *et al*., 2006). Again such type of synthetic insecticides showed good efficacy over DBM population in a field trial conducted by Mukherjee and Singh (2006). They studied the eco-friendly approaches to manage *Plutella xylostella* infestation on cauliflower crop with 6 treatments that included spraying of *Bacillus thuringiensis*, neem seed kernel extract and a broad spectrum insecticide endosulfan 35 EC. The results revealed that endosulfan 0.07 per cent was highly effective immediately after application whereas *Bt.* @ 1000g/ha was effective upto 15 days followed by NSKE 5 per cent.

Conclusion :

–All these observations indicate that diamondback moth developed multiple resistances in India and various parts of the world during the 1980 to 2008. Mehrothra (1991, 1993) reported widespread unacceptable control of this pest with current control strategies and expressed concern about the rising importance of this pest at national and international level.

–Indiscriminate use of synthetic insecticides for controlling DBM has led to development of resistance in this pest. In another hand, it leads to environmental pollution, and toxicity to human beings and natural enemies. Therefore, judicious use of promising bio-rational insecticides as an alternate strategy to overcome the above problem can formulate a component in DBM management strategy on cauliflower.

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