Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(5): 2271-2280

Received: 20-07-2020
Accepted: 24-08-2020

Akhilesh Kumar
JNKVV-Krishi Vigyan Kendra, CoA, Rewa, Madhya Pradesh, India

S Satpathy
ICAR-CRIJAF, Barracpore, West Bangle, India

TK Singh
JNKVV-College of Agriculture, Rewa, Madhya Pradesh, India

Rajesh Singh
JNKVV-Krishi Vigyan Kendra, CoA, Rewa, Madhya Pradesh, India

AK Pandey
JNKVV-Krishi Vigyan Kendra, CoA, Rewa, Madhya Pradesh, India

Mrigendra Singh
JNKVV-Krishi Vigyan Kendra, Shahdol, Madhya Pradesh, India

Krishna
JNKVV-College of Agriculture, Rewa, Madhya Pradesh, India

Corresponding Author:
Akhilesh Kumar
JNKVV-Krishi Vigyan Kendra, CoA, Rewa, Madhya Pradesh, India

Integrated pest management of major vegetable crops: A review

Akhilesh Kumar, S Satpathy, TK Singh, Rajesh Singh, AK Pandey, Mrigendra Singh and Krishna

Abstract
Eco-friendly tactics of pest management in vegetables have special significance not only for reduction in pesticide residues but also to maintain the natural enemy activity and making the production system more sustainable. These methods include suitable cultural practices or their alteration to reduce pest infestation and increase the natural enemy activity, adoption of biological control method either through conservation of natural enemies, mass release of natural enemies or application of microbial control agents, use of botanicals as insecticide against soft insects or both as insecticides and synergist with chemical insecticides against borer and leaf feeders, use of biorational methods particularly the integration of behavior modifying chemicals against lepidopteron and dipterans insects and finally need based use of safe insecticides with least persistence and low toxicity to natural enemies. Inclusion of insecticide can not be ruled out completely from ecofriendly practices rather safe insecticides can be tried exclusively or in low dosages in combination with botanicals, microbial or other integrated pest management tactics. Safety of chemicals also depends on the type of insect and natural enemies involved in particular growth stage of the plant and the mode of application.

Keywords: Integrated, management, vegetables, *Helicoverpa armigera*

Introduction
Insect pests are the major biotic constrains in vegetable production in India. Among these tomato fruit borer (*Helicoverpa armigera*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), chilli thrips, *Scirtothrips dorsalis* and mite, *Polyphagotarsonemus latus*, fruit and shoot borer, *Earias* spp. on okra, diamondback moth, *Plutella xylostella* on cole crops, fruit fly, *Bactrocera cucurbitae* on cucurbits are important ones. Average yield loss due to major insect pests in different parts of the country is reported to vary from 33 to 40%. Intensive and indiscriminate use of pesticides causes resistance, resurgence and the problem of pesticide residue. The eco-friendly methods of pest management need to be given due emphasis in vegetables. Focus is to be given on development and use of resistant varieties, biopesticides and insect pheromones. In vegetables, the resistance sources against major insect pests particularly borers are scarce/scanty. The researches on biological control with promising microbial agents like *Bacillus thuringiensis* Bt, Nuclear Polyhedrosis Virus NPV, *Entomopathogenic* fungi like, *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomurea rileyi* is to be re-oriented specifically for development of indigenous, economical and effective formulations. Pest monitoring and mass trapping using insect pheromones is an important and integral component to rationalize the insecticide based management system keeping harmony with natural enemies. In vegetables behavioral control strategy has been successful in managing, *L. orbonalis*, *S. litura*, *Earias* spp. and *B. cucurbitae*. Special attention and emphasis has been given for development of various plant derived insecticides which are ecofriendly, safe to natural enemies with least residue problem So far only neem formulations could be popularized. Various novel and biorational insecticide belonging to chloronicotinyl group insecticides, imidacloprid, thiamethoxam, dinotefuron, phenyl pyrazole fipronil, microbial metabolites, spinosad, avermectin with unique mode of action against major insect pests of vegetable crops are also in progress and well utilized.

Integrated pest management concept was the out come of challenges before the entomologist to develop tactics while keeping harmony with the ecological principles. Thus the eco friendly approaches of pest management carries a broad sense emphasizing the selection and practice of pest management methods based on ecological principles involving synthesis of components for crop protection in environmentally benign manner. The discovery of synthetic organic insecticides during 1940s and 1950s virtually suppressed and all on a sudden the age-old traditional practices of pest management were completely abandoned by farmers. In next decade the misuse and over use of insecticides caused early failures of chemical dominant pest control practices. Further the concerns over the hazards inflicted by toxic insecticides reflected in Riechel Carson's "Silent Spring". The post Silent Spring era again motivated the entomologists to think over to develop management practices safe to the environment in any form. Thus post-chemical era rather strengthen the cause of eco friendly methods of pest management in terms of Integrated Pest Management. Eco friendly management practices not only avoid the disturbance of biological relationship among the natural enemies, insects and other biotic agents in terms of existing food chain but also take into account the safety of immediate physical environment including the consumers.

Vegetables are too much susceptible to insect pest damage. These biotic stresses inflict considerably high amount of damage in vegetables that may go to the extent of 40%. Vegetables are intensively grown; high input oriented crops and need special plant protection attention in an economically feasible and environmentally safe manner. In vegetable agro-ecosystem the natural enemies and insect pests coexist which is very much to sensitive disruptive pest management practices especially heavy pressure of chemical insecticides. On the other hand short harvest interval of vegetables more often favors the probability of persistence of toxic residue in/on the harvestable fruits, pods and leaves. The farm gate vegetable samples analyzed after collection from various states of India indicated 55% of the samples to be contaminated with major group of pesticides (Agnihotri, 1999) [1].

Recently commercialization of vegetable cultivation has changed the traditional crop management practices. Consequently the varietal selection and insecticide dominant scheduled crop protection pattern reflected shift in the number, type and extent of pest infestation. Occurrence of resistance and resurgence in vegetable pests due to abundant use of broad-spectrum insecticides highlighted the pest problem to new heights Table 1. Besides, insect pests like serpentine tomato leaf miner, brinjal gall midge, okra stem fly and bitter gourd leafhopper are gradually achieving the greater pest status in different parts of the country.

Considering the present state of insecticide dominant pest management in vegetable crops and probable hazards on vegetable consumers, it is the need of the hour to develop and popularize the ecofriendly pest management practices in vegetables.

Ecofriendly tactics are not new to the plant protection specialists. These practices has no or least deleterious impact on the activity of natural enemies and pollinators on the plant system it self, on the animals or consumers and the environment.

In vegetable, several ecofriendly pest management practices have been tried some of which have given good result. These include suitable cultural practices or their alteration to reduce pest infestation and increase the natural enemy activity, adoption of biological control method either through conservation of natural enemies, mass release of natural enemies or application of microbial control agents, use of botanicals as insecticide against soft insects or both as insecticides and synergist with chemical insecticides against borer and leaf feeders, use of biorational methods particularly the integration of behavior modifying chemicals against lepidopteron and dipterans insects and finally need based use of safe insecticides with least persistence and low toxicity to natural enemies. Inclusion of insecticide can not be ruled out completely from ecofriendly practices rather safe insecticides can be tried exclusively or in low dosages in combination with botanicals, microbial or other integrated pest management tactics. Safety of chemicals also depends on the type of insect and natural enemies involved in particular growth stage of the plant and the mode of application. For example, use of selective, systemic, seed treating insecticide will be least disruptive to the environment, the natural enemies and consumers as it is used sufficiently ahead of flowering and fruiting stage when the leaf sucking insects and vectors are more active due to succulence of the plant. Consequently have least on no chance of persistence a fruits.

Different ecofriendly pest management practices recommended in vegetables based on various field and laboratory experiments are discussed below:-

Diamondback moth DBM, *Plutella xylostella* an important pest of Cole crops has developed resistance to several classes of insecticides and showed increase in its pest status in different parts of world and India. Sudden decrease in population of key natural enemies of DBM including *Cotesia plutellae*, *Tetrastictus sokolowskii* and *Diadegma semiclausum* due to intensive use of broad spectrum insecticides have made this pest difficult to control.

Myzus persicae was a minor pest of vegetable crops has now become a serious pest of brinjal, crucifers, potato, tomato, chilli and Cole crops in most of the southern states. Indiscriminate use of insecticides for tomato fruit borer, *Helicoverpa armigera* control has suppressed the activity of larval parasitoid, *Campoletis chloridae* causing the outbreak of tomato fruit borer. This pest has also increased its activity through diverse seasonal and host status. Consequently it is gradually becoming a dominant fruit borer of summer okra in some parts of North India particularly Eastern Uttar Pradesh. Similarly, *Spodoptera litura* has been recorded in many other vegetable crops in different parts of the country. In South India, leaf miner, *Liriomyza trifolii* was observed damaging tomato and cucurbits particularly on nitrogen responsive high yielding hybrids.

In brinjal, *Leucinodes orbonalis* is still a major pest and has because resistance against most of the organophosphate and synthetic pyrethroids. This insect becomes problematic further due to erosion of its low natural enemy complex caused by intensive and frequent spraying of insecticides. Besides jassids and fruit borer, stem fly, *Melanagromyza hibisci* have been observed to cause serious damage to okra. Field experiments were conducted to find out the bio-efficacy of emamaectin benzoate 5 SG against brinjal shoot and fruit borer, *Leucinodes orbonalis*, diamondback moth of cabbage, *Plutella xylostella* and the okra fruit borer, *Earias vittella*. Two sprays of each treatment were applied after initiation of infestation. On the basis of post treatment larval population and damage, emamectin benzoate was found to be most effective against all the test insects. In all the three test dosages of emamectin benzoate, no significant difference was noted in the level of infestation or damage caused by the three insects. Emamectin benzoate was effective against all the three insects even at the lowest dose ie, 7.50 g ai/ha against brinjal shoot and fruit borer and diamondback moth and at

5.00 g ai/ha against okra fruit borer (Shivalingaswamy *et al*., 2008) [2]. Kumar *et al*., 2017 [3] found that two spray of chlorantraniliprole 18.5 SC @ 15 g ai after 30 days sowing of okra at 15 days of interval of farmer's field was reducing the damage of pods and increased the crop yield.

Ecofriendly management practices of some important vegetable pests

Brinjal Crop

Brinjal shoot and fruit borer, *Leucinodes orbonalis*

Brinjal shoot and fruit borer is the most important pest of brinjal. The crop loss caused by this pest is enormous and varies from 37 to 63% in different parts of India (Dhankhar, 1988) [4]. The adults were nocturnal in habit; as such most of their feeding, mating and egg laying activities occurred during night between 02.00 to 06.00 h and lasted for about 16 minutes. Eggs were laid during the early hours of the next morning. Eggs were laid during the early hours of the next morning. The eggs were laid either singly or in batches on the ventral surface of the leaves (Kumar and Johnson, 2000) [5]. Newly hatched larvae bore into fruits or tender shoots and start feeding. They always preferred the fruits over the shoots. Maximum six larval instars are recorded and after feeding, larva pupate in soil among hood shaped fallen leaves and debris. Several overlapping generations occur in warm climates. The total duration of the life cycle is around 32 days. The fruits were always preferred over shoot. The pre-oviposition, oviposition, incubation, larval and pupal periods were sound to be 1.35, 2.01, 2.98, 16.32 and 8.01 days, respectively. The longevity of male and female was 3.50 and 5.70 days (Kavitha *et al*., 2008) [6].

Removal and destruction of infested twigs/fallen leaves twice in a week + Bt @ 0.5 kg/ha showed minimum infestation of shoot 1.23 and 1.13% and fruits 1.10 and 0.90% and produced maximum healthy fruits in managing the shoot and fruit borer infestation is followed by neem gold @ 2 mill + mechanical removal (Tiwari *et al*., 2009) [7]. Sasikala *et al*., 1999 [8]. observed that brinjal plots treated with neem oil 0.2%, neem oil 0.1% + B.t. 0.075%, neem oil 0.1% + lufenuron 0.01%, and neem oil 0.1% + carbaryl 0.075% gave higher fruit yield 40.76, 33.80, 31.35 and 29.07 kg/plot, respectively, compared with 17.5 kg/plot obtained from control plots. Five sprays of Dipel [*Bacillus thuringiensis* subsp. Kurstaki] 8L at 0.2% at 10 day intervals which resulted in minimum shoot 9.56% as well as fruit 11.78% infestation and maximum yield of marketable fruits (196.96 q/ha) and proved to be the most effective treatment (Puranik *et al*., 2002) [9]. The another study it was showed that indoxacarb 14.5% SC to be the most effective treatment against the pest and it was at par with spinosad, emamectin benzoate, diafenthiuron and endosulfan for managing the fruit borer in brinjal (Singh, 2010) [10]. To evaluate some biorational pesticides against brinjal shoot and fruit borer BSFB under field condition the treatments *viz*. chlorantraniliprole 18.5 SC 0.4ml/l, spinosad 45 SC 0.5ml/l, chlorfenapyr 10 SC 2ml/l, Indoxacarb 14.5 SC 1ml/l, *Bacillus thuringiensis* Bt 2g/l, azadirachtin 0.03EC 5ml/l, *Metarhizium anisoplae* 2.5g/l, *Beauveria bassiana* 2.5g/l, chlorpyriphos 20EC 2.5 ml/l were applied thrice at fifteen days interval starting from initiation of BSFB infestation. Mean shoot infestation was minimum in chlorantraniliprole plots 6.32% followed by spinosad, chlorfenapyr, indoxacarb. Among bio-pesticides, *Beauveria* and Bt were found effective treatments in reducing shoot infestation. Chlorantraniliprole recorded lowest fruit infestation 8.25% and highest marketable fruit yield 250.30q/ha followed by spinosad and Chlorfenapyr (Tripura *et al*., 2017) [11]. Insecticidal control of Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenn. has become a cause of concern as this highly damaging pest of brinjal is wide spread and known to attack other crops and therefore is a reason for heavy insecticide use in brinjal crop leading to contamination of food chain and increased pesticide related health risk. To protect this popular crop a combination of intercrop with coriander and fennel and different spray schedules of crude and commercial neem formulation on main crop of brinjal was tested to evaluate the level of percent shoot damage and fruit damage both by number and% fruit damage by weight. Minimum loss on all the three parameters 21.57%, 19.79% and 23.33%, respectively were found in brinjal + coriander with NSKE 5% spray followed by brinjal + fennel and 0.03% spray of commercial azadirachtin formulation 24.17%, 21.79% and 22.59%, respectively whereas the maximum shoot damage 50.60%, fruit damage 61.67% and fruit weight loss 64.84% were observed in sole Brinjal + Water Spray followed by Brinjal + NSKE 5% which recorded 35.60% shoot damage and 47.50% weight loss. Almost all the treatments were significantly superior to control i.e. sole crop of brinjal sprayed with water) though some of them were not significantly different to the other. In most cases, combinations of intercrop supplemented the need of application of neem formulations as combinations of intercrop or application of neem formulations on lone brinjal crop were found to be at par regarding difference in shoot damage, fruit damage and fruit weight loss (Singh *et al*., 2016) [12]. Flubendiamide 480 SC @ 72 to 90 g a.i. /ha could be effectively used for the management of *L. orbonalis* under field condition (Jagginavar *et al*., 2009) [13]. Bhanu *et al*., 2007[14] studied under farmers' field conditions and reported that that Leucinlure™, produced using indigenously synthesized pheromone concentrates, trapped significantly more number of adults when used with PCI's portable water traps 87.83 adults/trap over 10 weeks, as compared to funnel 21.00 and delta 15.17 traps. Singh *et al*., 2016[15] evaluated insecticides against brinjal shoot and fruit borer, *L. orbonalis*, Emamectin benzoate 5 SG @ 12.5g a.i./ha treated plots showed lowest infestation and gave higher fruit yield 253.12 followed by Flubendiamide 480 SC 249.33 and Novaluron 10 EC 243.63. The biopesticides NSKE 5% most effective followed by *Bacillus thuringensis*, *Verticellium lecanii* and *Beauveria bassiana*. The highest cost: benefit ratio was obtained from NSKE 5% 1:24.40 followed by Indoxacarb 14.5 SC 1:24.13 and Emamectin benzoate 5 SG 1:24.03 which were also economical than other treatments. Jaiswal *et al*, 2018[16] studied that the presence of whitefly, aphid, jassid and hadda beetle were recorded from the vegetative to maturity stage of the crop, while brinjal shoot and fruit borer as the most dominating species of the pest at vegetative as well as flowering and fruiting stage of the crop. The infestation of mealy bug and lace bug were recorded in the late season of the crop i.e. January to April 2017.

Tomato Crop

Tomato fruit borer, *Helicoverpa armigera*

Fruit borer is one of the most destructive pests of tomato. This is polyphagous in nature. In vegetable most preferred host is tomato; however it also infests okra, bottle gourd and Cole crops to variable extent. In tomato it prefers mostly the unripe green fruits. A circular hole around the calyx is the characteristics damage by the larvae. In non-cotton growing areas occurrence and intensity of infestation varies a lot. In these areas, the extent of infestation on tomato depends mostly on the presence or absence of other preferred host like chickpea and pigeonpea. Although large numbers of natural enemies have been recorded on fruit borer of tomato, *Trichogramma* spp., *Campoletis chlorideae* Uchida, *Carcelia illota* Curran and *Hexamermis* sp. are most important (Krishnamoorthy and Mani, 1990) [17]. *Campoletis chlorideae* generally parasitize the early instars of host larvae and remain active up to January. Further increase in temperature gradually declines the parasitization rate. *H. armigera* adults lay majority of the eggs in upper and lower leaf surfaces of first four leaves in the top of the canopy (Chandrasekhar, 1992) [18]. During the fruiting stage solitary eggs are observed on flower bud also. Initial instars of fruit borer larvae scrap on the foliage while late instars prefer to bore the fruits, keeping half part of the body inside the hole and rest exposed.

Considerable level of natural parasitization by different natural enemies supports the economic threshold attainment spray instead of schedule insecticide application. Further, in case of determinate tomato the use of chemical insecticides or other means against the larvae should be withdrawn after 50% ripening stage. This practice not only restricts the number of insecticide but also reduce the residual effect of chemicals on the fruits.

The natural parasitization of *H. armigera* eggs by *Trichogramma* spp. has prompted the entomologists for using this Ichneumonid as an ideal candidate for biological control through mass release. *T. chilonis* Ishii inaundatively released @ 2, 50, 000/ parasitized eggs/ha per week have been found effective in suppression of tomato borer (Yadav *et al*., 1985) [19]. *T. brasiliensis* also parasitizes the fruit borer eggs to the extent of 51.3%, innundative release of this species at the same rate is also suggested (Mani and Krishnamoorthy, 1983) [20]. The egg parasites should be released at the time of 50% flowering or egg monitoring through adult catches in sex pheromone traps. Specific use of 250-500 LE of HaNPV + 0.5% jaggery + 0.1% Ranipal or 0.5 kg/ha *Bacillus thuringiensis* var. Kurstaki or *Trichogramma* 50,000/ha per week during the adult activity period will help in combating the pest in more effective manner (Singh, 1990) [21].

Field experiments revealed that application of crude HaNPV @ 300 LE/ha twice at 15 days interval after flowering was as good as foliar spray of 100 LE HaNPV + endosulfan @ 350 g ai/ha at the same interval (Satpathy *et al*., 2000) [22]. The efficacy of HaNPV can be increased by applying in short intervals instead of two sprays at 15 days interval, 4 sprays at 10 days interval and application of *Trichogramma brasiliensis* 2, 50,000 at 7 days interval was reducing the fruit damage in tomato fruits (Kumar and Satpathy, 2005) [23]. Beside endosulfan at half the recommended dose neem seed kernal extract (3%) also showed synergistic effect by increasing the killing efficiency of NPV @ 250 LE against tomato fruit borer (Gopal and Senguttuvan, 1997) [24].

Use of marigold (*Tagetes erecta*) has been recommended for the management of tomato fruit borer. Planting two rows of marigold parallel to 14 rows of tomato in two sides, attracted *H. armigera* adults more to the marigold at tight bud stage reduced both the eggs and larvae of the pest in the intercropped tomato. The trap crop combination along with 2 sprays of endosulfan (0.07%) reduced the fruit damage by 50% as compared to unsprayed sole tomato (Srinivasan *et al*., 1994) [25].

Among the entomopathogens, *Bacillus thuringiensis* was also found effective and commercial formulation of *B. thuringiensis* Kurstaki provide suppression of *H. armigera* on tomato crops (Krishnaiah *et al*., 1981) [26]. Under the agro climatic condition of Himachal Pradesh where the climate is slightly mild compared to the plains and peninsular India, the egg parasite *T. brasiliensis* and *T. pretiosum* performed better and the mean reduction in larval population of tomato fruit borer was to the extent of 56% (Rawat and Pawar, 1993) [27].

Tomato fruit borer (*Helicoverpa armigera*)

Neem oil micro emulsion reduced the larval and pupal weight gain, pupal development and adult emergence, and increased the larval mortality, larval-pupal intermediates and the pupal deformity in the 3rd instar treated-larvae *H. armigera*. Its relative effectiveness in inhibiting adult emergence compared to the macro emulsion 1.0 was 1.68 (Dhingra *et al*., 2002) [28]. Kaushik, 1999[29] reported that diet having the crude leaf powder of *C. lanceolatus* leads to slow growth and development in *H. armigera* larvae. The larvae could not survive beyond L3 stage and% survival was only 20% at pre-pupal stage. To evaluate the efficacy of a new carbamate insecticide, Indoxacarb 15 SC 50, 60 and 75 g ai/ha compared with endosulfan 750 g ai/ha and *Bacillus thuringiensis* Bt formulation 500 g/ha for the management of tomato fruit borer, *Helicoverpa armigera*. The insecticides were applied at weekly interval just after 50% flowering stage. During the post treatment periods at 3, 5 and 7 days after treatment, Indoxacarb 15 SC recorded significantly less fruit damage in all the test doses compared to endosulfan and Bt. The efficacy was observed up to 7 days in Indoxacarb treated plots which suffered significantly less fruit damage 7.87%, 10.10% and 12.93% over endosulfan 15.13%. Bt 19.80% and untreated control 25.20%. Significantly highest yield 260.78 q/ha was obtained from Indoxacarb 75 g ai/ha treatment followed by other two doses of the same insecticide 259.78 and 257.35 q/ha (Shivalingaswamy *et al*., 2008) [30].

Tomato whitefly (*Bemisia tabaci*)

Whitefly is the most important sucking pest of tomato. It causes extensive damage not only by sucking cell sap from the leaves but also as a vector causing tomato leaf curl virus (TLCV). The early planted tomato is more affected as it coincides with greater population of whiteflies. The loss due to TLCV transmitted by white fly may range from 38-93% during different months of the year (Sastry and Singh, 1971) [31].

The importance of whitefly management is more due to its being the vector of TLCV rather their role as a damage caused due to sucking. Early crop stages need much attention to spread the disease further in the field.

Therefore, much attention must be given in the nursery to check further damage caused by whitefly. Nursery should be sparse and netted with 200 mesh nylon net fitted with wooden or iron angle. Seeds must be treated with imidacloprid @ 2.5 g/kg. Prior to transplantation the seedlings should be sprayed with imidacloprid @ 0.3% ml/lit. In main field spray of 0.05% monocrotophos at 10 days interval after transplanting delays the spread of tomato leaf curl virus (Saikia and Muniyappa, 1989) [32].

The yellow sticky cards that were placed parallel to tomato rows caught significantly more whitefly adults than those placed perpendicular to tomato rows (Gu-XiShu *et al*., 2008) [33]. Muthukumar and Kalyanasundaram, 2003[34] recorded that triazophos @ 0.05% was able to control the sucking pests complex in brinjal including *b. tabaci* was 70.99% followed by 0.05% cartap-hydrochloride 56.76% and 0.025% diflubenzuron 53.01%. entopathogenic fungi, *Beauveria bassiana*, *Isaria fumosorosea* wize (ifr) (=*paecilomyces fumosoroseus*) and *Lecanicillium lecanii* were evaluated against the developmental stages of b. tabaci infested on bean plants, *Phaseolus vulgaris* l. first and second instar nymphs were the most susceptible to these three microorganisms, with efficiency of 60 to 78.3%. *I. fumosorosea* caused higher efficiency on egg stage 40% (Espinel *et al.*, 2009) [35].

Cruciferous Crop

Diamondback moth, *Plutella xylostella* Linn

Diamondback moth (DBM) is the most destructive pest of Cole crops especially cabbage and cauliflower causing extensive leaf damage. Infestation of DBM in primordial stage of the crop particularly from 40-60 days after planting interferes in head formation and yield reduction. Early and late crop when the temperature is slightly higher than that persists during the main cropping season suffers more. Under favourable pre-disposing condition and critical growth stages the damage may result in 52% yield reduction (Krishna Kumar *et al*., 1986) [36].

Sensitivity of this pest to insecticides and association of natural enemies to considerable extent increased the importance of ecofriendly management of this pest. During the past two decades heavy reliance on insecticides for DBM management has resulted in large scale control failure. Inadequate control of DBM on cabbage following the application of both organophosphates and pyrethroids has been reported (Srinivasan, 1988) [37]. This pest has also developed resistance to wide variety of insecticides in other parts of Asia (Chen and Sun, 1986) [38]. *Cotesia plutella* Kurdjumov Hymenoptera: Braconidae is the predominant DBM specific larval parasitoid found in subtropical and tropical countries. This natural enemy has the capacity to disrupt the population of DBM in the field (Lim, 1982) [39]. In Taiwan, it regulates the DBM population by supplementing with *Bacillus thuringiensis* var. Kurstaki (AVRDC, 1990) [40]. In western India, highest parasitization 71.7%) on DBM larvae by *C. plutellae* have been reported in the first week of November (Yadava *et al*., 1975) [41]. Considerable extent of natural enemy activity in Cole crops might be one of the reasons of sudden upsurge in DBM population following large scale application of broad-spectrum insecticides as indiscriminate insecticide use would have eliminated *Cotesia plutellae*, the dominant parasitoid of DBM (Nagakatti and Jayanth, 1982) [42].

To avert the ill effects of insecticide on the natural enemies and consumers it is very important to encourage ecofriendly management practices against DBM including use of biopesticides and need based application of selective insecticides.

Selection of resistant/tolerant varieties exerts suppression of larval population and feeding to some extent. In cabbage dark green varieties should be given preference in DBM endemic areas as the infestation and damage is less due to greater content of wax (Satpathy *et al*., 2002) [43]. Slightly higher temperature favors the infestation of DBM. Particularly in northern plain timely planting may avoid or reduce DBM damage in cabbage and cauliflower. There exists relative preference of DBM adults among different crucifer species particularly for orientation and oviposition (Satpathy and Rai, 1999) [44]. Cartap hydrochloride followed by Lufenuron and Bt were found to be the most effective insecticides at controlling the DBM under Delhi condition (Nagesh and Verma, 1997) [45]. Torres *et al*., 2001[46] reported that extracts of *Aspidosperma pyrifolium*, *Azadirachta indica* and *Azadirachta indica* oil formulation caused 100% mortality of P. xylostella larvae while the extracts of *M. azedarach*, *C. glaberrima*, *Laurus nobilis*, *Prosopis juliflora*, Croton sp. and *Eugenia uniflora* caused larval mortality of 96.7, 93.3, 83.3, 66.7, 63.3 and 60%, respectively. In another study, Lad *et al*., 2009[47] noticed that *Trichogrammatoidea bactrae* @ 1.5 lakh eggs ha-1, *Bacillus thuringiensis* @ 1000 ml ha-1 and *Trichogramma chilonis* @ 1.5 lakh eggs ha-1 have found effective in controlling DBM and% larval reduction 53.94, 50.91 and 45.81 respectively. The efficacy of chlorfenapyr 10 SC @ 75 and 100 g ai/ha against diamondback moth (DBM) in cabbage along with recommended check endosulfan @ 700 g ai/ha, Bt @ 500 g ai/ha and untreated control. On the basis of post-treatment larval population, Chlorfenapyr was found to be most effect against DBM. There was significantly less infestation at both the test concentrations 100 g ai/ha and 75 g ai/ha of Chlorfenapyr. Chlorfenapyr @ 75 g ai/ha provided optimum control of DBM, over endosulfan and Bt (Satpathy *et al*., 2005) [48]. The bio efficacy of a new molecule, Spinosad along with recommended insecticides and Bt formulation was evaluated against diamondback moth DBM, *Plutella xylostella* L., infesting cabbage. Two sprays of each treatment were applied at attainment of ETL 2-3 DBM larvae/plant. At 3 days after first treatment, lowest larval population 1.6/plant was recorded in Spinosad (@ 20 g ai/ha) treated plot being at par with other Spinosad and Bt treatments. The larval population during different post-treatment periods indicated the superiority of Spinosad in controlling DBM larvae even @ 15 g ai/ha. The persistency of this insecticide on the basis of larval infestation was recorded to be 10 days after treatment (Satpathy *et al*., 2007) [49]. Kumar *et al*., 2007 [50] reported that Indoxacarb 15 SC @ 30 g ai/ha has lowest larval population of DBM in comparison of Bt @ 500g ai/ha. Satpathy *et al*., 2010 [51] studied that a few biological parameters and ovipositional preference of diamondback moth, *Plutella xylostella* L. among 6 crucifers for searching an effective and alternative host other than mustard (*Brassica juncea*) with potential of being used as trap crop for management of diamondback moth in cabbage, *Brassica oleracea* var. capitata. Although the larval weight was significantly more in Chinese cabbage, the larval period of diamondback moth was significantly more prolonged on Chinese cabbage 10.44 days than other cruciferous hosts. In laboratory experiments, both no-choice and free-choice tests consistently showed almost two-fold preference by diamondback moth for oviposition on Chinese cabbage over cabbage. In the net house, under free-choice situation also the egg laying preference on Chinese cabbage was significantly higher 377 eggs/plant than mustard 148.50 eggs/plant and cabbage 114.50 eggs/plant. The larval population at two intervals after release 10 and 15 days of adults among the test crucifers inside the field screen cage also confirmed maximum attractiveness of Chinese cabbage over mustard and cabbage for egg laying and larval survival. Considering these facts and better agronomic feasibility of Chinese cabbage as an ideal alternative to mustard for use as a trap crop in the management of diamondback moth of cabbage.

Chilli Crop

Management of Chilli, *Capsicum annuum* L. Thrips and Mites Using Organics

Chilli, *Capsicum annuum* L. is a tropical and subtropical crop grown all over India. Also known as 'red pepper', it is one of the most important commercial spice crops, earning valuable foreign exchange for the country. India produces about 10.70 lakh tonnes of chilli from an area of 9.08 lakh hectares. Of the total production, about 90-95% is consumed within the country and about 5-10% is exported in the form of dry chilli, chilli powder and oleoresins (Singhal, 2003) [52].

The attack of a multitude of insect pests and mite at different crop stages is of utmost concern. Surveys conducted by AVRDC in Asia revealed that, the major pests that attack chilli are aphids *Myzus persicae* Sulzer, *Aphis gossypi* Glover, mite *Polyphagotarsonemus latus* Banks and thrips *Scirtothrips dorsalis* Hood (Berke and Sheih, 2000) [53].

It is therefore imperative to resort to other non-chemical pest management strategies such as use of organic amendments, botanical pesticides and bioagents key components of organic farming, which are eco-friendly and completely safe to the consumers.

The best two organic treatments receiving vermicompost and neem cake in nursery were selected based on the Seedling Vigor Index and transplanted in the main field along with seedlings of standard check in split plot design. Main plot treatments included two organic amendments alone, a combination of organic amendments and 100% RDF + FYM + RPP as standard check. The best two organically raised seedlings referred as above were the sub plots along with the standard check. The sprays were taken up at 2, 5, 7 and 11 weeks after transplanting from 45 DAT, using high volume knapsack sprayer.

The pesticidal action of neem seed kernel extract NSKE which was superimposed in organically amended crop in the present study is in agreement with the findings of Varghese, 2003[54] who observed that neem seed kernel extract and neem oil 5% recorded lowest incidence of thrips and mites in chilli. The property of neem cake in reducing the leaf curl was reported by Varghese and Giraddi, 2005[55] who found that neem cake in combination with 50% RDF and two and three sprays v/s four sprays of chemicals recorded least leaf curl index. Among the organics tested, maximum dry chilli yield of 2.49 q/ha was obtained in Vermicompost @ 2.5 t/ha + neem seed kernel extract 5% and neemazal sprays followed by Neem cake @ 0.5 t/ha + neem seed kernel extract and neemazal sprays which recorded 2.39 q/ha. However maximum yield was registered in the standard check, i.e. 3.65 q/ha. Among the organically raised seedlings evaluated, S1 receiving vermicompost out yielded the rest of the treatments by recording a yield of 2.92 q/ha.

Two sprays of Abamectin 1.8 EC @ 750 ml/ha at 15 days interval were applied on farmers' fields as research practice RP and compared with farmers practice fields of indiscriminate use of insecticides. The Abamectin 1.8 EC treated fields showed 0.75 mites/leaf while, farmers practice fields showed 1.80 mites/leaf. The technology assessed showed promising and positive results with yield of 120 q/ha and net return of 139650 Rs./ha as compared to farmers practices of yield 78 q/ha and net return of 76100 Rs./ha of chilli crop. Thus, the technology was found suitable for mites management in Chilli showing reduction in mites infestation (Kumar *et al*., 2018) [56].

Cucurbits Crop

Cucumber melon fly, *Bactrocera cucurbitae*

Cucurbits are vegetable crops belonging to family Cucurbitaceous, which primarily comprises of many species consumed worldwide as food. The melon fly, *Bactrocera cucurbitae* is a serious pest of cultivated cucurbits. It was first reported in India by Lefroy during 1907[57] which reduce not only the quality of fruits and vegetables but also a serious limiting factor in the production of gourds, cucumber, melon and other cucurbits to the extent that it's growing may become highly unprofitable. Though a number of insecticides have been reported to be effective against this pest. The desired concentration was prepared with water and sprayed with the help of knapsack sprayer. In each plot five plants were selected and tagged. From the tagged plants healthy and infested fruits were counted and computed to work out% fruit damage. All the spray treatments were carried out 50 days after sowing and second and third spray at 70 and 90 days after sowing respectively.

Rajapakse, 2000 [58] who reported that the use of neem based products with predatory ants, *Oecophylla smaragdina* gave an excellent control of fruit flies *B. cucurbitae*. Schmutterer and Singh, 2002 [59] reported neem as oviposition and feeding deterrency, repellency, ovicidal action, sterilant effect and insect growth regulation, in the management of insect pests of cucurbits. Babu *et al*., 2002 [60] reported neemazal (@ 3 and 5 ml/l) provided significant control against fruit fly *B. cucurbitae* and recorded a reduction of 70.5% damage. Nath *et al*., 2007 [61] also reported NSKE @ 5%, bait spray Malathion 50 g + molasses 500 g + 50 l water and cypermethrin applied one after another as per schedule resulted minimum fruit damage by the fruit fly and the control plot exhibited maximum damage of bottle gourd fruits. Further, results obtained with application of acephate 75 SP corroborates with many earlier reports (Mehta *et al*., 2000 and Patnaik *et al*., 2004) [62, 63]. Similarly, results obtained with spinosad 45 SC were in close agreement with the report of Sookar *et al*., 2001 [64].

Okra Crop

Eco-Friendly management of major pests of okra

Okra is attacked by various serious economic pests i.e. cotton aphid, *Aphis gossypii*, spotted bollworm, Earias *insulana*) American bollworm, *Helicoverpa armigera*, jassid, *Amrasca devastans* and *Oxycaremus loetus*. Farmers generally practice insecticides for pest management and higher yield. A wide variety of insecticides e.g. organophosphates, carbamates, organochlorine and pyrethroids are used for the control of Okra pests in many countries. Extensive use of insecticides leads to the problems of pest resistance, resurgence, pesticides residues, destruction of beneficial fauna and environmental pollution.

Many of the botanicals have been explored having broad spectrum activity and have the potential to become alternatives to chemical insecticides. Since botanicals give effective control like the synthetic insecticides as they are environmental friendly, so the focus should be on the encouragement of the use of botanicals to tackle problems associated with other insecticides.

The first spray was performed before the appearance of the pest, followed by a spray after 15 days interval Thiodan 3.5 E.C, Neem seeds, Turmeric and Asafetida Henge were purchased from local market. Neem seed crude extract 2.5%, Turmeric, Asafetida Henge and Garlic crude extract was prepared by the procedure adopted by Munir, 2006[65].

Neem seed crude extract were the most effective insecticides against the insect pest of Okra. Lowest mean population of *E. insulana*, *A. devastans* and *O. leotus* were recorded in Neem. Yield and percent yield increase over control were also highest in Neem. Farmers can utilize Neem seed crude extract for the effective control of Okra pests in field as having low mammalian toxicity, low cost and less environmental hazard.

Eco-friendly techniques of Insect-Pest Management in Commercial Vegetable Production

A) Ecological Management of Pests: The manipulation of the farming practices for reduction or avoiding pest damage to crops is known as cultural control. Since these manipulations are based on habitat management and require a thorough understanding of different components of the ecosystem in which the pest thrives, this approach has also been called as ecological management or environmental control. The purpose of cultural control practices is to make the environment less favourable for the pest and facilitate the augmentation of population of natural enemies. Cultural practices include planting time, seed rate, plant spacing, tillage, plant diversity, crop rotation and nutrient management.

i) Plant diversity: Ram and Singh, 2010 [66] studied the effect of intercropping of spices, cereals and root crops on the incidence of tomato fruit borer, *H. armigera* in tomato. The results obtained from study indicated that the incidence of *H. armigera* was found minimum when tomato intercropped with coriander. Effect of interculture of four cruciferous cultivars *viz*. *Brassica juncea* Var. PBR-91, *B. napus* var GSL-1, *B. napus* var. PGSH-51 and *Eruca sativa* var. TMLC-2 on incidence of *H. armigera* on tomato after burying them in soil was evaluated. When two rows of crucifers were buried simultaneously six day after sowing, *B. napus* var. GSL-1 was the most effective in reducing the oviposition on tomato 1.37 eggs per plant against 2.73 in controls.

ii) Mulching: Mulching is often recommended to reduce weeds, disease and pests, and conserve soil moisture. Plastic mulch is outstanding for preventing weeds while organic mulch lowers soil temperatures. Natural organic mulches like rice straw conserve soil moisture and add to the organic matter of the soil. Many vegetable crops have shown significant increase in earliness, yield and fruit quality when grown with plastic mulches and under low tunnels. Bhullar and Dhatt, 2011 [67] studied the effect of some cultural practices like training system and various types of mulching was observed on incidence of *Tetranychus urticae* Koch on brinjal grown under both open field and net house conditions. Mite incidence was more in open field conditions than in net house, while in net house crop, incidence of mites was less on crop grown with training system and black polythene mulch.

B) Mechanical Control of Pests: The reduction or suppression of insect population by means of manual devices is referred to as mechanical control. Mechanical control includes collection and destruction, preventative barriers and trapping.

i) Trellis system: Trellis system is effective method to control insect-pests. Incidence of inset-pest is less in trellis system because more penetration of light and pest monitoring is as easy as compared to traditional methods.

ii) Protected cultivation: Insect-pests are known to cause direct damage to vegetable and fruit crops as well as indirect damage by acting as vectors. Polyhouse act as a physical barrier for spread of the pest and consequently plant disease also. It is evident that incidence of insect pests per plant was higher under open field as compared to polyhouse. This could be due to the fact that polyhouse acted as a physical barrier that necessitated more number of spraying of insecticide under open field conditions. Results further indicated that net income was low in open field condition as compared to polyhouse. It was further evident that yield and economic loss were very higher under open field condition as compared to polyhouse

iii) Sticky barriers or traps: Small flying insect pests are attracted by the unique yellow colour and stick to the non-drying glue coating the trap. Many insect pests are difficult to control with insecticides. By catching the winged adults with Yellow Sticky Traps before they reach the plants, the buildup of pests is delayed. Existing insect populations may also be reduced. Yellow sticky traps are a non toxic way to control and monitor – whiteflies, aphids, Onion fly, Cabbage white butterfly, fruit flies, thrips, cucumber beetles, fungus gnats, leafhoppers, froghoppers, moths, flea beetles, leaf miners etc. As an integral part of integrated pest management program they can be used in greenhouses, homes, orchards, flowers and vegetable gardens, anywhere insects are a problem.

iv) Lure and kill: Vines and creepers like cucurbits provide hiding place to insect-pest. Fruit fly lays eggs in fruit tissue, so that control of fruit fly is difficult and control measures directed toward adult flies. Some of the commonly used lure for attracting the adult fruit flies is Cue-lure, methyl eugenol, molasses etc. Chaudhary and Patel, 2008 [68] used two methods of fruit fly control, *viz*., aqueous sprays of poison bait PB and installation of lure traps as male annihilation MA technique, individual and in combination in pumpkin field. They found that combined use of cue-lure baited traps and sprays of poison bait with protein hydrolysate reduce the fruit infestation significantly over their individual treatments during different stages of pumpkin fruit growth as well as resulted in better yield of marketable fruits per unit area.

B) Host Plant Resistance: Plants with constitutive insect resistance possess genetically inherited qualities that results in a plant of one cultivar being less damaged than a susceptible plant lacking these qualities. Although insect resistant plants have been recognized for many years as a sound approach to crop protection, it is only during the last two decades that insect-plant interaction have been extensively investigated from the behavioral, ecological and physiological points of view. A number of plant characteristics are known to render the cultivars less suitable or unsuitable for feeding, oviposition and development of insect-pest. Broadly, these characteristic can be classified into two categories; biophysical and biochemical. Sultani *et al*., 2011 [69] studied the morphological and bio-chemical bases of resistance in okra genotypes against shoot and fruit borer, *E. vittella*. Resistance genotypes HB-03-29-7B and HBT-1-19-1-1-2 exhibited adverse effect on various biological parameters of *E. vittella*. Trichome density and length and thickness of fruit pericarp varied significantly among genotypes but they did not show significant relationship with larval duration or survival except that thickness of pericarp manifested significant negative correlation with larval survival. Among phytochemicals; total sugars, total phenols, phosphorus and tannin contents of resistant genotypes caused adverse effects on larval survival, pupal weight and adult emergence. Significant effects were shown by tannin for larval survival, sugar and tannin for pupal weight and tannin for adult emergence.

C) IPM: practices are basic and eco-friendly way to minimize the insect-pest population. Traps can be used for monitoring and suppression of pest population. Insect resistance varieties should be used along with refuge crop. Various biorational pesticides which are selective and eco-friendly are available to control pests. IPM is the best technique for management of insect-pest.

Conclusion
New tools of biotechnology such as transgenic and nanotechnology are also now available that can be used to accelerate the progress of crop protection in terms of improving pest resistance level, developing more efficient strains of microbial and bioagents and improving the efficiency of pesticide formulation and delivery system. Although, many potential elements of pest management have been recommended but majority are not of value to end users in practical sense for pest management in vegetable crops under field condition. Public-private partnership in production, distribution and quality control of different components of IPM is imperative to popularize the eco-friendly methods of pest management.

References
1. Agnihotri NP. Pesticide Safety Evaluation and Monitoring, edited by All India Coordinated Research Project (AICRP) on Pesticide Residues Division of Agricultural Chemicals. Indian Agricultural Research Institute, New Delhi. 1999,132-142.
2. Shivalingaswamy TM, Kumar Akhilesh, Satpathy S, Rai AB. Efficacy of emamectin benzoate in the management of vegetable pests. Progressive Horticulture. 2008;40(2):193-197.
3. Kumar Akhilesh, Pandey AK, Singh R, Baghel KS. Assessment of Rynaxypyr 18.5 SC and economic analysis in the management of Okra shoot and fruit borer. Bhartiya Krishi Anusandhan Patrika. 2017;32(3):196-197.
4. Dhankar DS. Progress in résistance studies in eggplant (*Solanum melongena* L.) against shoot and fruit borer of brinjal (*Leucinodes orbonalis* Guenee) infestation. Tropical Pest Management. 1988;34:343-345.
5. Kumar P, Johnsen S. Life cycle studies on fruit and shoot borer (Leucinodes orbonalis) and natural enemies of insect-pests of eggplant (*Solanum melongena*). Journal of Applied Biology. 2000;10(2):178-184.
6. Kavitha VS, Revathi N, Kingsley S. Biology of brinjal pest, *Leucinodes orbonalis* Guen. of Erode region in Tamil Nadu Biology of brinjal pest, *Leucinodes orbonalis* Guen. of Erode region in Tamil Nadu. Journal of Entomological Research. 2008;32(3):255-257.
7. Tiwari G, Prasad CS, Nath L. Integrated Management of Brinjal Shoot and Fruit Borer, (*Leucinodes orbonalis* Guenee) in Western Uttar Pradesh. Annals of Horticulture. 2009;2(1):54-61.
8. Sasikala K, Rao PA, Krishnayya PV. Comparative efficacy of eco-friendly methods involving egg parasitoid, *Trichogramma japonicum*, mechanical control and safe chemicals against *Leucinodes orbonalis* Guen. infesting brinjal. Journal of Entomological Research. 1999;23(4):369-372.
9. Puranik TR, Hadapad AB, Salunkhe GN, Pokharakar DS. Management of shoot and fruit borer, *Leucinodes orbonalis* Guenee through Bacillus thuringiensis formulations on brinjal. Journal of Entomological Research. 2002;26(3):229-232.
10. Singh SS. Comparative efficacy of certain bio-rational insecticides and *Bacillus thuringiensis* based bio-insecticides against *Leucinodes orbonalis* Guen. in brinjal. Indian Journal of Horticulture. 2010;67(3):353-356.
11. Tripura A, Chatterjee ML, Pande R, Patra S. Biorational management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.) in mid hills of Meghalaya. Journal of Entomology and Zoology Studies. 2017;5(4):41-45.
12. Singh JP, Gupta PK, Chandra U, Singh VK. Bioefficacy of newer insecticides and biopesticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). International Journal of Plant Protection. 2016;9(1): 1-7.
13. Jagginavar SB, Sunitha ND, Biradar AP. Bioefficacy of flubendiamide 480 SC against brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen Karnataka Journal Agricultural Science. 2009;22(3):712-713.
14. Bhanu KRM, Prabhakara MS, Jayanth KP. Field evaluation of indigenously developed sex pheromone lures for mass trapping brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). Pest Management in Horticultural Ecosystems. 2007; 13(2):115-121.
15. Singh SP, Nath P, Kumar Akhilesh, Chakravort S, Singh RS. Sustainable management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.).Vegetable Science. 2016;43(1):19-23.
16. Jaiswal SK, Dhingra MR, Kumar Akhilesh, Bagchi H, Kaushik U. Incidence of Insect Pest in Brinjal under Agro-Climatic Condition of Rewa District, Madhya Pradesh, India. International Journal of Current & Microbiology Applied Science. 2018;7(06):1241-1249.
17. Krishnamoorthy A, Mani M. Feasibility of managing *Heliothis armigera* on tomato through parasitoids, 195-205. In *Heliothis* management. Proceeding of National Workshop (Jayaraj, S; Uthamasamy, S.; Gopalan, M. and Rabindra, R.J. Eds.). Centre for Plant Protection Studies, TNAU, Coimbatore.1990,328.
18. Chandrasekhar J. Spatial distribution of eggs and fruit borer by *Helicoverpa armigera* (Hubner) in tomato. In: Subject matter training report (Bangalore: Agricultural Research Services, IIHR). 1992,4.
19. Yadav DN, Patel RC, Patel DG. Impact of inundative releases of *Trichogramma chilonis* Ishii against *Heliothis armigera* (Hubn.) in Gujrat (India). Journal of Entomological Research. 1985;9:153-159.
20. Mani M, Krishnamoorthy A. Recovery of two exotic parasites, Trichogramma brasiliensis (Hym: Trichogrammatidae) and *Eucelatonia bryani* (Dip:

Tachinidae) from *Heliothis armigera* (Lep: Noctuidae) in tomato fields. Entomophaga. 1983;20:401-406.
21. Singh SP. *Heliothis armigera* (Hubner), prospects of its biological suppression, *Heliothis management* Proce. of Nat. Workshop, Jayraj, S. Uthamaswamy Goplan, M. and Rabindra, R.J. (eds.), Centre for Plant Protection Studies, TNAU, Coimbatore. 1990;328:223-239.
22. Satpathy S, Rai S, Rai S. Preliminary field evaluation of NPV and insecticides against tomato fruit borer, *Helicoverpa armigera* (Hubner). Insect Environment. 2000;6(1):21-22.
23. Kumar Akhilesh, Satpathy S. Use of bioagents for tomato fruit borer management. Bhartiya Krishi Anusandhan Patrika. 2005;20(4):241-244.
24. Gopal S, Senguttuvam T. Integrated management of tomato fruit borer with insecticides, neem products and virus. Madras Agricultural Journal. 1997;84(2):82-84.
25. Srinivasan K, Moorthy PNK, Raviprasad TN. African marigold as a trap crop for the management of the fruit borer, *Helicoverpa armigera* on tomato. International Journal of Pest Management. 1994;40(1):56-63.
26. Krishnaiah K, Jagan Mohan N, Prasad GV. Efficacy of Bacillus thuringiensis for control of lepidopterous pests of vegetable crops. Entomon. 1981;6:87-93.
27. Rawat US, Pawar AD. Biocontrol of tomato fruit borer, *Heliothis armigera* (Hubner) in Himachal Pradesh, India. Plant Protection Bulletin. 1993;45(2, 3):34.
28. Dhingra S, Hedge RS, Vohra S, Parmar BS. Bioefficacy of neem oil micro emulsions against gram pod borer, *Helicoverpa armigera* (Hub). Pesticide Research Journal. 2002;14(2):224-248.
29. Kaushik N. Larval development and survival of gram pod borer (*Helicoverpa armigera*) on diet containing Eucalypts and Callistemon leaf extracts., In abstract presented in X/V International Plant Protection Congress. Jerusalem, 1999.
30. Shivalingaswamy TM, Kumar Akhilesh, Satpathy S, Rai AB. Efficacy of Indoxacarb against tomato fruit borer, *Helicoverpa armigera* Hubner. Pestology. 2008;32(8):39-41.
31. Sastry KS, Singh S. Effect of different insecticides on the control of whitefly (*Bemisia tabaci* Genn.) population in tomato crop and the incidence of tomato leaf curl virus. Indian Journal Horticulture. 1971; 28:304-309.
32. Saikia AK, Muniyappa V. Epidemiology and Control of tomato leaf curl virus in Southern India. Tropical Agriculture. 1989;66(4):350-354.
33. Gu-XiShu, Bu-WenJun, Xu-WeiHong, Bai-YiChuan, Liu-BaiMing, Liu TX. Population suppression of *Bemisia tabaci* (Hemiptera: Aleyrodidae) using yellow sticky traps and Eretmocerus nr rajasthanicus (Hymenoptera: Aphelinidae) on tomato plants in greenhouses. Insect Science. 2008;15(3):263-270.
34. Muthukumar M, Kalyanasundaram M. Efficacy of certain insecticides against major sucking insects of brinjal (*Solanum melongena* L.). South Indian Horticulture. 2003;51(1-6):207-213.
35. Espinel C, Torres T, Cotes PAM. Effect of entomopathogenic fungi over development stages of *Bemisia tabaci* (Hemiptera: Aleyrodidae). Revista Colombiana de Entomologia. 2009;35(1):18-21.
36. Krishnakumar NK, Srinivasan K, Suman CL, Ramachandran RP. Optimum control strategy of cabbage pests from a chemical control trial. Progressive Horticulture. 1986;186:104-110.
37. Srinivasan K. Changing pest complex in relation to cropping systems - vegetables. National seminar on "Changing pest situation in the current agricultural scenario of India". Indian Agricultural Research Institute, New Delhi, India. 1988,27.
38. Chen JS, Sun CN. Resistance of diamondback moth (Lepidoptera: Plutellidae) to a combination of fenvalerate and piperonyl butoxide. Journal of Economic Entomology. 1986;79:22-30.
39. Lim GS. The biology and effects of parasites on the diamondback moth, *Plutella xylostella* (L.). Ph.D. Thesis, University of London. 1982; 317.
40. AVRDC. Progress Report, 1989. Asian Vegetable Research and Development Centre, Shanhua, Taiwan. 1990,350.
41. Yadav DN, Patel RC, Manjunath TM. Seasonal activity of *Apanteles plutellae* (Kardj.). A larval parasite of *Plutella xylostella* (L.) at Anand (Gujrat, India). Indian Journal of Plant Protection. 1975;3:111-115.
42. Nagarkatti S, Jayanth KP. Population dynamics of major insect pests of cabbage and their natural enemies in Bangalore district (India). Proceedings of International Conference on Plant Protection in Tropics, Kualalampur, Malaysia. 1982;325-347.
43. Satpathy S, Rai S, Singh B. Impact of host plant colour on the susceptibility of cabbage (*Brassica oleracia* var. Capitata) cultivars to diamondback moth (*Plutella xylostella* L.). Indian Journal of Entomology. 2002; 64(2):164-169.
44. Satpathy S, Rai S. Host preference and biology diamondback moth *P. xylostella* (L.) on crucifers: Society of Plant Protection Science, New Delhi organized National Symposium on "Crop Pest and Disease Management: Challenges for the new millennium". 27-28 November, MPKV, Rahuri. 1999,24-25.
45. Nagesh M, Verma S. Bioefficacy of certain insecticides against diamondback moth (*Plutella xylostella*) on cabbage. Indian Journal of Entomology. 1997;59(4):411-414.
46. Torres AL, Barros R, Oliveira JV-de And de-Oliveira JV. Effects of plant aqueous extracts on the development of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). Biorational management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) in mid hills of Meghalaya. Neotropical Entomology. 2001;30(1):151-156.
47. Lad SK, Peshkar LN, Baviskar SS, Jadhav RS. Efficacy of microbial and bioagents for the management of *Plutella xylostella* (L.) on cauliflower. Journal of Soils and Crops. 2009;19(1):129-134.
48. Satpathy S, Kumar, Akhilesh, Singh AK, Pandey PK. Chlorfenapyr: A new molecule for diamondback moth (*Plutella xylostella* L.) management in cabbage. Annals of Plant Protection. 2005;13(1):88-90.
49. Satpathy S, Kumar Akhilesh, Shivalingaswamy TM, Rai M. Evaluation of new molecules for diamondback moth (*Plutella xylostella* L.) management in cabbage. Indian Journal of Horticulture. 2007;64(2):175-177.
50. Kumar Akhilesh, Satpathy S, Shivalingaswamy TM, Rai M. Field efficacy of Indoxacarb against diamondback moth, *Plutella xylostella* L. on cabbage. Pestology. 2007; 31(4):41-43.
51. Satpathy S, Shivalingaswamy TM, Kumar Akhilesh, Rai

AB, Rai M. Potentiality of Chinese cabbage as trap crop for diamondback moth, *Plutella xylostella* L. management in cabbage. Indian Journal of Agricultural Sciences. 2010;80(3):238-241.
52. Singhal V. Chilies. In Indian Agriculture 2003, Indian Economic Data Research Centre, Mayapuri, New Delhi. 2003;565-570.
53. Berke T, Sheih SC. Chilli peppers in Asia. Capsicum and Egg Plant Newsletter. 2000;19:38-41.
54. Varghese TS. Management of thrips, *Scirtothrips dorsalis* Hood and mite, *Polyphagotarsonemus latus* (Banks) on Chilli using biorationals and imidacloprid. M.Sc (Agri) thesis, University of Agricultural Sciences, Dharwad, India,2003.
55. Varghese TS, Giraddi RS. Integration of neem cake in the plant protection schedule for thrips and mite management in chilli (cv. Byadagi). Karnataka Journal of Agriculture Science. 2005;18:154-156.
56. Kumar Akhilesh, Sharma A, Vishwakarma N, Singh M. Study of Cost Economics of Management of Chilli Mites through Abamectin 1.8 EC. International Journal of Current & Microbiology Applied Science. 2018;7(9):1659-1663.
57. Lefroy HM. Ent. Mem. Dept. Agri. Indian Journal of Entomology Series. 1907 1:113- 252.
58. Rajapakse R. The management of major insect pests Bactrocera cucurbitae and *Aulacaphora* spp. In cucurbits under 3 intensive systems: integrated chemical and organic agriculture in Southern Sri Lanka. Proc. British Crop Protection Council Pests and Diseases Vegetables, Volume-3, 13-16 November, 2000, Brighton, United Kingdom. 2000,981-985.
59. Schmutterer H, Singh RP. List of insect pests susceptible to neem products. In: the Neem Tree (*Azadirachta indica* A. Juss.) and other Meliaceous Plants. Ed. Schmutterer, H., VCH Publications, Weinhiem, Germany. 2002,411-456.
60. Babu PG, Reddy DJ, Jadhav DR, Chiranjeevi C, Khan MAM. Comparative efficacy of selected insecticides against pests of watermelon. Pesticide Research Journal. 2002;14:57-62.
61. Nath P, Bushan S, Kumar Akhilesh. Efficacy of certain ecofriendly insecticides and bait spray against fruit fly (*B. cucurbitae*) infesting fruits of bottle gourd. Vegetable Science. 2007;34:150-152.
62. Mehta PK, Chandel RS, Kashyap NP. Control of fruit fly *Bactrocera cucurbitae* (Coq) on cucumber in Himachal Pradesh. Pestology. 2000;10:53-55.
63. Patnaik HP, Sarangi PK, Mohapatra P. Studies on the incidence of fruit flies and jassids on summer bitter gourd and their control. Orissa Journal of Horticulture. 2004;32:87-90.
64. Sookar P, Seewooruthun SI, Khayratee F. Assessment of protein baits for the monitoring and control of fruit flies (Diptera: Tephritidae). Revue Agricole et Sucriere de l'-Ile Maurice. 2001;80:287-294.
65. Munir K. Efficacy of different plant crude extracts for the control of insect pests of okra. M. Sc (Hons.) Thesis, The University of Agriculture Peshawar, Pakistan. 2006,1-50.
66. Ram S, Singh S. Effect of intercropping of spices, cereal and root crops on the incidence of *Helicoverpa armigera* (Hub.) in tomato. Vegetable Science. 2010;37(2):164-166.
67. Bhullar MB, Dhatt AS. Spider mite, *Tetranychus urticae* Koch incidence in relation to cultural practices in nethouse on brinjal. Journal of Insect Science. 2011;24:121-123.
68. Chaudhary FK, Patel GM. An integrated approach of male annihilation and bait application technique for fruit fly management in pumpkin. Pest Management and Economic Zoology. 2008;16(1):57-61.
69. Sultani MS, Singh R, Dhankhar. Morphological and biochemical basis of resistance in selected okra genotypes against *Earias vittella* (Fab.). Journal of Insect Science. 2011;24(1):33-40.