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Insecticidal Resistance of Okra Fruit Borer (*Earias vittella*) and its Management

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A B S T R A C T

Insect pest is one of the major *Earias vittella* is one of the important pest of okra and its management is also difficult for its insecticidal resistance mechanism though few chemical and bioagent are effective against fruit borer. Insecticidal like quinalphos, monocrotophos, fenvalerate, deltamethrin, Flubendiamide etc. are effective to manage this insect. Combination of these insecticides is also effective and also able to overcome Insecticidal resistance mechanism. Few biological agent like *Trichogram machllonis*, *T. brasiliensis* etc. also identified as an effective control measure against this pest. But Insecticidal resistance is a bottleneck for its management. Many resistance mechanisms like metabolic resistance, non-metabolic, GST, EST etc. play an important role for its resistance behaviour. However many technique like log dose probit (hlp) assays, dry film technique etc. are being used to identify Insecticidal resistance in *Earias vittella*.

Introduction

Vegetables constitute as one of the important component of our food calander, supplying carbohydrates, vitamins and minerals needed for a balanced diet. Among the vegetables grown in India, okra (*Abelomoschus esculentus* L. Moench.) also known as lady's finger is an important crop grown throughout the year. Though okra finds its origin in South-Africa still India stands top in area and production because of favorable climatic condition. It is grown on an area of 5.33lakh hectare with an annual production 6.34 lakh tons and productivity of 11.9ton per hectare (NHB, 2014). Okra is an economically important vegetable crop which accounts for 21% of total exchange earnings from export of vegetables from India. Insect pests are the major constraint to production of this important export oriented crop.

Several insect pests reducing its fruit yield, the shoot and fruit borer is the most devastating pest and mainly responsible for causing direct damage to tender fruits about

57% fruit infestation and 23-54% net yield loss in okra. *E. vittella* is cosmopolitan species and has been reported on okra and cotton growing areas of the country. It is reported to be more serious in Karnataka, Madhya Pradesh, Gujarat and Maharashtra, where moderate climatic conditions make it breed (Brar *et al.,* 2004).

E. vittella being devastating pest of okra with high damage potential, its suppression becomes inevitable. Use of various chemical insecticides belonging to different classes is in vogue for suppression of this pest but only partial control of this pest could be achieved. indiscriminate and extensive use of these insecticides since past few decades have led to many serious problems like development of insecticide resistance, Resurgence of minor pests, destruction of natural enemies and environmental pollution (Mahapatro and Gupta, 1998).

Though many non-chemical control strategies have been developed under the IPM umbrella, still farmers like to use synthetic chemical insecticides. Due to which *E. vitella* has developed resistance against the conventional insecticides making it difficult to control (Kranthi *et al.,* 2002). After the era of indiscriminate use of synthetic pesticides, inundative release of biotic agents as a means of pest management subsequent to their mass production on a commercial scale has become very popular. *Trichogramma* is one of the impotent bioagent that is extensively exploited for successful management of lepidopteran.

Resistant of pest species exhibit various resistance mechanisms like enhanced metabolism of insecticides mediated by higher titres of detoxifying enzymes, reduced cuticular penetration, reduced sensitivity or altered target sites and behavioural mechanisms (Scott, 1991). The same mechanism of resistance may not always be responsible for populations of pest species even against the same insecticide. Therefore, it is very important to understand the basic mechanisms of resistance present in different species of insect pest against a particular insecticide or group of insecticides. Very complicated resistance mechanisms are exist in *Earias vittella*, but the most important ones is metabolic mechanism. Esterases, glutathione S-transferases and mixed-function oxidases are the most important detoxifying enzymes in the insecticide resistance caused by metabolic factors (Hung *et al.,* 1990).

Materials and Methods

Biology and economic importance of okra fruit borer

The genus *Earias* includes the old world species *Earias* vitella (Fabricius) (Lepidoptera: Noctuidae) 'which is generally considered to be the most important species within the group, *E. vitella*. This insect pest is also found on some of the members of malvaceac family.

The pest status of a particular insect depends on its ability to breed on host plants, cornparative growth rate, fecundity, population dynarnics and distribution. The spotted bollwonns, *E. vitella* (Fab.) and *E. insulana* (Boisd.) are polyfagaous preferences for various host plants and they are known to attack 38 plant Species. However, the preferred hosts have a great influence on oviposition. fecundity, developlnental period and adult longevity (Hiremath, 2004).On the other hand, different components of the environment particularly temperature and relative humidity determined theinsects metabolism and susceptibility to insecticides (Ananthkrishnan, 1999). *Earias vittella*lay spherical eggs, about 0.5mm in diameter, light bluish green in colour, with ridges. A female lays on an average 400 eggs, incubation, larval and pupal period lasts for 3-9, 9-20, and 18-12 days respectively. Single life cycle takes about 22-25 days extending up to 74 days during winter. On hatching, larvae enter fruits and feed on inner contents, the borer is reported to cause about 57% fruit infestation and 23-54% net yield loss in okra (Brar *et al.,* 1994).

Determination of insecticide resistance in *Earias vittella*

It is most importent to understand the insecticidal resistance mechanism of any insect to develop strategic plan to manage them.

Insecticide resistance status in India

Nearly 50% of the total national insecticides consumed are being consumed by cotton crop alone with only 5% of the total cropping area in the country (Ghosh, 2001). Conventional insect pest control strategies are depends majorly on chemical insecticides. Due to heavy use of chemical insecticide many insect species developing resistance to insecticides.

Insecticide resistance in *Earias vittella*

Pesticide resistance is emerging as one of the key constraints to successful crop protection and public health problems worldwide (Dover and Croft, 1984). Although the resistance is a natural mechanism for survival but its development has been accelerated in recent year due to excessive use of chemical pesticides. Insecticides resistance especially to pyrethroids in *Earias vittella* is now common in many okra growing countries. Resistance may create a serious problem crop production and protection. It is therefore, necessary to undertake further studies towards recognition and monitoring of resistance in *Earias vittella* and other insects that are exposed very frequently with insecticides. Kranthi *et al.,* (2002) mansion that in recent days, *E. vittella* the borer has developed resistance against many basic insecticides which makes it difficult to control. Since the produce is harvested at short intervals and consumed fresh in many cases.

Low resistance indicates no problems with field efficacy. Moderate resistance can cause field efficacyproblems just after 1-2 applications of the insecticide in the region (Kranthi, 2005).

It has been observed that fenvalerate (500 g a. i./ha) sprayed five times at 15 days intervals starting from 30 days after transplanting could record significantly lower incidence of *E. vittella* compared to endosulfan 35 EC (525 g a. i./ha) (Brar *et al.,* 1994)

Saini *et al.,* (1989) used dry film technique to study the development of resistance in *Earias vittella* againest fenvalerate and cypermethrin. Results indicate that insect developed 7.8-fold resistance against cypermethrin, whereas no resistance was observed for fenvelerate. Saini and Chopra, 1988, observed differential response in Monitoring of insecticide resistance in field population of *E. vittella* revealed. They reported that two populations from northern India showed high resistance, > 70.0-fold resistance to cypermrthrin. So it may be concluded that cypermrthrin *E. vittella*has developed the resistance macanisom againest cypermrthrin. Again In a susceptibility study in field colonies of *E. insulana* revealed that the LC50 of fenvalerate against colony of E. insldana was 1.5. However later fenvalerate was replaced by its active isomer, esfenvalerate and no difference was observed (Hirano *et al.,* 1993).

In a log dose probit (hlp) assays on *E. vittella* population reflacts that LD50 of cypermethrin, endosulfan, quinalphos, chlorpyriphos and carbaryl to be 0.025, 2.121,0.190,0.112 and 0.669 µg/larva indicating 3.12, 0.95,1.72 and 1.24 fold resistance to cypermethrin, endosulfan, quinalphos and chlorpyriphos, respectively. It also reported that *E. vitella* population from Akola is resistant to cypermethrin, quinalphos and chlorpyriphos as compared to endosulfan. So endosaulfan would be an effactive chemical to manage the same, though moliqule endosaulfan is no longer in use.Akola strain was comparatively more resistant to many insecticides except quinalphos when compared with Amravati, Washim and Nagpur strains. But quinalphos was not vey effactive on Washim strain as they exibite more resistant over the same (7.55 to 12.66-fold) (Satpute *et al.,* 2003). `

Mushtaq and Iqbal, (2009) reported that Resistance label of *E. vittella* field population were very low to low levels againest organophosphorous chlorpyrifos, profenophos, triazophos and phoxim. Again *E. vittella* had no or very low resistance againest new moliquils like spinosad, emamectin benzoate and methoxyfenzoide, a very low to low resistance to abamectin. A very low to moderate resistance to indoxacarb and a moderate resistance to chlorfenapyr. In follow up studies it was further reported that oxidases, which provided resistance by degradation of pyrethroids in resistant individuals, also activate triazophos in its toxic oxon form resulting in a negative cross-resistance (Martin *et al.,* 2003) (Table 1).

Metabolic resistance mechanisms

According to Kitturmath, 2008, increased enzymatic detoxification is the most common insecticide resistance mechanism in insects. In insects the most common type of metabolic resistance is MFO (Mixed-Function Oxidase) mediated resistance (Scott, 1991), though EST (and GST (glutathione S-transferases) are also equally important. Three major detoxifying enzymes, viz., esterases (EST), MFO and GST were found to be involved in the metabolic detoxification of insecticides in many lepidopteran insects (Hung *et al.,* 1990). Many *Earias* trains exhibit both metabolic and non-metabolic mechanisms of resistance against different classes of insecticides.

The non-metabolic resistance mechanisms exhibited by *Earias* include reduced sensitivity of target sites, behavioural resistance (Moore *et al.,* 1989) and reduced cuticular penetration of insecticides (Motoyama *et al.,* 1992).

Resistance associated with glutathione-S-transferases

Detoxifying glutathione S-transferases (GST) are a family of enzymes that catalyze the conjugation of glutathione with electrophilic substrates including insecticides (Soderlund, 1997). These enzymes metabolise insecticides by facilitating their reductive dehydrochlorination or by conjugation reactions (O-dealkylation and O-dearylation) with reduced glutathione to produce water-soluble metabolites that are more rapidly excreted.

According to Vontas *et al.,* (2002), selection of a laboratory colony of the *E. vittella* againest permethrin and cyhalothrin increased its resistance to both insecticides. Studies with specific insecticide synergists have also shown involvement of GSTase in resistance to OP insecticides. Cheng *et al.,* (1992) observed synergistic effect of tridiphane (TDP), an inhibitor of enzymatic conjugation of insecticides with GSTase on mevinphos, profenofos, quinalphos, methidathion, phenthoate and parathion suggesting involvement of GSTase in the metabolism of OP insecticides in OP-resistant populations with higher GSTase activity.

Resistance associated with esterases (EST)

Esterases are frequently involved in the resistance of insects against organophosphates, carbamates, pyrethroids and neonicotinoids. Maa *et al.,* (1990) reported that membranous esterases activities of malathion-resistant larvae were about twice then the susceptible larvae. It also reported that higher esterase activity conferred a major part of the resistance to permethrin and other primary alcohol ester pyrethroids. On the other hand Li *et al.,* (1998) observed same activity of carboxylesterase in the resistant strain and susceptible strain.

Resistance associated with mixed-function oxidases

Wilkinson (1983) indicated some characteristics of that make them specially adapted for general purpose protection in herbivorous insects. Microsomal monooxygenases shows a remarkable degree of non-specificity for lipophilic xenobiotics. The enzymes are located primarily in the gut tissue. They are induced by a wide variety of foreign compounds and the presence of the enzymes in the tissues is synchronized with periods of maximum chemical compound exposure. It also observed that The chewing insects have high laval of microtonal monooxygenase activity then the sucking insects. MFO activity was significantly correlated with that of the methamidophos resistance in the decline stage, i.e., 9 generations after withdrawal of selection pressure. Microsomal mixed-function oxidases (MFO) are capable of metabolizing insecticides with a seemingly endless array of chemical specificities. Because of this, they represent possibly the major detoxification mechanism available to insects when exposed to a chemical compound. The oxidative metabolism mediated by microsomal oxidases is concederded to be a major factor in resistance macanisom againest organophosphates, cabamates, pyrethroids and neonicotinoids (Puniean *et al.,* 2009).

Results and Discussion

Management of *Earias vittella* on okra

Chemicals used for controlling *E. vittella*

Management of any insect pest is always a challenge. *E. vittella*, being an important pest of okra it's very important to manage the same scientifically and effectively. Integrated management of *E. vittella* is very effective rather than chemical, biological or cultural management alone.

Significant reduction of fruit borer infestation was after 3 weeks of final treatment with acetamiprid 20 SP at 50 g a.i/ha, acephate 75 WSP 333 g a.i/ ha, imidacloprid 17.8 SL at 100 ml, profenofos 50 EC at 1500 ml/ha resulting in infestation levels of 12.42, 14.25, 15.36 and 15.70% respectively compared with the control (44.26%). Manjanaik *et al.,* (2002) reported endosulfan (0.05%), carbaryl (0.10%), monocrotophos (0.05%), quinalphos (0.03%), dimethoate (0.05%), chloropyriphos (0.04%), and triazophos (0.03%) as effective controlling fruit damage by *E. vittella* on okra with endosulfan (0.05%) recording the lowest per cent fruit damage (2.92%) and highest fruit yield of 6185.33 kg/ha. Singh, (2001) also found that endosulfan, quinalphos, phosphamidon, cypermethrin and fenvalerate were effective in controlling of shoot borer of okra *E. vittella*.Bhargava *et al.,* (2001) fobserved that quinalphos and endosulfan at 500 g a.i/ha gave superior protection against fruit borer and jassids in okra. Das *et al.,* (2000) observed efficacy of imidacloprid, acetamiprid, acephate and profenofos against the fruit borer, *E. vittella* on okra and observed that there was reduction in borer infestation to the extent of 15.36, 12.42, 14.25

and 15.70% after 3 weeks of spray with the respective insecticide against 44.26% infestation in control.

Emamectin benzoate @ 8.50 g.a.i/ha recorded lower fruit damage and higher fruit yield and found to be highly promising insecticide against okra fruit borer complex (Bheemanna *et al.,* 2005).Indoxacarb is a very promising insecticide in many lepidopteran and in case of *E. vitella* a dose of 75g.a.i/ha showed maximum reduction (78.6%) of population after five days of second spray which was significantly superior over all other treatments and Lamda cyhalothrin @ 50g.a.i/ha also resulted on high reduction of pest population (71.2%) and it was statistically on par with the result obtained with Indaxacarb @ 50 g.a.i/ha, Alpha cypermethrin @ 25 and 20g.a.i/ha. Endosulfan @ 500g.a.i/ha was found to be least effective against okra fruit borer by (Sharma and Bhati, 2008). Sarkar and Nath (1989) evaluated eight insecticides against the fruit borer, *E. vittella*, at Agartala (Tripura) and found that fenvalerate at 0.5 ml/litre and 750 litres/ha gave the highest reduction in number of infested fruits.

Raj (1985) revealed from field trials conducted in New Delhi that fruit borer of okra was effectively managed by the application of deltamethrin (0.0065 %). Field experiments conducted at Kanpur (Uttar Pradesh) indicated that malathion (0.03 %, 3 sprays) gave satisfactory protection against okra shoot and fruit borer infestation (Verma, 1985).Lowest damaged of fruits was recorded from dimethoate treated plots followed by profenophos and neem (Supriya *et al*., 2009).At Varanasi (Uttar Pradesh), 2 applications of malathion (1000 ml /ha) on okra gave satisfactory reduction of *E. vittella* (Konar and Rai, 1990).

Four sprays of cypermethrin 25 EC (0.0075%) at an interval of 10 days starting from flowering were found effective in reducing infestation of okra fruits by *E. vittella* at Rahuri in Maharashtra (Patil *et al*., 2002). According to Gupta and Mjshra (2006), monocrotophos gave only low to moderate level of protection to okra crop against *E. vittella* in field experiments conducted in Bihar.

Table.1 Summary of insecticide resistance profile of *Earias vittella*

Insecticide Group	Insecticide	North	Central	South
Pyrethroid	Cypermethrin/ Fenvelerate	Moderate	Low	Low
Organophosphate	Quinolphos Chlorpyriphos Monocrotophos	Low Moderate Low	Low Low Low	Low Low Low
Carbamate	Thiodicarb Methomyl	Moderate Moderate	Low Low Low	Low Low Low
Cyclodiene	Endosulfan	Low	Low	Low
Spinosyns	Spinosad Emamectin	Low Low	Low Low	Low Low

Table.2 Parasitoids of *Earias* spp

Trichogramma species	**State where recorded**	**References**
Trichogramma sp.	Tamilnadu	Cherian and Margabandha (1943)
Trichogramma achaeae	Punjab Bangalore Gujarat	Nagana Goud and Thontadarya (1984)
T. chilonis Ishii	Punjab Bangalore Gujarat	Nagana Goud and Thontadarya (1984)
T. chilotraeae Nagaraja and Nagarkatti	Gujarat Punjab	Manjunath (1974)
T. evanescens Westwood	Punjab	Hussain and Mathur (1924)
Trichogrammatoidea near guamensis Nagaraja	Punjab	Maninder *et al.,* (1983)

Combination of insecticide is always a good strategy for management of insect pest and also helpful to overcome the insecticidal resistance. Application of chloropyriphos 20 EC and cypermethrin 3 EC + quinalphos 20 EC gave lowest fruit damage of 18.86% and 19.97% and lowest number of bored holes per fruit of 1.17% and 1.19% respectively on okra (Papal *et al.,* 2009). Papal *et al.,* (2010) have shown chloropyrifos to be most effective followed by ready mixture of cypermethrin and quinalphos, endosulfan and ready mixture chlorpyrifos along wiht α-cypermethrin in controlling the fruit borer, *E. vittella* in okra. Again Sinha *et al.,* (2009) sujested that bifenthrin, indoxacarb, thiamethoxam, chlorpyrifos + cypermethrin and fipronil were highly effective against *E. vittella* of okra. Nauen *et al.,* (2007) reported that flubendiamide is a new chemical option for control of multi-resistant noctuid lepidopteran pests and an excellent choice in resistant management strategies for lepidopteran pests in general.

In the other hand, very few insecticidal molecule are safe for the natural enemy for the targeted insect hence IPM in this case is not so fusible. But few chemical been identified to be safe for the many natural enemy. Tang *et al.,* (2008) observed that Flubendiamide, a diamide insecticide has a unique chemical structure and a novel mode of action shows excellent efficacy, a broad insecticidal spectrum against lepidopteran insect pests but very safe for the beneficial arthropods and natural enemies. No cross-resistance to existing insecticides. Flubendiamide, first practical synthetic insecticide with a mode of action as an activator of ryanodine receptors with high and spacific activity against lepidopteran insect pests. It has been reported as very effective in the field with highly safe against non-target organisms (Tohinshi *et al.,* 2010). So all those chemicals are very effactive in IPM.

Biocontrol agents + insecticides used for controlling *E. vittella*

Sustainable insect management is a need of recent area. Safe pest management strategies, biological suppression is considered as an effective, environmentally non-degrading, economically viable and socially acceptable method of pest management (Singh, 2001). Among the various biological control agents, *Trichogramma* egg parasitoids are being utilized for managing several Lepidoptera pests management as it is very effective. It has been reported that *T. chllonis* has the distinction of being the highest produced and most utilized biocontrol agent (Brar *et al.,* 2000). *T. chilonis* releases at the rate of 50,000 /ha during the active egg-laying period hold promise against a number of lepidopteran insect-pests (Table 2).

Under laboratory conditions *T. brasiliensis* also parasitize eggs of *E. vittella* to the extent of 64 but when released under field conditions at Parbhani (Maharashtra) proved less efficient (Rao *et al.*, 1978). It could be because of the unfavorable condition but it may be utilize as an effective control measure with certain standardization.

It is all known that neem has insecticidal property. Multi neem (*Azadirecta indica*) and NSKE (Neem Seed Kernel Extract being used against shoot and fruit borer and jassid on okra and found that all the treatments significantly reduced fruit infestation percentage and increased the yield of okra(Ansari *et al.*,2008). In an IPM trial in Punjab and Gujarat, the yield recorded was 11.9, 13.7, 15.7 and 4.4t/ha and 12.1, 18.6, 19.7 and 8.6 t/ha, respectively in *T. chilonis*alone, *T. chilonis* with five insecticide sprays, *T. chilonis* with 7 spray and in control plots (Anonymous, 1993).

In conclusion, insecticide resistance is defense mechanism of insect to overcome the effect of insecticide. It is the causes of indiscriminate and repeated use of a particular insecticide. In order to overcome the problem it is always advisable to use the combination of insecticide rather than a single one. One step ahead, it is always desirable to use integrated management strategy to overcome the resistance problem as bio control agent are very effective against *Earias vittella*.

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