

LIFE TABLE STUDIES AND MANAGEMENT OF DIAMONDBACK MOTH, *Plutella xylostella* L. THROUGH ORGANIC APPROACH IN CABBAGE

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I. INTRODUCTION

Vegetables are considered as protective food of great value because of their high nutrient content and richness in vitamins and minerals. Thus they constitute a valuable supplementary food and form an important constituent of our diet.

In vegetable production, India is the second largest producer in the world next only to China with an annual production of 81 million tonnes from 5.12 million hectares of land. But due to heavy post harvest losses (approximately 30%) and high population in the country the per capita availability of vegetables is only 140 g/day, when compared to 300 g of recommendations by nutritional experts (Fageria *et al.*, 2001). At present vegetables constitute only eight to ten per cent of total food intake of Indians who are mostly vegetarians. There is a necessity to popularize vegetables, as major part of the diet, especially for the weaker section of the society. By giving more importance to vegetables in the diet, the shortage of cereals could be counter balanced. Most of the vegetables are short duration crops which will be ready for harvest in a relatively short time, thus enabling the farmer to get more income per unit area by taking 3 to 4 crops in a year.

Cole crops are one of the most abundantly consumed vegetables all over the world. They belong to the genus *Brassica* of the family Brassicaceae. This group includes a wide variety of vegetable crops. Cabbage (*Brassica oleracea* Var. *Capitata* Linnaeus) is a leafy winter vegetable grown for its edible enlarged terminal bud. In addition to several minerals such as P, K, Ca, Fe, cabbage also contains high percentage of vitamin A, B and C. It is consumed either cooked or raw as salad.

Cabbage is of Cyprus and Mediterranean origin. It is cultivated extensively in tropical and temperate regions of the world *viz.*, China, Germany, India, Indonesia, Japan, Korea, Poland, Russia, Taiwan, Turkey, Ukraine, USA, Uzbekistan and several other countries with total area of 16.56 lakh hectares and output of 50.17 million tonnes. Of this India's contribution is 3,862 lakh metric tonnes from an area of 2.2 lakh hectares with a productivity of 18.26 t/ha (Anon., 2005). There is substantial increase (25%) in the area of cabbage during the last decade in India. Some of the most important cabbage growing states in the country include Uttar Pradesh, Karnataka, Maharashtra, Bihar, West Bengal, Punjab, Haryana, Orissa, Assam and TamilNadu (Anon., 2005). In Karnataka it is grown in all the seasons over an area of 3,200 hectare with an annual production of 1.98 lakh metric tonnes having an average productivity of 24.6 t/ha (Krishnamoorthy *et al.*, 2002). Cabbage is cultivated extensively in North Karnataka especially in Dharwad, Belgaum and Bidar districts.

Although the crop has got huge domestic requirement, a number of limiting factors have been attributed for low productivity. Among them, the chief constraint in the production of cabbage is damage caused by pest complex right from germination till harvesting stage. Maison (1965) listed 51 insect pests to damage cruciferous crops throughout the world. In India, a total of 37 insect pests have been reported to feed on cabbage (Lal, 1975). Of these, two species of aphids, three species of defoliators and one species of head borer are of economic importance in Karnataka (Mallapur, 1988). Aphids and defoliating insects are most destructive to the crop. The extent of damage due to these pests in India is known to range from 7 to 90 per cent with consequent reduction in yield from 20 to 80 per cent (Prasad, 1963).

Diamondback moth (*Plutella xylostella* Linnaeus.), a cosmopolitan pest is a major defoliating caterpillar that hampers the successful cultivation of cabbage in the world. In India it was first recorded on cruciferous vegetables in 1914 (Fletcher, 1914). Now the pest has been noticed all over India where plants belonging to family Brassicaceae are grown (Devi *et al.*, 2004). This pest causes colossal loss to cabbage every year. It damages the crop by feeding on the foliage. Attack by a large number of larvae hinders the growth of the plant leading to significant reduction in yield. The crop loss is estimated to vary from 52 per cent (Anuradha, 1997) to 100 per cent (Cardleron and Hare, 1986). According to Talekar (1992) the annual cost of managing this pest globally is estimated to be one billion US dollar.

Since cabbage is a highly remunerative vegetable crop, intensive plant protection measures involving use of a number of insecticides are of common practice. In spite of large scale and repeated applications of insecticides, the pest has been found to occur in severe form in all cabbage growing areas of North-Western Karnataka.

Hence ecological studies which are basic in understanding the causes for high population of the pest and identification of long term control measures are of great importance. Life tables are one of the most important tools in pest management as they reveal the most opportune periods and vulnerable stages of the insect species. Series of life tables of the pest increase the understanding about pest dynamics and key mortality factors (Reddy *et al.*, 2004). Thus life table studies enable us to devise an intelligent and practical manipulation of control factors for sound pest management strategy.

Further, in recent years, there is a lot of awareness and preference for organically produced food stuff in the country. Both GOI and GOK have been earmarking significant amount of funds for popularizing organic farming systems, especially in consumable crops. This has led to research programmes for development of organic package of practices in several crops. Since cabbage is consumed raw as salad, the presence of insecticide residues is a dangerous health hazard to consumers. On the other hand, undesirable effects of insecticides such as adverse effects on natural enemies, environmental pollution and spiralling cost of synthetic chemicals have encouraged the development of non-chemical package or a programme with least pesticide usage as need of the hour. Along with this, soil and ecological health are also of paramount importance in the changed scenario of switching over to organic agriculture from chemical based conventional agricultural strategies. In this context, use of organic soil amendments and ecofriendly insecticides in crop production assume greater significance. Neem cake, pongamia cake, vermicompost, poultry manure and plant and microbial based insecticides etc. could become some of the key agro-inputs in organic farming system.

As a result of these, there is a growing strong perception to adopt an integrated approach of pest management by combining different pest control methods so that there is least adverse effect on environment in general and human health in particular. Thus any non-chemical strategy for managing diamondback moth could be a welcome approach.

Keeping these points in view, detailed investigations were undertaken with the following objectives.

1. To identify the key mortality factors for diamondback moth and construction of life tables
2. Management of diamondback moth through organic approach involving
 - a. Organic amendments, botanicals and vermiwash and
 - b. Eco-friendly insecticides
3. To develop and compare IPM modules against diamondback moth

II. REVIEW OF LITERATURE

The available literature on diamondback moth (DBM) *Plutella xylostella* (Linnaeus.) pertaining to the objectives envisaged in the introductory chapter is reviewed here under.

Literature available on the distribution and biology of DBM is reviewed. A voluminous literature is available on the efficacy of different insecticides in the control of DBM in India and abroad. In contrast, the information available on the use of organic amendments in cabbage and population dynamics with regard to construction of life mortality table is scanty. Hence, pertinent literature available on other insect pests have been reviewed and included under the following heads.

2.1 IDENTIFICATION OF KEY MORTALITY FACTORS AND CONSTRUCTION OF LIFE TABLES

2.1.1 ORIGIN AND DISTRIBUTION OF *P. xylostella*

The diamondback moth is believed to have originated from Mediterranean area (Harcourt, 1954), the origin for some of the most important crucifers (Tsunoda, 1980). The members of this genus occur in temperate and tropical climates and represent a diverse, wide spread and important plant groups which includes cabbage, broccoli, cauliflower, collards, rape seed, mustard and Chinese cabbage (Li, 1981). DBM is an important pest of these crops and now it occurs throughout the world wherever crucifers are grown. It is believed to be the most universally distributed of all Lepidopterans (Meyrick, 1928).

In India, the pest was first reported by Fletcher in 1914 on cruciferous vegetables. Now this pest has been recorded throughout India wherever plants belonging to family Brassicaceae are grown. The distribution of this pest in India has been noticed in all the major cabbage producing states such as Uttara Pradesh, Orissa, Bihar, Assam, West Bengal, Maharashtra, Karnataka, Tamilnadu, Gujarath, Haryana and Uttaranchal. In Karnataka, the pest has been reported from Bangalore, Kolar, Mysore, Dakshina Kannada, Hassan, Dharwad and Belgaum districts (Anon, 2005).

2.1.2 LIFE HISTORY OF *P. xylostella*

Studies on the biology of the pest has been documented by many workers in different parts of the world including India. These studies have been conducted under laboratory and natural field conditions.

2.1.2.1 The egg

The eggs are minute and ivory white or light yellow in colour with cylindrical to oblong shape measuring 0.5 mm in size (Abraham and Padmanabhan, 1968). The chorion of the eggs is more or less uniformly pitted. A day prior to hatching, egg becomes pale black in colour revealing the young coiled larva through the chorion (Jayarathnam, 1977).

The incubation period was observed to last for 3 to 11 days at temperatures ranging from 26 to 15⁰C and 60 to 90 per cent relative humidity (Kanervo, 1936). Abraham and Padmanabhan (1968) recorded an incubation period of 3-6 days, whereas Jayarathnam (1977) reported it to be 3-4 days under both laboratory and field conditions. According to Bhalla and Dubey (1986) the mean incubation period was 3.10 days and it was 2.18 days in Manipur (Devjani and Singh, 1999).

2.1.2.2 The larva

Reichardt as back as 1921 stated that the young larvae after hatching initially wander over the leaf surface and then feed like leaf miners in between the cuticle through parenchyma of leaves. According to Harcourt (1957), the larva emerge from the mine at the end of first instar after which the rest of the instars feed from lower surface of leaves (70.3%) leaving the epidermis.

The freshly hatched larvae were pale white with pale brown head (Abraham and Padmanabhan, 1968). The larva under went three moultings resulting in four instars. They have further reported the larval period to extend from 14-21 days. Whereas, as per the investigation of Patil and Pokharkar (1971) there were five larval instars with total period ranging from 8-11 days.

Jayarathnam (1977) noticed only four instars each occupying a range of 3-5 days, 2-3 days, 2-3 days and 2-4 days, respectively for different seasons. He described the fully grown caterpillar to be light green in colour measuring 8.62 to 10 mm in length, moderately stout and smooth with short scattered hairs. On slight disturbance, the larvae wriggled actively and dropped down the leaf suspending themselves by silken thread. Larval period was found to be 10 days in hot and rainy seasons and 12 to 15 days in cold seasons.

The larvae passed through four larval instars occupying 2-3, 1 - 1.5, 1 - 2 and 1.5 - 2.5 days for the first, second, third and fourth instar respectively at Palampur, Himachal Pradesh (Bhatia and Verma, 1994). In Manipur, the total larval period took 10-15 days (Devjani and Singh, 1999).

2.1.2.3 The pupa

Abraham and Padmanabhan (1968) described the newly formed pupae to be yellowish green which in a day or two became brown and gradually turned dark brown by the time of adult emergence. The mean length of pupae was 6 mm and the stage lasted for 7-11 days. Patil and Pokharkar (1971) noted the pupal period to range from 3-7 days with an average of 5 days. Jayarathnam (1977) recorded the pupal period to be 4 days in summer and rainy seasons and 4 to 5 days in cold season. The duration of pupal period was noticed to vary from 4 to 15 days depending on temperature (Chellaiah and Srinivasan, 1986). It was ranging from 3-5 days at Palampur, Himachal Pradesh (Bhatia and Verma, 1994). Mean pupal period of 6.86 days was noticed in Manipur (Devjani and Singh, 1999).

The mature caterpillar formed a beautiful gauzy loosely spun cocoon. Thereafter is shortened its body longitudinally but remained active (Lingappa *et al.*, 2000).

2.1.2.4 Total life cycle

Most of the authors have considered the total life cycle (TLC) as the period from egg laying to adult emergence and not from egg to egg stage.

Total life cycle from egg to adult was found to occupy 16-47 days (Marsch, 1917), 25 - 30 days (Gunn, 1918) and 18 - 34 days according to weather conditions (Reichardt, 1921). Kanervo (1936) recorded TLC to range between 20 - 25 days at 12 - 26°C. Patil and Pokharkar (1971) reported that the total development of DBM occupied 15-24 days at constant temperature of 80 ± 2°F.

Jayarathnam (1977) recorded the TLC of *P. xylostella* to range from 19 - 27 days in different seasons. The total developmental period of DBM from egg to adult emergence was 17.8, 20.80, 19.40 and 16.50 days when reared with leaves of Brussel sprouts, cabbage and cauliflower, knol khol and sprouting broccoli, respectively under laboratory conditions (Sood *et al.*, 1996).

2.1.2.5 The adult

At 27° and 77° F (mean 49°F) adult lived for maximum of 100 and 90 days, respectively when fed continuously on honey solution or a mixture of honey and bee bread and for 30 to 40 days when starved or given either food for one day or water for one day or continuously (Given, 1944). Miner (1947) reported that adults lived for 7 days. Females lived for 7 to 49 days and males 3 to 58 days (Harcourt, 1957). Hassanein (1958) made detailed investigation on the biology of DBM. According to him, the average life span of male and female was 6.3 to 15.4 and 5.7 to 10.3 days, respectively with shorter period in June and longer one in April and female died a day after oviposition.

Abraham and Padmanabhan (1968) described the morphological appearance and the ecobiological habits of DBM. Adult moths are slender and greyish brown with an expans of 14 mm and live for 3 to 11 days. When at rest, the moths folded the wings on abdomen and

along the mid dorsal line where the anal ends of forewings meet, a diamond shaped design of three creamy yellow or white patches are formed. Patil and Pokharkar (1971) reported that the life span of male and female was 16.4 and 12.1 days, respectively.

Jayarathnam (1977) noticed the moths to survive for 3 to 6 days without food and for 11 to 16 days with food. The average longevity of the male and the female was 77 days. While at Palampur, Himachal Pradesh it was 6 to 9 and 14 to 20 days, respectively (Bhatia and Verma, 1994). The adult longevity was 16.7 days in Manipur (Devjani and Singh, 1999).

2.1.2.6 Oviposition and fecundity

Gupta and Thorsteinson (1960) studied the oviposition behaviour of the DBM. The female moths of *P. xylostella* starts laying eggs in the evening hours after mating. The eggs are generally laid singly or in groups of two to four on the under surface of leaves often along the midrib or principal vein. Typically, the eggs are laid in depression on the leaf along the midrib and larger veins or on concave surfaces near smaller veins rather than smooth surfaces. The oviposition period last for four days. Majority of the eggs are laid on the same day of emergence (90%). The eggs were found to be laid on the underside of the leaves of cabbage (Marsch, 1917) and also on the upper surface of the leaf (Gunn, 1918).

At 70 per cent relative humidity, average number of eggs laid per female was 0, 35, 224, 252, 134 and 38 at 10, 15, 20, 25, 30 and 35°C, respectively in laboratory and in field cage, female laid 92 to 364 eggs (Hassanein, 1958). Patil and Pokharkar (1971) reported the fecundity to range from 71 to 203 eggs per female in 1 to 2 days. Each female can lay 220 to 315 eggs with an average of 284. The mean fecundity of 153 eggs per female was noticed in Palampur, (Devjani and Singh, 1999). Whereas, Sharma *et al.* (1999) reported it to vary from 147 to 251 eggs.

2.1.3 Natural enemy complex

All stages of diamondback moth are attacked by numerous parasitoids and predators with parasitoids being the most widely studied. Additionally, adults are attacked by polyphagous predators such as birds and spiders (Talekar and Shelton, 1993).

Alam (1999) enlisted number of natural enemies on *P. xylostella* in Jamaica (Table 1). The list of natural enemies recorded in India is furnished separately in Table 2.

2.1.3.1 The parasitoids

Thompson (1946) listed 47 parasitoids of DBM from different parts of the world. According to Goodwin (1979) although over 90 parasitoid species attack diamondback moth, only about 60 of them appear to be important. Among these, six species attack diamondback moth eggs, 38 attack larvae and 13 attack pupae (Lim, 1982). Egg parasitoids belonging to the polyphagous genera *Trichogramma* and *Trichogrammatoidea* contribute little to natural control and require frequent mass releases, whereas larval parasitoids are most predominant and effective, majority of these belong to *Diadegma* and *Cotesia* (=Apanteles); a few to *Diadromas* sp. which are mainly pupal parasitoides also exert significant control (Talekar and Shelton, 1993).

2.1.3.1.1 Parasitization of diamondback moth egg by *Trichogramma*

Several reports are available on the parasitization of diamondback moth by *Trichogramma* sp. Eventhough, the pest population were very low, reduction was obtained in the numbers of *P. xylostella* in Netherlands when large numbers of *T. evanescens* were released in brussel sprouts fields. Moreover, it was observed that the female parasitized more efficiently on egg batches than on eggs laid singly (Lenteron and Smits, 1982). Nguyen and Nguyen (1982) obtained 45.5 per cent parasitism of *P. xylostella* by *Trichogramma* in Vietnam. Weekly observation of pest and parasitoid populations in the cabbage fields in Japan from April to November during 1987 showed that *T. chilonis* was one of the primary parasitoid which resulted 11.9 per cent parasitism (Okada, 1989).

Under laboratory conditions, parasitization by *Trichogrammatoidea bactrae* was to a tune of 30 per cent on DBM (Singh and Jalali, 1993). The per cent parasitization of

Table 1: A complex of parasitoids, predators and fungi attacking various stages of diamondback moth, *Plutella xylostella* in Jamaica

Name	Status
PARASITOIDS	
Hymenoptera	
Trichogrammatidae, - <i>Trichogramma</i> sp.	Egg parasite
Inchneumonidae - <i>Diadegma insulare</i> (Cresson)	Larval parasite
Braconidae : <i>Cotesiini</i> – <i>Cotesia</i> (=Apanteles) sp.	Larval parasite
Pteromalidae: <i>Oomyzus</i> (= <i>Tetrastichus</i>) sp.	Larval pupal parasite
Eulophidae - <i>Trichospilus</i> sp.	Pupal parasite
Hyper parasitoids	
Ceraphronidae – <i>Aphanogmus</i> (=Ceraphron) <i>fijiensis</i>	Pupae of <i>Cotesia</i> sp.
Eulophidae – <i>Horismenus</i> sp.	Pupae of <i>Cotesia</i> sp.
Pteromalidae – <i>Catoloccus</i> sp. (Species new to science)	Pupae of <i>Cotesia</i> sp.
Chalcididae – <i>Spilochalcis</i> sp. (Species new to science)	Pupae of <i>Cotesia</i> sp. and <i>Diadegma insularae</i>
PREDATORS	
Coleoptera	
Coccinellidae – <i>Coleomegilla</i> sp., <i>Cycloneda</i> sp., <i>Hippodamia</i> sp.	Egg and young larvae
Staphylinidae – <i>Belonuchus gagates</i>	Larvae and pupae
Diptera	
Syrphidae – <i>Toxomerus</i> sp., <i>Pseudodoros</i> sp.	Young larvae
Neuroptera	
Chrysopidae : <i>Ceraeochrysa</i> sp.	Larvae
Fungi	
<i>Beauveria</i> sp.	Larvae and pupae
<i>Hirsutella</i> sp.	Larvae
<i>Paecilomyces</i> sp.	Pupae

Table 2 : Natural enemies of *P. xylostella* in India

Sl. No.	Species	Stage	References
I. PARASITIDS			
1	<i>Trichogramma chilonis</i> Ishii (Trichogrammatidae : Hymenoptera)	Egg	Anuradha (1997)
2	<i>Trichogramma armigera</i> Nagaraj (Trichogrammatidae : Hymenoptera)	Egg	Manjunath (1972)
3	<i>Trichogrammatoidea bactrae</i> Nagaraj (Trichogrammatidae: Hymenoptera)	Egg	Singh and Jalali (1993)
4	<i>Cotesia</i> (Apanteles) <i>plutellae</i> (Braconidae : Hymenoptera)	Larvae	Nagarakatti and Jayanth (1982)
5	<i>Diadegma fenestrata</i> Holmgren <i>Diadegma collaris</i> Graven horst	Pupa	Chauhan <i>et al.</i> (1997) and Devi and Raj (1995)
6	<i>Diadegma semiclausum</i> Horstmann	Pupa	Chandramohan (1994)
7	<i>Tetrastichus sokolowskii</i> Kundj (Eulopidae : Hymenoptera)	Larval	Nagarakatti and Jayanth (1982)
8	<i>Brachymeria exacarinata</i> Gahan (Chalcididae : Hymenoptera)	Pupa	Cherian and Basheer (1938)
II. PREDATORS			
1	<i>Chrysoperla cornea</i> Stephens (Chrysopidae : Neuroptera)	Egg & larva	Anuradha (1997)
2	<i>Coranus</i> sp. (Reduviidae : Hemiptera)	Larva	Anuradha (1997)
Ants			
1	<i>Tapinoma melanocephalum</i> (Formicidae : Hymenoptera)	Larva	Jayarathnam (1977)
2	<i>Componatus sericus</i> (Formicidae : Hymenoptera)	Larva	Jayarathnam (1977)
3	<i>Pheidole</i> sp. (Formicidae : Hymenoptera)	Larva	Jayarathnam (1977)
Birds			
	Yellow wag tail (<i>Motacilla flava</i>)	Larva	Jayarathnam (1977)
	Cattle egret (<i>Bulbueus ibis</i>)	Larva	Jayarathnam (1977)
III PATHOGENS			
1	<i>Bacillus thuringiensis</i> var. Kurstaki	Larva	Narayan <i>et al.</i> (1970)
2	Nuclear polyhedrosis virus (NPV)	Larva	Anuradha (1997)
3	Granulosis virus (GV)	Larva	Rabindra <i>et al.</i> (1996)
4	<i>Paecilomyces farinosus</i> (Fungus)	Larva	Anuradha (1997) and Gopalakrishna (1998)
5	<i>Beauveria bassiana</i> (Fungus)	Larva	Voon <i>et al.</i> (1999)
6	<i>Zoophthora radicans</i> (Fungus)	Larva	Gopalakrishna (1998)
7	<i>Varriomorpha</i> sp. (Protazoa)	Larva	Anuradha (1997)
8	Nematode	Larva	Anuradha (1997)

diamondback moth eggs after release of *Trichogramma chilonis* @ 1 lakh per ha was 30 to 33.5 whereas 51.5 to 57.0 when released @ 2 lakh per ha (Anuradha, 1997).

2.1.3.1.2 Parasitization of DBM larvae by *C. plutellae*

A. Reports from other parts of the world.

Fan and Ho (1971) observed 19.6 per cent parasitization by *C. plutellae* in Taiwan. Two weeks after the release of parasitoid in Taiwan, it was observed that there was reduction in the pest density and increase in the natural rate of parasitism [18.2 to 26.31 per cent] (Chiu *et al.*, 1974).

Yaseen (1974) reported that the parasitism by *C. plutellae* increased steadily upto 55.9 per cent after field release in Trinidad. The mean number of diamondback moth larvae per ten plants in Malaysia at four different sites were 295, 100, 136 and 132 while parasitism by *C. plutellae* was 12.3, 18.5, 18.2 and 19.1 per cent. The findings of Ooi (1979) indicated the increase in host density to be accompanied by decrease in parasitoid density. In Philippines, the main biotic mortality agents were *A. plutellae* (1.9 to 16.4%) and *Entomophthora radicans* (Velasco, 1983). Chua and Ooi (1986) observed 11.7 per cent parasitism in field.

B. Reports from India

Joshi and Sharma (1974) found that 36.6 per cent of diamondback moth larvae collected from cabbage and cauliflower in Rajasthan were parasitized by *A. plutellae* in 1969. In Gujarat, the parasitoid was active from July to March and resulted in 71.7 per cent parasitism (Yadav *et al.*, 1979).

Larval parasitization of about 72 per cent (Yadav *et al.*, 1975), 18 to 75 per cent (Nagarakatti and Jayanth, 1982) and 80 per cent (Jayarathnam, 1977 and Chandramohan, 1994) was noticed by *C. plutellae* from different plants of India.

Mustaque and Mohyuddin (1987) recorded highest rate of parasitism by *A. plutellae* in April (41.3%) and May (20%) on cauliflower and 24.5 per cent in September in unsprayed radish and no parasitism in the treated field. When parasitoids were released in the fields of Taiwan, 10.2 – 24.0 per cent parasitism was recorded in the low lands while 20-80 per cent parasitism was recorded in the uplands. The optimum temperature range was 20-35°C (Anon., 1988).

Many authors from India have indicated that the larval population of DBM was considerably reduced by the parasitoid *C. plutellae*.

Reena (2000) recorded only two parasitoids of DBM in Dharwad of which the larval parasitoid *C. plutellae* recorded 18-30 per cent parasitism when compared to the other parasitoid.

2.1.3.1.3 Pupal parasitization

Cherian and Basheer (1938) noticed 20 to 60 per cent pupal parasitization by *Brachymeria exacarinata* with peak activity in August. Chandramohan (1994) recorded 68 per cent pupal parasitization by *Diadegma semiclausom* from Tamil Nadu. Devi and Raj (1995) observed the *Diadegma fenestrae* parasitizing the pupa of DBM to an extent of 66 to 80 per cent in Himachal Pradesh.

2.1.3.1.4 Parasitization by larval-pupal parasitoid

Parasitization upto an extent of 28 to 96 per cent by *Tetrastichus sokolowskii*, a larval pupal parasitoid with peak activity during November-December was recorded by Jayarathnam (1977) in Bangalore. Whereas, Nagarkatti and Jayanth (1982) reported 30 to 78 per cent parasitization with peak activity of the same larval pupal parasitoid during August-September in Bangalore.

A total of nine hymenopteran parasitoids attacking different stages of the pest has been reported from Himachal Pradesh by Chauhan *et al.* (1997). Reena (2000) reported the

peak activity of *T. sokolowskii* during cold season as compared to rainy season near Dharwad.

2.1.3.2 The predators

Under fields conditions of birds like yellow wag tail and cattle egret were found devouring the larvae of DBM (Jayarathnam, 1977). He further reported three species of ants to feed on the larvae of the pest.

A chrysopid predator was found preying on the larvae of *P. xylostella* on rape in Saskatchewan (Burgess, 1980). Krishnamurthy (1988) reported that the predator larvae preyed upon neonate larvae of diamondback moth. In Dharwad, spiders, coccinellids, syrphids and brown lace wings were observed to feed on DBM larvae (Reena, 2000).

2.1.3.3 The pathogens

2.1.3.3.1 Bacterial infection

The control experiments both under laboratory and field revealed that *Bacillus thuringiensis* Berliner was effective in managing the DBM population as quoted by many of the workers (Oka, 1957, Krishnaiah *et al.*, 1981 and Anuradha, 1997).

2.1.3.3.2 Fungal pathogens

Robertson (1939) stated that a high degree of infection by the fungus *Entomophthora* sp. occurred only with high humidity. But, Harcourt (1963) stated the fungi apparently did not persist in an active form among host population except during high humidity accompanied by heavy rainfall. Spraying of various fungal inoculum *viz.*, *Paecilomyces* sp. (Anuradha, 1997), *Zoophthora* sp. (Gopala Krishna, 1998), *Beauveria* sp. (Voon *et al.*, 1999) and were found to reduce the DBM population.

2.1.4 Life table studies

Thorough understanding of the population dynamics of any insect requires the construction of life tables. According to Deevey (1947), life table is a concise summary of certain vital statistics of a population beginning with a cohort, real or imaginary, whose members start life together, the life table states for every interval of age, the number of deaths (dx) the survivors remaining [lx], the rate of mortality (qx) and the expectation of further life (ex) where x stands for age and the age structures (lx). Atwal and Bains (1974) opined that the life table records series of sequential measurements that indicate population changes throughout the life cycle of the species under natural conditions.

2.1.4.1 Construction of life table

Life table approach was first introduced in insect ecology by Morris and Miller (1954). They constructed the life tables for the natural insect population of the spruce budworm in Canada. They accounted for the birth (egg) and mortalities due to parasitoids, predators, diseases, weather and dispersal at various stages of the insect development. The age interval was divided into life stages of insects which could be sampled as eggs, larval instars, pupae and adults, with an additional column, dxF, to indicate the factor responsible for dx, which listed all the mortality factors that could be quantified. And the ex column was dropped, while 100 dx was used as percentage mortality.

Based on the method devised by Morris and Miller (1954), Harcourt (1969) prepared life tables for *Plutella maculipennis* (Curt.) by using the following column heads which are now widely used.

- x = Age interval at which the sample was taken
- lx = The number of living at the beginning of the stage noted in x column
- dx = The number of dying within the age interval stated in the x

column

dx_F = The mortality factor responsible for dx

$100 q_x$ = Percentage mortality

S_x = Survival rate within x

Life table studies have been carried out by several workers from time to time with different insects.

2.1.4.1.1 Life table for DBM

Harcourt (1963) prepared 22 life tables of *P. maculipennis* and on analysing these he found 55 per cent mortality due to rain in the early larval stages, 20 per cent due to parasitoids in larval and pupal stages and 16 per cent adult mortality. Mortality of gravid female due to inclement weather was the key factor.

Jayarathnam (1977) prepared life tables for ten generations of *P. xylostella* in Bangalore. It was found that the major mortality factor in the pupal stage was the parasitoid *Tetrastichus sokolowskii* Kundj. And in the larval stage major mortality factor was the parasitoid *A. plutellae*. The density independent mortality factors operated in general.

The diamondback moth (*P. xylostella* L.) passed through five generation on cabbage at Hyderabad. The parasitization of *P. xylostella* by *Cotesia plutellae* kurdj was 13.13, 21.42, 34.17, 29.59 and 36.17 per cent during first, second, third, fourth and fifth generations, respectively in larval phase I. While, during larval phase II it was 18.33, 21.42, 32.43, 35.14 and 43.33 per cent, respectively in five generations. The trend index was more than one in all the generations and the generation survival ranged from 0.09 to 0.14 (Reddy and Singh, 1998).

2.1.4.1.2 Life table for other insect pests

During the period of mid June to mid November, it was observed that the rainfall had negative correlation with the egg count and the larval population of *Crocidolomia binotalis* Zell. in Bangalore. The major mortality factor included parasitization by *Bracon hebetor* Say and *Palexorista solensis* (Walk.) in the later larval instars. The other factors recorded were larval diseases in all the instars, predatory ants, spiders and birds and rainfall in larval periods I and II (Iqbal Singh, 1978).

In Dharwad, life tables of *Pyrausta machaeralis* Wlk. were prepared by Patil (1981) for 22 generation. The key mortality factors observed were larval parasitization by *Apanteles machaeralis* Wilkinson, *Trathala flavoorbitalis* [Cam.] and *Phanerotoma hendecasisella* Cam. According to Mallapur (1993), the major mortality factors influencing population fluctuation of *Mythimna separate* Walker included parasitoids and diseases.

Life table study of *Lucinodes orbonalis* Guenee indicated that the highest mortality was noticed in the younger larvae (48.68%) followed by pupae (38.14%) and older larvae (32.14%). The generation survival value was 0.21 indicating the mortality factors that were effective in causing pest decline (Hanapur, 2002).

Siddegowda (2004) reported that the major mortality influencing factor of the chickpea pod borer *Helicoverpa armigera* (Hubner) were disease occurrence and parasitization. The occurrence of HaNPV was key mortality factor. Among the parasitoids, *Campoletis chloridae* Uchida was the only key mortality causing agent. He further stated that the mortality by the parasitoid was negligible.

2.1.4.2 Analysis and interpretation of population data

A simple graphical method for the identification of key factors was put forth by Varley and Gradwell (1960). By this, it is possible to ascertain quickly which factor contributes most of the fluctuation of K , the total mortality by using graph in which the values of k and K are plotted against the number of generations.

Morris (1963) suggested that the egg stage is most suitable to indicate the index of population trend, but Varley and Gradwell (1965) noticed the damaging stage, as a proper trend index. Patil (1981), Mallapur (1993) made analysis of life table data with survivorship and death rate curves and key factor identification.

2.2. MANAGEMENT OF DIAMONDBACK MOTH THROUGH ORGANIC APPROACH

2.2.1 To evaluate the organic soil amendments, botanicals and vermiwash

2.2.1.1 Effect of organic soil amendments on cabbage

A study was conducted to find out the effect of organic soil amendment. The treatment comprised of pre sowing soil application of neem cake @ 300 kg/ha, foliar application of NSKE/neem oil @ 9 ml/l and 1 or 2 applications with phosphomidon @ 2 ml a.i./l were found to be effective against diamondback moth and aphids. These treatments were significantly superior to chemical check (Chakraborti, 2001).

The incidence of DBM in neem cake @ 250 kg/ha applied plots was compared with a check plot where no cake was applied. The results indicated that neem cake application reduced the DBM significantly to < 2 per plant as compared to >5 per plant in check (Krishnamoorthy *et al.*, 2001).

The integrated organic farming system and plant production for cabbage includes the application of neem cake @ 500 kg/ha, spray of 10 per cent garlic, green chilli and asafoetida extract 3 times on 45th, 60th and 75th day after planting and spraying of vermiwash 10 per cent, 5 times at 15 days interval from one month after sowing (Anon., 2001).

In a study conducted to find out the effect of organic manure and biofertilizer on growth quality and nutrient uptake and yield on cabbage, results indicated that the treatments with biofertilizers and vermicompost application in all the combinations was superior with respect to all the above mentioned parameters (Saifee *et al.*, 2006). In another study by Velmurugan *et al.* (2006) the combined application of vermicompost along with panchagavya expressed highest total dry matter content in cauliflower.

2.2.1.2 Effect of indigenous products against DBM in cabbage ecosystem

Fargoone (1987) opined that NSKE was found to be as effective as deltamethrin against DBM in Chinese cabbage and cauliflower. Patel *et al.* (1993) opined that NSKE 5 per cent suspension was effective against *P. xylostella* while neem leaf extract 5 per cent suspension was least effective. Three applications of NSKE 4 per cent were adequate to reduce DBM population of more than 40 per cent to negligible level (Krishnamoorthy *et al.*, 1998). On the contrary Ram *et al.* (2001) reported NSKE and neem oil were found to be less effective in controlling the DBM during all the three years of study. Similar was the report by Pandey and Raju (1991) and Rajasri and Narayana (2006).

2.2.1.3 Effect of soil amendments against lepidopteran pests in other crop ecosystems

Field study by Mallikarjun Rao *et al.* (1998) showed that the combination of soil application of neem cake at the rate of 500 kg/ha + seedling root dip with 1 per cent neem oil emulsion for 12 hours + 1 per cent neem spray at weekly interval was found to be effective against chilli fruit borer *H. armigera* and *S. litura*.

Sudhakar *et al.* (1998) reported that the effect of fertilizer and insecticides on brinjal shoot and fruit borer *Leucinodes orbonalis* Guane. Among the different treatments shoot infestation and per cent fruit damage was least in soil application of neem cake (2 t/ha) and this was on par with vermicompost @ 6.6 t/ha.

The effect of application of neem and pongamia cake @ 250 kg/ha while planting and twice or thrice at 30 days interval in brinjal was studied by Krishnamoorthy *et al.* (2001). This treatment reduced the shoot and fruit borer incidence to 6-10 per cent compared to 30-50 per cent in insecticide treated plots.

In a study carried out by Krishnamoorthy and Krishnakumar (2001) from IIHR, Bangalore, revealed that soil application of neem cake 250 kg/ha reduced the tomato fruit borer *H. armigera* incidence to 13.21 per cent as compared to 33.23 in untreated control.

Studies on the management of *L. orbonalis* by application of neem cake (250 kg/ha) four times during the crop growth period decreased the incidence of borer to 8 per cent from 40 per cent (untreated) along with reduction in the cost of production of brinjal to more than half (Sreenivasa Murthy *et al.*, 2001).

Giraddi *et al.* (2003) reported 8.7 per cent fruit damage by *H. armigera* and yield of 3.2 q/ha in chilli plot treated with neem cake 500 kg/ha + 50% RDF. This was on par with standard chemical check + 100% RDF which recorded 7.2 per cent fruit damage and a yield of 3.6 q/ha. Ravikumar (2004) reported that application of neem cake @ 1 t/ha found effective as RPP by recording significantly less larval population, fruit damage and higher green chilli yield.

Venkateshwaralu *et al.* (2003) studied the influence of application of 5 organic manures *viz.*, neemcake, pongamiacake, castorcake (all at 1 t/ha), farmyard manure and vermicompost (@ 10 t/ha) alone and in combination with chemical fertilizer on *L. orbonalis* in brinjal. Among the cakes, neem cake was most effective followed by vermicompost and castor cake.

Shobharani and Nandihalli (2004) reported that single application of neem cake @ 240 kg/ha was effective in reducing *L. orbonalis* incidence in potato and gave a yield of 28.07 q/ha and this was on par with pongamia oil 2 per cent foliar application (30.91 q/ha).

2.2.1.4 Effect of indigenous products against other lepidopteran pests

Rajashri *et al.* (1991) tested four neem formulations *viz.*, neem oil, neem guard, repelin and biozol and some synthetic insecticides against chilli fruit borers, *H. armigera* and *S. litura*. These neem products gave 48.5 to 64.35 per cent reduction in fruit damage over control.

Vijayalakshmi *et al.* (1996) reported effectiveness garlic extract in combination with other extracts like neem, chilli, ginger, tobacco, cow urine against *H. armigera* and *S. litura* upto 13 days of spraying in tomato. Mallikarjun Rao *et al.* (1998) reported the effectiveness of garlic extract in combination with other extracts like neem, chilli, ginger, tobacco and cow urine against *H. armigera* and *S. litura* upto 13 day of spray.

Kasyapa (1998) reported from Medhak district of Andhra Pradesh that chilli + garlic extract and NSKE spray were common practices followed by local farmers for pest management.

Spraying of cow urine (5%), cow dung suspension (5%) and turmeric (5%) in alteration with monocrotophos were moderately effective against the chilli fruit borer *H. armigera* (Ukey and Sarode, 2001).

Mallapur (2002) evaluated indigenous materials like nimbecidine (5ml/l), GCK (garlic chilli kerosene extract) 0.5%, nimbecidine (2.5 ml/l), GCK alone (0.5 and 1.0%), turmeric + cow urine (25%) and cow urine (17%) for the management of chilli pests. Among the different treatments GCK (5%) + nimbecidine (2.5 ml/l) recorded less percentage of fruit damage due to fruit borer *H. armigera* and highest yield (11.3 q/ha).

2.2.1.5 Effect of organic soil amendments and biorationals on the incidence of natural enemies

Since the information on the effect of organic amendments on natural enemies in cabbage ecosystem is lacking, the review on natural enemies in other crop ecosystems have been quoted. Smitha (2002) reported that neem cake 2 q/ha was safer to coccinellid beetles and predatory mites which was found next best to untreated check. Organic amendments like vermicompost (1 to 2 t/ha), neem cake (0.5 to 1 t/ha), biogas spent slurry (1 t/ha) and FYM (12.5 to 25 t/ha) were found safe to coccinellids as well as *Chrysoperla sp.* in chilli ecosystem (Ravikumar, 2004).

Abhilash (2005) studied the effect of organic amendments and bio-rationals on predators in soybean ecosystem and reported that the activity of natural enemies was noticed in all the plots where organic amendments and bio-rationals were applied indicating the safety of these materials. Among bio-rationals, vermivash recorded higher number of predators. Manu (2005) reported safety of soil organic amendments to natural enemies like coccinellids and chrysoperla in cotton ecosystem.

Gundannavar (2006) reported the activity of natural enemies to be quite normal as that of control in plots with organic interventions in chilli ecosystem.

2.2.2 Use of eco-friendly insecticides

Voluminous literature is available on the efficacy of different insecticides for the control of DBM but it is scanty for other defoliators especially the information on efficacy of new molecules, plant predators and microbial insecticides is lacking.

2.2.2.1 Diamondback moth : *Plutella xylostella* (L.)

a. Organic phosphorous compounds

Early works indicated that malathion spray 0.28 per cent given at weekly intervals from transplanting to two weeks before harvest gave satisfactory control of DBM (Henderson, 1957). Chien *et al.* (1964) claimed 0.1 per cent malathion as effective in controlling the pest. Similar reports on the effectiveness of malathion against DBM were made by several authors Verma and Sandhu (1968), Wan (1970), Ramaiah (1977) and Chatterjee and Senapati (2000).

Rajavel *et al.* (1991) reported that monocrotophos 500 ppm was significantly superior in controlling DBM as compared to other treatments tested in a field trial on cauliflower. Rameshbabu (1996) reported that quinalphos at 250 g a.i./ha and the combination treatment of quinalphos + cartap hydrochloride (125+250 g a.i./ha) were excellent in controlling DBM on cauliflower.

b. Insect growth regulators

Ong and Ng (1988) reported the efficacy of diflubenzuron at a weekly application at the rate of 62.5 ppm on cabbage and brinjal gave good control of DBM. The IGR cascade @ 40 g a.i./ha was found to be significantly superior to remaining treatments viz., fenvalerate, Delfin, padan in reducing infestation of DBM at 3.7 and 10 days after application (Thambe *et al.*, 1997).

Sangareddy *et al.* (1999) found novaluron at 0.5, 0.075 and 0.1 per cent to be highly toxic to DBM, based on per cent reduction of larval population in cauliflower. Maheshkumar *et al.* (1999) concluded that novaluron at 0.1 per cent or 0.075 per cent was found to be best against DBM in cabbage. Only two sprays of Rimon (Novaluron 10 EC) was found to be a good alternative for 8-15 sprays of insecticides by giving good control of DBM and better benefit cost ratio (Kulkarni, 2001). Novaluron at 0.0075 per cent maintained its superiority in increasing 85.24 and 85.30 per cent mortality of larvae at 72 hours and 120 hours respectively (Hadapad *et al.*, 2001).

Among the chemicals tested, lufenuron (Match 5 EC) @ 30 and 40 g a.i./ha was found to be the most effective one on *Plutella xylostella* (Sakthi *et al.*, 2003). Harishkumar *et al.* (2003) reported novaluron @ 0.75 ml/l to provide 90 per cent mortality of DBM larvae under laboratory condition. Significantly superior control was obtained by flufenoxuron at 0.01 per cent by recording lowest DBM population and highest marketable yield (Bhavani and Punnaiah, 2004). Harishkumar and Jaglan (2005a) reported that the larval mortality of DBM ranged from 30 to 100 and 16 to 100 per cent in early and late instar larvae respectively for six concentrations of novaluron under laboratory study. Further at 200 ppm novaluron could afford 66.67% kill of larval population persisting effectively upto seven days (Harishkumar and Jaglan, 2005b).

c. Use of botanical insecticides

Fargoone (1987) opined that NSKE was found to be as effective as deltamethrin against DBM in Chinese cabbage and cauliflower. Patel *et al.* (1993) opined that NSKE 5% suspension was effective against *P. xylostella* while neem leaf extract 5 per cent suspension was least effective. Three applications of NSKE 4% were adequate to reduce DBM population from more than 40 per cent to negligible level (Krishnamoorthy *et al.*, 1998). On the contrary, Ram *et al.* (2001) reported NSKE and neem oil were found to be less effective in controlling the DBM during all the three years of study. Similar was the report by Pandey and Raju (1991), Rajasri and Narayana (2006).

d. Microbial insecticides

i) Bacteria

According to Rajamohan and Jayaraj (1978) *B.t. berlinear* @ 3 kg/ha was more effective than the spray of insecticides in reducing the larval population of *P. xylostella* in the initial period after treatment. Almost similar trend was obtained using Bt products SAN-145 at 0.5 kg (Anon., 1989). Justin *et al.* (1990) with bactrospaine, Panchabhavi and Sudhindra (1994) with delfin at 0.5 kg, Kulkarni *et al.* (1995) with Delfin at 0.5 kg and wock biological at 1 kg/ha. Asokan *et al.* (1996) with Bt sub species Kurstaki at 1 ml/l, Bt sub species aizawai at 1 g/l, Nagesh and Verma (1997) with biolep (0.2%) and Gopalkrishnan and Vishalakshi (2001) with Spicbio (0.7 ml/l). In a field trial carried out by Nagamani *et al.* [1995], thuricide + triazophos (0.08 + 0.06%) combination treatment was found to be the most effective against DBM followed by Thuricide alone (0.08%) in cabbage.

A field experiment conducted by Kulkarni *et al.* (1999) revealed that the treatment with Delfin 50 WG @ 0.5 kg/ha and Halt 1.0 kg/ha was found to be superior in reducing the DBM infestation at 3, 7 and 10 days after application and increasing the yield of cabbage and quality heads. The two Bt based insecticides Dipel (0.3%) and biobit (0.3%) gave reduction of less than 10 per cent after one day of spraying but proved better after 14 days of spraying (Jastotia and Suri, 2002). Pokharkar *et al.* (2002) opined that the Bt formulation to persist on the leaves of field grown cabbage plants for atleast 5 days with OAR (Original Activity Remaining) thus providing high protection against DBM. On the contrary, Mukherjee and Singh (2006) stated Bt to be most effective treatment on the 7th day onwards upto 15 days.

ii) Fungi

The combination of low concentration of fungus (*N. rileyi*) @ 1.6×10^8 conidia/ml + endosulfan (0.035%) effectively brought down the larval population of *P. xylostella* when compared to check (Anon., 1993). But Dhanraj (2000) reported Bt to give moderate control of DBM with 63.5% whereas neemazal and *Nomuraea. rileyi* (Farlow) Samson proved non-effective against DBM.

The commercial entomopathogenic fungal based formulation bio-power (*Beauveria bassiana*) gave significantly higher per cent mortality ranging between 6.7 to 86.7 per cent (Sood *et al.*, 2001) and 47.6 to 83.2 per cent (Ramarethinam *et al.*, 2002) against DBM. Among the entomogenous fungi, mortality caused by *N. rileyi* was inferior to *B. bassiana* (Vastrad *et al.*, 2002).

iii) Spinosyns

Peter *et al.* (2000) reported spinosad 2.5 SC @ 15, 20 and 25 g a.i./ha to be effective against DBM. The results indicated the superiority of spinosad @ 15 g a.i./ha for better control of diamondback moth for a period of ten days and giving better yield of marketable cabbage heads compared to its lower dosages treatments, other chemicals and untreated check (Walunj *et al.*, 2001). Spinosad gave excellent control of *P. xylostella* when applied @ 15, 20 and 25 g a.i./ha in both cabbage and cauliflower upto 7 days (Peter and Vedham, 2001). Similar were the results obtained by other workers such as Dey and Somchoudhary (2001) and Rachappa *et al.* (2004).

In a laboratory study conducted by Arora *et al.* (2003) to study the toxicity of newly introduced and commonly used insecticides against DBM, spinosad, the least used was the most toxic than the most commonly used insecticides.

iv) Avermectins

In a laboratory study conducted by Wu *et al.* (1998) out of two insecticides of microbial origin, abamectin was found to be most effective followed by spinosad by having least LC₅₀ values against *P. xylostella*. These results are supported by work of several other workers such as Xiao *et al.* (1999), Pramanik and Chatterjee (2004) and Shi *et al.* (2004).

A week after application, emamectin @ 10 g a.i./ha showed excellent efficacy by way of reducing the population upto 81.2 per cent and maintained the status till 14 DAT which was comparable with spinosad 15 SC (12.5 g a.i./ha) (Kanna *et al.*, 2005b). Field experiments conducted to evaluate the bio-efficacy of emamectin benzoate (5% SG) against diamondback moth recorded that the chemical @ 150 g and 200 g/ha were found to be effective in reducing the larvae and increasing the yield of cabbage (Kumar and Devappa, 2006).

Field experiments conducted to assess the Bioefficacy of avermectin (Vertimec) against DBM in comparison with conventional insecticides revealed vertimec 1.8 EC @ 15 g a.i./ha was found to be highly effective in checking DBM larval population and also recorded significantly higher yield (Murugan and Ramachandran, 2000, Ghosh *et al.*, 2001, Jasmine *et al.*, 2006).

e. Oxadiazines

Babu *et al.* (2002a) from their experiment concluded indoxacarb, a new chemical was found to be effective against *P. xylostella* which follows abamectin under laboratory condition. Further the same workers (2002b) based on their field experiments stated that indoxacarb @ 29 g a.i./ha was effective in reducing the larval population of DBM on cauliflower and there by increasing the yield.

Liu *et al.* (2003) reported indoxacarb @ 0.05 to 0.07 kg a.i./ha was effective against DBM by suppressing the larvae below economic threshold level. In addition indoxacarb was as effective as spinosad and significantly more effective than emamectin benzoate.

2.2.2.2 Tobacco caterpillar : *Spodoptera litura* Fabr.

a. Organophosphorous compounds

Malathion effectively controlled the larvae of *S. litura* on cabbage (Rajamohan and Jayaraj, 1978). In a field trial, Ramzan and Darshan Singh (1980) obtained cent per cent larval mortality of *S. litura* in cauliflower with 0.1 per cent trichlorophos and 0.05 per cent quinalphos. However, these insecticides did not differ significantly from endosulfan, fenitrothion and methomyl at 0.05 per cent concentration. Further similar trend in results were obtained with profenophos (Harikrishna, 1996) and quinalphos at 250 g a.i./ha alone and in combination with cartap hydrochloride (125 + 250 g a.i./ha) (Ramesh Babu, 1996).

b. Insect growth regulators

Application of diflubenzuron at 250 g a.i./ha resulted in cent per cent mortality of *S. litura* for five days after spray (Ramzan and Darshan Singh, 1980). Similar trend was observed by Vaishampayan and Verma (1992), the larval survival of *S. litura* was 6.33 and 18.17 per cent at 0.025 and 0.0125 per cent concentration of diflubenzuron respectively compared to 81.5 per cent in control five days after treatment.

Field trials carried out by Rao *et al.* (2001) revealed that the insecticidal efficacy of novaluron at 0.1 per cent was best in reducing the boll damage by *H. armigera* followed by novaluron 0.0075 per cent.

Pramanik and Chatterjee (2004) reported that adult emergence of *S. litura* was inhibited at 1250 ppm of novaluron in a laboratory study. Patil and Jamadagni (2006) recorded minimum pod damage of 2.24 and 3.47 per cent with the treatment of novaluron @ 3.47 per cent with the treatment of novaluron @ 1.00 ml/l during *kharif* and *rabi* season respectively against the blackgram pod borers *i.e.*, *S. litura* and *H. armigera*.

c. Botanicals

Rajasri *et al.* (1991) tested four neem formulations *viz.*, neem oil, neem guard, repelin and biozol and some synthetic insecticides against chilli fruit borers, *H. armigera* and *S. litura*. These neem products gave 48.5 to 64.35 per cent reduction in fruit damage over control.

S. litura is currently being managed with neem extract in South India (Joshi *et al.*, 1993).

Shivaprakasam (1998) tested NSKE (5%) and neem oil (2%) along with NPV and insecticides for the management of tomato fruit borer, *H. armigera*. These were found to be moderately effective by recording 21 per cent and 20 per cent fruit damage respectively. Shivaramu (1999) studied the effect of botanicals and biological pesticides on *H. armigera* in chilli. Among the plant products NSKE (5%), neem oil (5ml/l) and Achook (5 ml/l) were found to be on par with each other by recording 9.77, 12.99 and 9.66 per cent fruit damage, respectively.

d. Microbial insecticides

i) Bacteria

Rajamohan and Jayaraj (1978) reported that Bt at 3 kg/ha was most effective than the spray of other insecticides in reducing the larval population of *S. litura* in the initial period after treatment in cabbage. Similarly Amonkar *et al.* (1985) were of the opinion that Bt sub species Kenyae, Bt sub species aizawai and Bt. Sub species Kurstaki (all at 10^8 spores/ml) were found effective against first instar larvae of *S. litura* after 72 hours of spray in a laboratory study. However, the per cent larval mortality of *S. litura* on cauliflower with *B. cereus* (8×10^8) and Bt (7.4×10^8) was 40.0 and 51.3 per cent respectively under field condition (Zoz, 1990).

Nagamani *et al.* (1995) reported that thuricide (0.08%) and acephate (0.075%) and half the concentration of acephate (0.0375%) with thuricide (0.08%) proved excellent in reducing the population of the tobacco caterpillar on cabbage.

ii) Fungi

Application of four rounds of *N. rileyi* 3.2×10^8 conidia 1 ml + triton x -100 (0.01%) at weekly intervals during evening hours significantly brought down the population of *S. litura* in tomato and beet root. Where as in cabbage the combination of low concentration of fungus @ 1.6×10^8 conidia per ml + endosulfan 0.035 per cent effectively brought down the larval population of *S. litura* (Anon., 1993).

Devi (1995) found that soil treatment with *N. rileyi* conidia together with its substrate crushed sorghum resulted in high mortality of *S. litura* larvae due to mycosis. Similarly *N. rileyi* caused maximum mortality (36.9%) of *S. litura* in groundnut field over three generations (Sridhar and Prasad, 1996).

Gloriana *et al.* (2001) opined that the late instars of *S. litura* was susceptible to *B. bassiana* and B.t at high doses of entomopathogens. The LC₅₀ values of these were 2.9 log conidia/ml and 17.3 log cells/ml for *B. bassiana* and *B.t.* respectively.

Larvae of *S. litura* when treated with *N. rileyi*, *B. bassiana* under laboratory conditions exhibited mortality which had the mycosis of both the fungal pathogens indicating that both the fungal pathogens were effective against *S. litura* (Rao *et al.*, 2006).

Elanchezhyan (2006) reported that *B. bassiana* to be highly effective than *N. rileyi* on second instar larvae of *H. armigera*. Similar reports were also given by Ananthi and Pillai (2006).

iii) Spinosyns

Persistence of spinosad was upto 6.68-7.00 day on cabbage and cauliflower against *S. litura* were reported by Paliwal (2000) and Peter *et al.* (2000). Dey and Somchaudhary (2001) reported that spinosad to be effective in controlling *S. litura* on cabbage @ 15-25 g a.i./ha

The efficacy of spinosad 45 SC was tested on *H. armigera* at four dosages viz., 45, 56, 73 and 90 g a.i./ha in comparison with endosulfan 35 EC (700 g a.i./ha). Spinosad 45 SC at higher dosages recorded significantly lower pod damage and higher grain yield than its lower dosages, endosulfan and untreated check (Siddegowda *et al.*, 2003).

iv) Avermectins

In a laboratory study conducted by Pramanik and Chatterjee (2002) abamectin was found to be effective followed by spinosad against *S. litura*.

Studies conducted to evaluate the efficacy of emamectin 5 SG against *H. armigera* indicated that the new insecticide formulation @ 10.0 g a.i./ha and 8.75 g a.i./ha were more effective against the pest which was comparable with spinosad 2.5 SC (12.5 g a.i./ha) in reducing the larval population and fruit damage (Kanna *et al.*, 2005b). Similarly Murugaraj *et al.* (2006) reported emamectin benzoate to be effective in reducing the larval population of *H. armigera* when applied @ 0.11 g a.i./ha in tomato. Application of emamectin 5 SG @ 200 g/ha was effective in reducing dead hearts and fruit damage in brinjal (Kumar and Devappa, 2006).

Based on the laboratory studies Ahmad *et al.* (2006) reported emamectin benzoate to be the most effective efficient insecticide when compared to spinosad and indoxacarb which had almost similar LC₅₀ and LT₅₀ values.

d. Oxadiazines

Indoxacarb @ 75 g a.i./ha recorded lower incidence of *H. armigera* there by resulting in higher seed cotton yield (Bheemanna and Patil, 1999). Similarly indoxacarb @ 75 g a.i./ha was effective in suppression of pod borer damage resulting in higher grain yield compared to its lower dosage and other treatment (Suhas Yelshetty *et al.*, 1999).

Srivastava and Pande (2003) reported indoxacarb 14.5 SC to be highly toxic to *S. litura* larvae under laboratory conditions with 0.004 per cent by causing 92.8 percent mortality.

Ladaji *et al.* (2004) reported indoxacarb (0.5 ml/l) to give good control of pod borer in chickpea.

2.2.2.3 Leaf webber : *Crociodolomia binotalis* Zell.

a. Organophosphorous compounds

Rai (1973) recorded complete kill of leaf webber after 24 hrs of treatment with malathion at 0.14 per cent at Bangalore. Singh and Rawat (1978) reported that quinalphos (0.025% and 0.05%) controlled the *C. binotalis* excellently in a laboratory study. Further, Rameshbabu (1996) reported that quinalphos at 256 g a.i./ha and the combination of treatment of quinalphos + cartap hydrochloride (125 + 250 g a.i./ha) were quite effective against the pest in cauliflower.

b. Insect growth regulator

All the five dosages of diflubenzuron (75,100,125,150 and 200 g a.i./ha) evaluated against *C. binotalis* larvae on radish were found equally effective in suppressing the pest upto 10 days after application (Clement Peter and David, 1988). The field efficacy of IGR, flufenoxuron (cascade) at 0.1 per cent was found to be significantly superior in controlling *C. binotalis* by recording low population of the pest (Bhavani and Punnaiah, 2004).

Goud *et al.* (2006) were of the opinion that the bio-efficacy of novaluron (0.01%), flufenoxuron (0.01%) exerted superior control of cabbage leaf webber when compared with other treatments.

c. Botanical insecticides

Iqbal Singh (1978) could record only 50 per cent control of the cabbage leaf webber with 5 per cent NSKE. Similar results with 2 per cent extract from neem was reported by Fargoone, (1987) who opined that NSKE was found to be as effective as deltamethrin against *C. binotalis* on Chinese cabbage, cabbage and cauliflower in Mauritius.

d. Microbial insecticides

i) Bacteria

Rabindra and Jayaraj (1988) reported that Bt significantly reduced the larval number of *C. binotalis* on mustard when compared to untreated check. But it was not as effective as monocrotophos or endosulfan. In a laboratory study delfin (Bt) was the most effective product against *C. binotalis* with greatest larval mortality at lowest concentration (Anon., 1996). However, biobit (Bt) at 0.15 per cent was found to be least effective against *C. binotalis* (Murthy *et al.*, 1997). Gopalkrishnan and Vishalakshi (2001) observed 98.33 per cent mortality of *C. binotalis* @ 0.7 ml/l.

ii) Spinosyns

Peter *et al.* (2000) found that the commercial formulation of the actinomycetes *i.e.*, spinosad 2.5 SC was effective in reducing the population of *C. binotalis* upto 7 days.

iii) Avermectins

Avermectin (0.01%) was found to be effective against the pest by giving 81.54 per cent control of the larvae of cabbage leaf webber (Ghosh *et al.*, 2001).

2.2.2.4 Natural enemies

2.2.2.4.1 Effect of chemicals on *C. plutellae*

a) Botanicals

NSKE 4% was found to be slightly toxic to the adults of *C. plutellae* (17.5–20.0% mortality] under laboratory conditions (Sannaveerappanavar, 1995 and Jyothi *et al.*, 2001]. On the contrary NSKE (2%) and neemark (2%) were found to be completely safe to *C. plutellae* (Reena, 2000).

b) Insect growth regulators

Haseeb and Amano (2002) reported emamectin benzoate (1%) and 3 IGR's *viz.*, chlorfluazuron (5%), flufenoxuron (10%) and teflubenzuron (5%) to be selective against parasitoid *C. plutellae*.

c) Microbial insecticides

i) Bacteria

Counts of *C. plutellae* cocoons on cabbage in the various treatments revealed no significant difference in the parasitism (%) between the Bt treated plants and untreated control (Lim *et al.* 1986). Similar results were obtained by studies of Kao and Tzeng (1990), Rejesus and Soyaboc (1990), Asokan and Mohan [1996] and Athira (2002).

ii) Spinosyns

Spinosad 2.5 SC at the recommended dosage (17.5 g a.i./ha) was found to be extremely toxic to adults of *T. bactrae* and *C. plutellae* and also to immature stages of *T. bactrae* (Jalali and Ramani, 2001). Similar were the results obtained by Richter (1999) to *T. pretiosum* and *C. marginiventris* and by Pieteanonio and Benedict (1999) against *C. plutellae* and *C. marginvetris*. On the contrary, Schoonover and Larson (1995) have found the chemical to be safe to beneficial organism. Dey and Somchoudhary (2001) observed that spinosad @ 15-25 g a.i./ha showed very little adverse effect on two most important parasitoids of DBM *viz.*, *A. plutellae* and *Brachymeria* sp.

iii) Avermectin

Shi *et al.* (2004) reported that avermectin showed differential toxicity to two parasitoids of DBM. Avermectin was slightly toxic to *C. plutellae* in the residue assay with cocoons of the parasitoid the chemical did not reduce adult emergence.

2.2.2.4.2 Effect of chemicals on other natural enemies

Subhadra Acharya *et al.* (2002) reported abamectin @ 20 g a.i./ha to be safe to lady bird beetle. Udikeri *et al.* (2004) reported the activity of predators (*Chrysoperla* and Coccinellids) in emamectin benzoate and spinosad treated plots to be as good as untreated check indicating the safety of these molecules to predominant natural enemies in cotton ecosystem.

Kadam *et al.* (2005) studied the impact of insecticide sequence on natural enemies in brinjal ecosystem and revealed that among different sequences the treatment with imidacloprid –NSKE– imidacloprid recorded significantly lower population of coccinellid (9.0/plot) as compared to spinosad –NSKE– spinosad (12.6 coccinellid/plant) and untreated control (13.00 coccinellids/plant).

2.3 TO DEVELOP AND COMPARE MODULES OF INTEGRATED PEST MANAGEMENT FOR DBM

The information regarding the use of different components of IPM in combination for managing the DBM is restricted.

NSKE consistently provided significant reduction of *P. xylostella* larvae on cabbage as compared to other treatments grown under IPM involving mustard as trap crop (Srinivasan and Krishnamurthy, 1991).

Similarly, they reported that the incidence of *P. xylostella* and *C. binotalis* was significantly low among IPM plots involving one row of mustard for every 20, 25, 30 and 35 rows of cauliflower and single spray of cartap hydrochloride (0.1%) as compared to weekly sprayed and control plots. Similar results were obtained by Srinivasan and Krishnamoorthy (1992a and 1993) involving mustard as trap crop and spray of 4 per cent NSKE or with neemazal 100 ppm and 4 per cent crude NSKE in cabbage.

Greatest success has been achieved in the development of IPM for pest complex of cabbage, using mustard as a trap crop. Growing of paired rows of mustard at the beginning and after 25 cabbage rows, spraying of NSKE 4 per cent at primordial stage on cabbage and dichlorvos (0.1%) on mustard at 10-15 days interval for the management of pests colonizing on them (Srinivasan and Krishnamoorthy, 1992b).

The combination of low concentration of fungal pathogen *N. rileyi* @ 1.6×10^8 conidia/ml + endosulfan 0.03 per cent effectively brought down the larval population of *P. xylostella* and *S. litura* in cabbage (Gopalkrishnan and Mohan, 1992).

Pawar and Lawande (1995) opined that planting of mustard as a trap crop in cabbage gave maximum cost benefit ratio of 1:6 and recorded 75 per cent higher yield of marketable heads than untreated. Similarly, Nataraju *et al.* (1998) reported that cabbage raised in IPM plots with mustard as trap crop and spraying on an average eight times with insecticides at recommended dose realized 152 per cent more net returns as compared to farmer's practice in which on an average 25 sprays were taken up. Dandapani *et al.* (2006) revealed that non-chemical methods adopted plots recorded lower population of DBM (0.72 per plant) with high yield of 27.19 t and B:C ratio of 3.46:1 when compared with untreated check.

Chakraborti (2001) reported the integrated treatment with inclusion of double spray of phosphamidon + neem cake + azadiractin was the best treatment against DBM and aphids. This treatment was significantly superior to chemical check and also was quite safe to predator coccinellids, syrphids and spiders.

Chavan *et al.* (2001) studied cabbage and tomato intercropping involving 4 lines of cabbage with 2 lines of tomato. Cabbage was sprayed with four sprays of NSKE 3 per cent and Bt at 0.1 per cent alternatively at 15 days interval. The results indicated that tomato intercropped in cabbage helped in keeping DBM at low level.

Economics of various IPM modules against DBM on cabbage was worked out. Among these modules M₃ comprising of endosulfan (1.25 l/ha) + beta-cyfluthrin (7.5 ml/ha) + azadiractin (2 lt/ha) gave a benefit cost ratio of 9.75:1 and 10.71:1 in two years with a pooled

mean of 10.25:1. Minimum BC ratio was recorded when the crop was treated (Module M6) with diflubenzuron (200 g/ha) + spinosad (15 g a.i./ha) + azadirachtin (2 l/ha) (Shukla and Ashok Kumar, 2003).

The IPM technology using Indian mustard as a trap crop, spraying of neem and pongamia soaps and pulverized neem seed powder extract for the control of major pests of cabbage was found to be economically viable as it enhanced the yield by 7.2 per cent and reduced the cost by 13.33 per cent and increased the net returns by 44 per cent (Gajanana *et al.*, 2004).

III. MATERIAL AND METHODS

The present investigations were carried out in farmers field at Garag village near Dharwad and in the Laboratory of Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad during *kharif* and *rabi* seasons of 2005-06 and 2006-07.

Dharwad comes under the transitional belt of Karnataka state that lies at 15° 26' North latitude and 75° 07' East longitude at an altitude of 761.8 meters above mean sea level. Garag village, where the field studies were carried out is situated 12 km away from the college of Agriculture and is to the North of Dharwad city. This has the same weather conditions as that of Dharwad. During the period of study, rains were well spread in this region from June to November. The meteorological data collected from MARS, Dharwad during the period of study are furnished in Appendix I. The details of the methods followed and the materials used for different investigations are presented below.

3.1 LIFE TABLE STUDIES OF *Plutella xylostella* L.

3.1.1 Development and maintenance of laboratory culture

Pure culture of diamondback moth (DBM), *Plutella xylostella* L. was initiated by collecting the pupae from farmers field near by Dharwad and was maintained in the laboratory in wire mesh cages measuring 60 cm³. DBM was mass cultured following the procedure developed by Liu and Sun (1984) with slight modifications. Ten pairs of freshly emerged adults were released in the oviposition cage of 60 cm³ with five days old mustard seedlings for oviposition and provided with 10 per cent honey as food. On hatching the larvae were transferred on to rearing trays with fully expanded cabbage leaves raised in green house under insecticide free conditions (Plate 1). Fresh cabbage leaves were placed as food for the larvae and were changed daily till pupation. The pupae formed were collected and placed in an oviposition cage and the procedure was repeated. This initial culture was built up for subsequent studies.

3.1.2 Life history of the pest

Since adequate knowledge on the biology of the pest is an essential prerequisite in the study of population dynamics, detailed studies on biology of the pest was made in the laboratory for three generations, (once in each season) during August-September, December-January and March-April of 2005-06. The studies were carried out in the laboratory of the department of Agricultural Entomology, Dharwad.

Life history of individuals of the diamondback moths was studied from egg to adult in glass specimen tubes (7.5 cm length, 2.5 cm diameter) with the mouth of the tube covered with polythene sheet of 100 gauge using rubber band. Fresh eggs of *P. xylostella* obtained from laboratory cultures were maintained individually in specimen tubes. On the next day after placing the egg, a fresh cabbage leaf bit of size 4 x 1.5 cm was provided inside each specimen tube cage for the emerging larva to feed. After emergence individual larva was transferred to fresh tube containing fresh leaf bit. Old tube as well as leaf bit were checked for exuvium of the caterpillar. This was maintained till the larva pupated.

In each season life history data on ten larvae were collected. Observations were made daily to determine the incubation period of egg, number of larval instars based on moultings, duration of each larval instar, pupal period and total developmental period. Further, the morphological characters such as colour, shape, habits of larva were recorded.

Longevity and fecundity

For this one newly emerged female moth and two males were confined along with a fresh cabbage leaf in a lantern chimney of 25 cm height covered at the bottom with polythene sheet and at the top with muslin cloth using rubber band. 10 per cent honey solution was provided as food. The set was replicated 10 times. Fresh cabbage leaves were provided daily for oviposition and the eggs laid by each female were counted with the help of hand lens. The maintenance of record was continued till the death of the female. Total number of eggs laid by the mated fed female and longevity of male and females were recorded. This experiment was carried out for three generations once in each season of a year (*viz.*, August-September, December-January and March-April of 2005-06).

3.1.3 Life table studies

This study was carried out during *kharif* and *rabi* seasons of 2005-06 and 2006-07 in the farmer's field at Garag village and in the laboratory of Department of Agricultural Entomology, UAS, Dharwad. The cabbage plants were grown in an area of 0.06 ha. An early maturing variety of cabbage, F₁ super ball which is popular among the farmers was cultivated through out this study. This variety was usually ready for harvesting in 70-80 days after transplanting. Four crops were raised for the purpose during 2005-07 and life tables of *P. xylostella* were prepared for eight generations. Of these two crops were raised in rainy season of 2005 and 2006 and two in winter season of 2005-06 and 2006-07. No crop was taken up in summer due to inadequate irrigation facilities. For each crop, seedlings were raised in three nursery beds and transplanting of three week old seedlings were in main field was done with a spacing of 45 x 30 cm following all the recommended package of practices (Anon., 2005) except plant protection measures.

3.1.3.1 Sampling plan and techniques

Sampling techniques and the sampling plan developed by Harcourt (1961) for studies on the population dynamics of *P. xylostella* with the objective of preparing life tables was adopted in this study with necessary modifications Harcourt (1961) decided certain age intervals (age groups or stages) of the pest for population sampling. These stages were egg, larval period I (from hatching till middle of IV instar), Larval period II (middle of IV instar to cocoon formation), larval period III (from cocoon formation to pupation or pre-pupae) and pupa were chosen for sampling *P. xylostella* during the present investigation. The larval stages are conveniently divided into LP1, LP2 and LP3 because of ease of identifying the larvae after third moult satisfactorily based on the size and colour.

Taking into consideration the changed situation under which the present studies were carried out, as compared to the conditions under which earlier workers conducted their experiments, it was found necessary to introduce certain modifications as follows.

1. The reference stages of the insect were reared in the laboratory instead of field cages, under normal conditions of prevailing temperature, humidity, natural food etc (Mallapur, 1993).
2. For recording the parasitoids and their density, the pathogens and their incidence, the field sampled insect stages were further reared in the laboratory
3. Samples of egg stage were examined in the laboratory instead of in the field for convenient recording of data; the remaining stages viz., LP1, LP2, LP3 and pupa were recorded in the field itself.

3.1.3.2 Time of sampling

Sampling for egg stage was done based on the activity of adult moths in the main field by regular direct observations. Whenever the sampling for egg stage was done, the eggs from the samples were carefully separated along with the leaf tissues, adhering to them and kept on a fresh cabbage leaf in a Petri dish of 20 cm x 5 cm diameter. After hatching, the larvae emerging from them were reared on cabbage leaves kept inside rearing cages of 36 cm³ size (Plate 2). This formed the reference stage for the successive stages of sampling. When the larvae in the cage reached IV instar stage, sampling for larval period I was done in the field. Similarly, when the larvae in reference stage reached middle of IV instar, pre-pupae and pupal stage, sampling for larval period II, III and pupa, respectively were carried out in the field.

Since the generations of *P. xylostella* were overlapping considerably and all stages of the pest were found simultaneously. The sampling done for a generation in the field was based on the age structure of the eggs obtained by egg sampling and rearing in the indoor cages. This generation was assumed to be distinct from the overlapping field generations. An interval of 10 days was provided between sampling for pupal stage of one generation and egg stage of next generation, for completion of egg laying by moths of previous generation. Again these eggs were brought to the laboratory and further reared. This served as reference for the next generation of the insect. Like wise, the procedure was continued till the disappearance of the pest or harvest of the crop in the field.



Plate 1. Plastic tubs used for mass multiplication of diamondback moth



Plate 2. Cage used for rearing of reference stage for life table studies

Observations were made on the number of generations for each season along with approximate dates of egg laying, hatching, pupation and moth emergence for each generation. The duration of egg, larval and pupal periods were recorded and total life cycle for each generation was determined. The extent of egg, larval and pupal mortality and parasitism for each insect stage was recorded. The parasitoids recorded on the larvae and pupae were sent to Project Directorate of Biological Control (PDBC), Bangalore for identification. For simultaneously recording field incidence the area under each crop was arbitrarily divided into four quadrants of equal size using the block and row numbers. From each quadrant 25 plants were randomly selected and observed (total of 100 plants were observed from all the quadrants). Care was taken not to select the same plant for further sampling. The egg counts were recorded at the time of sampling for egg stage.

3.1.3.3 Preparation of life tables

The column headings used in the present study of life table were according to the format proposed by Morris and Miller (1954).

1. x = Stage or age interval at which the sample was taken ; egg, larva and pupa
2. l_x = The number surviving at the beginning of the stage stated in the x -column
3. dx = The number of dying with in the age interval stated in the x – column
4. $d \times f$ = The mortality factors responsible for dx
5. $100 q x$ = Percentage mortality (dx as percentage of l_x)
6. S_x = Survival rate with in the stage mentioned in the x column

Criteria for filling the column in life table

The criteria used by Harcourt (1963) for filling the data in the life table for each age interval was used with slight changes. The columns were filled by collecting and rearing known number of each stage from the field apart from recording the actual counts in the field.

Recording of dx value of each stage

While recording the number in each stage *viz.*, egg, larval period 1 larval period 2, 3 and pupa these were collected and reared upto adult stage. Eggs were transferred along with the leaf bit attached to it, to a fresh cabbage leaf kept in a covered petridish. When the larvae emerged, the number of unfertile eggs were recorded. Like wise different sampling stages were reared in the laboratory and the number of parasitoids was recorded by counting the number of solitary parasitoid emerging from them or by examining the larvae or pupal cases from which parasitoids emerged (Plate 3 and 4). All the stages were reared upto adult stage, since the majority of parasitoids laid eggs in I instar larvae and adults parasitoids emerged in IV instar larvae or pupae. The dx values in the egg, larval periods 1, 2 and 3 and pupa were based on rearing 100, 50, 50 and 25 number respectively.

Other mortality factors were evaluated by regular observation in the field during the study of population dynamics.

Filling l_x column according to absolute unit

The absolute unit was kept as 100 plants. The data collected for specific age intervals of life table were totaled and tabulated.

3.1.3.4 Statistical analysis of the population data

3.1.3.4.1 Interpretation of life table data

Life tables were prepared for 8 generations of *P. xylostella*. Mean life table for 4 generations each of rainy and winter seasons were prepared separately. Interpretations were made on the life table data using following methods.

Survivorship curves : These curves have been drawn for each life table data and also for the average of 8 life tables by plotting the number of survivors ' l_x ' against ' x '. The interpretations of these curves have been made by the method suggested by Slobodkin (1962).

Death rate curves : Death rate curves have been drawn for life table data of each generation and also for the average of 4 generations in rainy and 4 generations in winter season by plotting age ' x ' against $100 q x$ and interpretations have been made on these curves.

3.1.3.4.2 Identification of key factors causing population fluctuation of *P. xylostella*



Plate 3. DBM larva with emergence hole of *C. Plutellae*



Plate 4. DMB pupa with exit hole of *T. Sokolowskii*

Graphical method : A simplified method for detecting key factors based purely on graphical correlation as proposed by Varley and Gradewell (1960) was adopted for this study. By this the killing power or k value of each mortality factor or groups of mortality factors in each age group was estimated as the difference between the logarithms of population density before and after its action i.e., the logarithm of dx values in life table. As a series of mortality factors operated on a population in succession in a generation, the total killing power or K value was equal to the sum of the killing power or k's. Thus, if $k_1 = \log lx$ of egg stage – $\log lx$ of larval stage 1, $k_2 = \log lx$ of larval stage 1 – $\log lx$ of larval stage 2, $k_3 = \log lx$ of larval stage 2 – $\log lx$ of larval stage 3 and $k_4 = \log lx$ of larval stage 3 - $\log lx$ of pupal stage. Then $K = k_1 + k_2 + k_3 + k_4$.

The changes in k value for different age intervals and K for the 8 generations were plotted and each of these were joined by lines separately. Then the graph was examined to find out which of the age intervals exhibited similar types of fluctuation as K value. The mortality factors of such age intervals were considered as key factors.

3.2 MANAGEMENT OF *Plutella xylostella* BY ORGANIC APPROACH

This investigation had two sets of experiment viz., 1) use of organic amendments, botanicals and vermiwash 1) To evaluate organic soil amendments for their efficacy 2) Use of eco friendly insecticides

3.2.1 Use of organic soil amendments, botanicals and vermiwash

Field experiment to evaluate the combined efficacy of soil organic amendments, botanicals and vermiwash in managing diamondback moth were carried out in the farmers field in Garag village near UAS, Dharwad. The trials were conducted during *rabi* season of 2005-06 and 2006-07. For this purpose cabbage variety F₁ super ball was selected. 21 days old cabbage seedlings were transplanted during first week of December in 2005 and first week of November in 2006, in plot size of 5 x 4 sq. m with 45 x 30 cm spacing. Each plot had a density of 120 plants. There were 10 treatments laid out in RBD and replicated thrice. The details of the treatment are presented in Table 3.

Application of amendments was done at the time of transplanting and spraying was taken up at 10 days intervals starting from 22 days of transplanting, when sufficient incidence of DBM was noticed. To compare the efficacy of the treatments 100 per cent recommended dose of fertilizer (RDF) and recommended insecticidal sprays as per the package of practices (RPP) as chemical check and a control with no amendments and no chemicals was maintained.

3.2.1.1.1 Preparation of neem seed kernel extract (NSKE)

Neem seeds (50 g) were shade dried, crushed and then soaked over night in a litre of water. Later the mixture was squeezed and filtered through muslin cloth and the volume was made upto one liter so as to obtain 5 per cent NSKE. Every time fresh NSKE solution was prepared before spraying and teepol was added to the solution.

3.2.1.1.2 Preparation of cow urine

On the day of application, fresh cow urine was collected during morning hours and was exposed to sunlight for one hour 50 ml of such urine was diluted with water and the volume was made to 1 liter to get 5 per cent concentration.

3.2.1.1.3 Preparation of garlic chilli kerosene extract (GCK)

Ten grams each of dried garlic bulbs and green chilli were thoroughly ground separately with the help of grinder by adding little quantity of water. Each of the ground materials were separately soaked in 2.5 ml kerosene over night. Next day the extract was squeezed using a thin muslin cloth. The extract of garlic and chilli were mixed and the volume was made to 100 ml to obtain 1 per cent garlic chilli kerosene extract.

3.2.1.1.4 Preparation of vermiwash

Vermiwash was collected from the vermiwash equipment developed at UAS, Dharwad and mixed with equal quantities of water to obtain 1:1 dilution and sprayed.

Table 3 : Details of organic amendments and spray sequence evaluated against *P. xylosteella*

Tr. No.	Treatment details
T ₁	50% RDF + vermicompost (1.25 t/ha) superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₂	50% RDF + vermicompost 2.5 t/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₃	50% RDF + vermicompost 250 kg/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₄	50% RDF + vermicompost 500 kg/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₅	50% RDF + pongamia cake 250 kg/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₆	50% RDF + pongamia cake 500 kg/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₇	50% RDF + poultry manure 1 t/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₈	50% RDF + poultry manure 2 t/ha superimposed with spraying of vermiwash 1:1 – NSKE (5%) - GCK (1%) + cow urine (5%) – Neemazal (2 ml/l)
T ₉	100% RDF + RPP
T ₁₀	Untreated check (100% RDF)

* - Spraying at 10 days interval starting from 22 DAT (days after transplanting)

3.2.1.2 Criteria for evaluation

3.2.1.2.1 Population density of DBM

The population count of DBM larvae was taken 15, 30, 45, 60 and 75 days after transplanting (DAT) on 10 randomly selected and tagged plants in each replication.

3.2.1.2.2 Population density of other defoliators and natural enemies

For recording the population density of *Crocidolomia binatalis* and *Spodoptera litura* larval count were made on 10 randomly selected plants in each replication on 15, 30, 45, 60 and 75 DAT. Pupal count of the natural enemy of DBM viz., *Cotesia plutellae* was recorded in all the treatments on 15, 30, 45, 60 and 75 DAT.

3.2.1.2.3 Yield

Harvesting of cabbage heads was done three times at weekly interval. The yield of total heads per plot was recorded based on the average weight of ten cabbage heads taken randomly in all the three harvest and then computed to per hectare based on the average weight of three harvests.

3.2.1.3 Statistical analysis of the experimental data

The mean population of *P. xylostella*, *C. binotalis* and *S. litura* were converted to $\sqrt{x+1}$ transformation and then were subjected to one way ANOVA using M-STAT C® software package. Mean number of pupae of the parasitoids were also subjected to square root transformation before analysis of variance and means were separated by Duncans Multiple Range Test.

3.2.1.4 Benefit : Cost ratio

Economics for different treatments was calculated based on the prevailing market rate of inputs, cost of pest control operations and the price of produce and B:C ratio was calculated.

3.2.2 Use of eco-friendly insecticides

Field experiments were carried out for two seasons to evaluate the efficacy of botanicals and microbial based new insecticide molecules against, DBM during *rabi*, 2005 and 2006. The experiment was laid out in farmer's field at Garag village, near UAS, Dharwad. The experiment consisted of 10 treatments replicated thrice in Randomized Complete Block Design (RCBD). Three week old cabbage seedlings of F1 super ball were transplanted during third week of December 2005 and first week of November 2006, in plot size of 3 x 3 m with a spacing of 45 x 30 cm between rows and plants respectively. Each plot had density of 45 plants.

All the agronomic practices except plant protection measures were followed as per recommended package of practices for zone-8 (Anon., 2004). All the insecticides were procured from the department of Agricultural Entomology. NSKE 5 per cent was prepared as mentioned earlier. The required volume of the spray solution was prepared at the time of application. Spraying was initiated when the population of DBM reached economic threshold level (ETL) i.e., 1 larva per plant (Mallapur, 1988). Subsequent sprays were taken up at 10 days interval. To compare the treatment efficacy, both chemical (malathion) and untreated check were maintained in the experiment. The treatment details are given in Table 4. All the sprays were taken up using high volume knapsack sprayer with 400-500 liters of spray fluid per hectare depending upon the age of the crop.

3.2.2.1 Criteria for evaluation

3.2.2.1.1 Assessment of population density of DBM

The population count of DBM larvae was taken on ten randomly selected plants in each plot. Pre-treatment counts were made one day before spraying and post treatment counts were made on one, three, seven and ten days after imposition of treatments. The tenth day population counts served as the pre-treatment counts for the next spray.

3.2.2.1.2 Other defoliators and natural enemies

Larval load of leaf webber and tobacco caterpillar were recorded along with the DBM count on 1 day before spray and on 1, 3, 7 and 10 days after spray as described under 3.2.1.2.2. The tenth day population counts served as pre-treatment counts for the next spray.

Population counts of *C. plutellae*, the natural enemy of DBM were recorded by counting the number of cocoons of the parasitoids in the treated as well as untreated plots.

3.2.2.1.3 Yield

Cabbage yield was recorded as mentioned under 3.2.1.2.3.

3.2.2.2 Statistical analysis

The mean population of *P. xylostella*, *C. binotalis* and *S. litura* were computed to per cent larval reduction over pre treatment. The percentage values were transformed to arc sine values and then were subjected to one way ANOVA using M-STAT C® software package. Mean number of pupae of the parasitoids were subjected to square root transformation before analysis of variance and means were separated by DMRT.

Table 4 : Treatment details of evaluation of ecofriendly insecticides against *P. xylosteella*

SL. No.	Treatments	Trade name	Dosage (g a.i/ha)
1	Spinosad 2.5 SC	Success	15
2	Emamectin benzoate 5 SG	Proclaim	7.5
3	Novaluron 10 EC	Rimon	50
4	Indoxacarb 14.5 SC	Avaunt	35
5	Btk	Dipel	60
6	<i>Nomuraea rileyi</i>	UAS, lab strain	2 g/l
7	<i>Beauveria bassiana</i>	Bio power	5 g/l
8	NSKE 5%	Locally made	5%
9	Malathion 50 EC	Malathion	250
10	Untreated check	-	-

Per cent reduction in larval population was calculated using the following formula.

$$\text{Per cent larval reduction} = (\text{PrLC} - \text{PoLC} / \text{PrLC}) \times 100$$

Where,

PrLC = Pre treatment larval count

PoLC = Post treatment larval count

To find out the effect of different treatments on yield the data were subjected to analysis of variance and means were separated by DMRT.

3.2.2.3 Benefit : Cost ratio

Economics for different treatments was calculated based on the prevailing market rate of pesticides, cost of pest control operations and the cost of produce and B:C ratio was calculated.

3.3 COMPARISON OF IPM MODULES AGAINST DBM

Two different IPM modules were formulated by selecting best treatment from objective II as well as by picking proven components of IPM available for DBM. These two modules were compared with that of recommended package of practices (RPP) and Indian Institute of Horticulture Research Module (IIHR-Module). The details of different IPM modules evaluated are indicated in Table 5.

Table 5 : Details of IPM modules evaluated for the management of *P. xylosteella*

Module	Details
Module I (Recommended Package of Practices)	Mustard trap crop* + 100% RDF, super imposed with sprays of NSKE (5%) at 15 and 25 DAT, malathion (1 ml/l), at 35, 45, 55 and 65 DAT.
Module II (IHR module)	Mustard trap crop* + 100% RDF super imposed with sprays of Btk @ 1 g/l from 15 DAT (5-6 sprays at 10 days interval).
Module III (Adoptive Module)	Mustard trap crop* + neem cake 250 kg/ha + 50% RDF super imposed with sprays of Btk (1 g/l) @ 15 and 45 DAT, spinosad (1.2 ml/l) at 25 and 55 DAT, Emamectin benzoate (0.3 g/l) at 35 and 65 DAT.
Module IV (Bio-intensive module)	Mustard trap crop* + neem cake 250 kg/ha + 50% N and 100% P and K super imposed with sprays of NSKE (5%) at 15 and 45 DAT, <i>T. bactrae</i> (50,000/ha) at 21 DAT, Btk (1.5 ml/l) at 25 and 55 DAT, novaluron (1 ml/l) at 35 and 65 DAT.

* - Mustard trap crop in 25:2 ratio 1st row 15 DBT and 2nd row 25 DAT
 2-3 sprays of dichlorovos at 15 days interval starting from 15 DAT
 DBT – Days before transplanting
 DAT – Days after transplanting

To evaluate the efficacy of these IPM modules against DBM, an experiment was laid out in duplicate during early summer of 2007 in Farmers field at Garag village. Each IPM module was laid out in an area of 15 x 20 m with 2 m buffer zone in between each module. Each module was further demarcated into five regions to serve as replications for observations and statistical analysis.

F1 super ball variety of cabbage was transplanted during 3rd week of January 2007 with spacing of 45 x 30 cm between rows and plants respectively. Application of amendments was done at the time of transplanting. All the insecticides were obtained from the Department of Agricultural Entomology, UAS, Dharwad. Whereas, the bio-agent *Trichogramma bactrae* was obtained from Project Directorate of Biological Control (PDBC), Bangalore.

Sowing of bold seeded mustard for every 25 rows of cabbage was done 15 days prior to transplanting and the second row of mustard was done 25 days after transplanting to synchronize the flowering of mustard with primordial stage of cabbage. The treatments were imposed as per details given in Table 5.

3.3.1 Criteria for evaluation

Observations on various parameters were recorded as described under 3.2.1.2.1 to 3.2.1.2.3.

3.3.2 Cost economics

Benefit cost ratio for each module was calculated based on the prevailing market rate of pesticides, cost of amendments, cost of pest control operations and the price of the produce. And B:C ratio was obtained by dividing net monetary returns by treatment cost.

3.3.3 Statistical analysis

All experimental data were subjected to statistical analysis as described under 3.2.1.3.

VI. EXPERIMENTAL RESULTS

Results of the present investigations on the diamondback moth, *Plutella xylostella* L. on cabbage with reference to life table construction, use of organic amendments and ecofriendly insecticides in its management and integrated management studies are presented here under.

4.1 LIFE TABLE STUDIES

4.1.1 Biology

4.1.1.1 Life history in the laboratory

The results presented here include the morphological characters, duration of development of all the stages and habits of larvae.

Egg

Eggs are minute, yellowish white in colour with cylindrical to oblong shape and with the chorion more or less uniformly pitted (Plate 5a). Eggs were laid singly or some times in groups of 2 to 4. The average egg period lasted for 3 days in rainy and summer season and 3.7 days in winter (Table 6). One day prior to hatching eggs become pale black in colour revealing the young, coiled larva through the chorion.

Larva

The larva gnawed a circular opening through one end of egg shell and emerged. There were 4 larval instars and the exuvium was cast off on the cabbage leaf bit only. Just after casting off the exuvium larva of all instars were having pale white coloured head, body and setae. When disturbed, the larvae in all the instars wriggled backwards quickly and dropped from the surface through silken thread and when the disturbance was over, they climbed back on the silken thread.

I instar

Freshly emerged larvae had dark brown head and light grey coloured body bearing grey setae all over (Plate 5b). Newly emerged larvae wandered on the leaf bit and then started mining into the leaf tissue through the mesophyll layer. The 1st instar period occupied 3.6 days in hot, 3.8 days in rainy and 4.8 days in cold seasons.

II instar

The larvae are slender, cylindrical with light brown head and pale grey coloured body with scattered setae. The larvae fed on leaf tissue by keeping the head and thoracic segments buried inside leaf tissue. The average duration of the instar was 2.3, 2.3 and 3.3 days in summer, rainy and winter seasons, respectively.

III instar

Head was light brown in colour and body pale greyish covered with setae. The larvae varied in colour i.e., the larvae that fed on thick green leaves are darker in colour. The instar generally fed on mature leaves and lasted for 2.2 days in summer and rainy seasons and 3.5 days in winter season.

IV instar

The head is pale coloured with many irregular brown patches and the body is light yellow, beset with black setae as in the case of previous instar. The larvae in the middle of this instar is spindle shaped (Plate 5c). Fully grown caterpillars are light green in colour, moderately stout and smooth with short scattered hairs. Fourth instar larva excluding the pre pupal stage consume the largest quantity of leaf tissue and lasted for 2.3, 2.4 and 4.3 days, respectively in hot, rainy and winter seasons.

Pre pupa

The mature caterpillar stopped feeding and built a loosely spun silk cocoon on the surface of the leaf bit. The cocoon was spindle shaped having an opening at the anterior end. The larva there after shortened its body and rested inside the cocoon on the side of their body with thoracic legs directed forward (Plate 5d). Pre pupal period lasted for one day in all the three seasons.

Table 6 : Developmental period of different stages and adult longevity of *P. xylostella* under laboratory condition during 2005-06

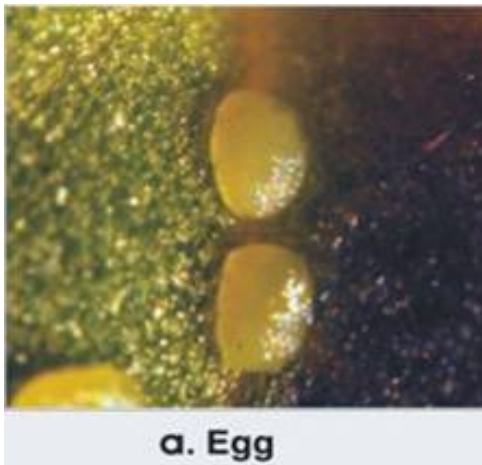
Period	Incubation of egg		Larval period (days)								Pre pupa (days)	Total larval period (days)		Pupal period (days)		Total developmental period (days)	
			I instar		II instar		III instar		IV instar								
	R	M*	R	M*	R	M*	R	M*	R	M*		R	M*	R	M*		
Aug-Sept.	3-3	3	3-4	3.8	2-3	2.3	2-3	2.2	2-3	2.4	1	11-14	12.1	4-5	4.2	18-21	19.4
Dec-Jan	3-4	3.7	4-6	4.8	3-4	3.3	3-4	3.5	4-5	4.3	1	15-18	16.8	4-6	4.9	24-26	25.2
March-April	3-3	3	3-4	3.6	2-2	2.3	2-3	2.2	2-3	2.3	1	10-12	10.8	3-4	3.8	10-12	11.1

Period	Adult longevity				Fecundity	
	Male		Female			
	R	M*	R	M*	R	M*
Aug-Sept.	9-10	9.4	10-12	11.5	147-249	193.4
Dec-Jan	10-11	10.5	11-13	12.1	108-260	201.3
March-April	9-10	9.2	11-12	11.7	123-236	191.6

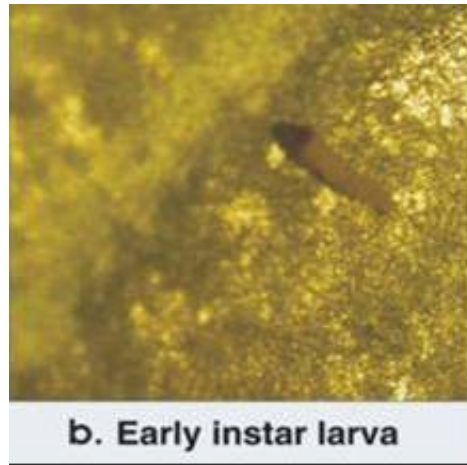
R – Range

M* - Mean

* - Mean of ten replication



a. Egg



b. Early instar larva



c. Late instar larva



d. Pre-pupa



e. Pupa



f. Adult

Plate 5. Life cycle of *P. xylostella* showing different development stages

The total larval period including pre pupal stage ranged from 10-12 days in summer, 11-14 days in rainy and 15-18 days in winter. With an average of 10.8, 12.1 and 16.8 days in the corresponding seasons, respectively.

Pupa

Newly formed object pupa was yellowish green in colour but in a day or two it became brownish and gradually attained dark brown colour by the time of adult emergence (Plate 5e). The pupal period ranged from 3-4, 4-5 and 4-6 days with an average of 3.8, 4.2 and 4.9 days during summer, rainy and winter seasons, respectively.

Adult

Table 7: Total life cycle of *P. xylostella* in the field

	Generation period		Peak egg		Pupation	Moth emergence	Duration of stages (days)			Total life cycle (days)
	From	To	Laying	Hatching			Egg	Larva	Pupa	
2005-06										
I	11-9-05	30-9-05	11-9-05	14-9-05	27-9-05	30-9-05	3	13	4	20
II	10-10-05	29-10-05	10-10-05	13-10-05	26-10-05	29-10-05	3	13	4	20
III	13-12-05	5-1-06	13-12-05	17-12-05	2-1-06	6-1-06	4	15	5	24
IV	15-1-06	6-2-06	15-1-06	19-1-06	2-2-06	6-2-06	4	14	5	23
2006-07										
I	18-9-06	7-10-06	18-9-06	21-9-06	4-10-06	7-10-06	3	13	4	20
II	18-10-06	7-11-06	18-10-06	21-9-06	4-11-06	7-11-06	3	14	4	21
III	12-12-06	4-1-07	14-12-06	16-1-06	30-12-06	4-1-07	4	15	5	24
IV	14-1-07	5-2-07	15-1-07	18-1-07	31-1-07	5-2-07	4	14	5	23

Table 8: Life table for the first generation of *P. xylostella* in the first crop in rainy season during 2005-06

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	168	Infertility	21.00	35.00	20.83	0.79	2.00	0.10
LP1	79	133* (109)**	Unknown causes	10.00	16.00	12.03	0.88	1.90	0.06
LP2	69	117 (62)	<i>C. plutellae</i>	23.46	39.78	34.00	0.62	1.84	0.21
			Unknown causes	2.54	4.22	3.61			
			Sub total	26.00	44.00	37.61			
LP3	43	73 (26)	<i>T. sokolowskii</i>	2.00	3.00	4.11	0.96	1.63	0.02
Pupa	41	70 (21)	<i>T. sokolowskii</i>	1.64	2.80	4.00			
			Fail to emerge	4.36	8.20	11.71			
			Sub total	6.00	11.00	15.71	0.84	1.61	0.07
Moth	35	59 (2)	Sex= 48.57%	2	3.00	5.08			
Female x 2	34								
GS	0.20								
Generation total				95.00		95.37	Total K = 0.46		

LP1 – Larval period I

LP2 – Larval period II

LP3 - Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 9: Life table for the second generation of *P. xylostella* in the first crop in rainy season during 2005-06

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	215	Infertility	16.00	35.00	16.28	0.84	2.00	0.08
LP1	84	180* (151)**	Unknown causes	9.00	18.00	10.00	0.90	1.92	0.04
LP2	75	162 (97.00)	<i>C. plutellae</i>	31.56	68.56	42.32			
			Unknown causes	3.44	3.44	2.12	0.56	1.88	0.28
			Sub total	35	72	44.44			
LP3	40	90 (23)	<i>T. sokolowskii</i>	4.000	7.00	7.70	0.92	1.60	0.04
Pupa	36	80 (20.00)	<i>T. sokolowskii</i>	3.32	6.64	8.39	0.84	1.56	0.07
			Fail to emerge	1.68	3.04	3.66			
			Sub total	5.00	13.00	12.05			
Moth	31	70 (2)	Sex= 48.57%	1.00	2.00	2.86			
Female x 2							1.49		
GS	0.14								
Generation total				146		93.40		Total K = 0.51	

LP1 – Larval period I

LP2 – Larval period II

LP3 - Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 10: Life table for the first generation of *P. xylostella* in the second crop in winter season during 2005-06

Age interval (x)	No. alive at beginning of x (lx)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (lx)	k's
	Lab	Field		Lab	Field				
Egg	100	587	Infertility	11	65.00	11.07	0.89	2.00	0.05
LP1	89	522* (415)**	Unknown causes	10	63.00	12.07	0.87	1.95	0.05
LP2	79	459 (293)	<i>C. plutellae</i>	17.38	100.68	21.93	0.74	1.90	0.16
			Unknown causes	6.62	18.32	3.99			
			Sub total	24.0	119.0	25.92			
LP3	55	340 (46)	<i>T. sokolowskii</i>	7	40	11.76	0.88	1.74	0.06
Pupa	48	300 (49)	<i>T. sokolowskii</i>	11.52	72.61	24.20	0.68	1.68	0.16
			Fail to emerge	3.48	23.39	7.80			
			Sub total	15	96	32			
Moth	33	204 (1)	Sex= 48.48%	1	6	2.94		1.52	
Female x 2	32								
GS	0.05								
Generation total				326		95.76		Total K = 0.48	

LP1 – Larval period I

LP2 – Larval period II

LP3 - Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 11: Life table for the second generation of *P. xylostella* in the second crop in winter season during 2005-06

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	845	Infertility	14	118.0	13.96	0.86	2.00	0.07
LP1	86	727* (613)**	Unknown causes	10	87	11.97	0.88	1.93	0.05
LP2	76	640 (387)	<i>C. plutellae</i>	13.68	115.26	18.00	0.74	1.08	0.13
			Unknown causes	6.32	51.74	8.08			
			Sub total	20.00	167.00	26.09			
LP3	56	473 (51)	<i>T. sokolowskii</i>	7.00	57	12.05	0.88	1.75	0.06
Pupa	49	416 (48)	<i>T. sokolowskii</i>	19.62	166.45	40.01	0.48	1.69	0.33
			Fail to emerge	6.38	49.55	11.91			
			Sub total	26.00	216.00	51.92			
Moth	23	200 (-)	Sex= 47.82%	1	8	4.00		1.36	
Female x 2	22								
GS	0.02								
Generation total				645		119.99	Total K = 0.64		

LP1 – Larval period I

LP2 – Larval period II

LP3 - Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 12: Life table for the first generation of *P. xylostella* in the third crop in rainy season during 2006-07

Age interval (x)	No. alive at beginning of x (lx)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (lx)	k's
	Lab	Field		Lab	Field				
Egg	100	283	Infertility	18	51.00	18.02	0.82	2.00	0.09
LP1	82	232* (176)**	Unknown causes	7.00	37	15.95	0.84	1.91	0.03
LP2	75	195 (112)	<i>C. plutellae</i>	28.5	37.05	19.00	0.76	1.88	0.29
			Unknown causes	7.50	9.95	5.10			
			Sub total	36.0	47.00	24.10			
LP3	39	418 (23)	<i>T. sokolowskii</i>	5.00	18.00	12.16	0.88	1.59	0.06
Pupa	34	130 (21)	<i>T. sokolowskii</i>	2.72	10.4	8.00	0.80	1.53	0.10
			Fail to emerge	4.28	15.6	12.00			
			Sub total	7.00	26.00	20.00			
Moth	27	104 (4)	Sex= 48.15%	1	4	3.85		1.43	
Female x 2	26								
GS	0.091								
Generation total					183	94.09		Total K = 0.57	

LP1 - Larval period I

LP2 - Larval period II

LP3 - Larval period III

GS - Generation survival

* - Expected population in the field

** - Actual field population

Table 12. Life table for the generation of *P. xylostella* in the third crop in rainy season during 2006-07

Table 13: Life table for the second generation of *P. xylostella* in the third crop in rainy season during 2006-07

Age interval (x)	No. alive at beginning of x (lx)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (lx)	k's
	Lab	Field		Lab	Field				
Egg	100	463	Infertility	13	60.00	12.96	0.87	2.00	0.06
LP1	87	403* (254)**	Unknown causes	9.0	40	9.92	0.90	1.94	0.05
LP2	78	363 (106)	<i>C. plutellae</i>	31.2	145.28	40.02	0.58	1.89	0.26
			Unknown causes	3.8	7.72	2.13			
			Sub total	35.0	153.00	42.15			
LP3	43	210 (27)	<i>T. sokolowskii</i>	4.00	17	8.09	0.92	1.63	0.04
Pupa	39	193 (23)	<i>T. sokolowskii</i>	6.24	30.88	16.00	0.80	1.59	0.10
			Fail to emerge	1.76	7.12	3.69			
			Sub total	8.00	38.00	19.69			
Moth	31	155 (3)	Sex= 48.15%	1	5.00	3.23		1.49	
Female x 2	30								
GS	0.69								
Generation total					308	96.04		Total K = 0.51	

LP1 – Larval period I

LP2 – Larval period II

LP3 – Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 14: Life table for the first generation of *P. xylostella* in the fourth crop in winter season during 2006-07

Age interval (x)	No. alive at beginning of x (lx)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (lx)	k's
	Lab	Field		Lab	Field				
Egg	100	1253	Infertility	11	138.00	11.01	0.89	2.00	0.05
LP1	89	1115* (813)**	Unknown causes	6.00	67	6.01	0.94	1.95	0.03
			<i>C. plutellae</i>	23.24	293.44	28.00			
LP2	83	1048 (596)	Unknown causes	3.76	41.56	3.97	0.68	1.92	0.17
			Sub total	27.00	335.00	31.97			
LP3	56	713 (137)	<i>T. sokolowskii</i>	5.00	57	7.99	0.92	1.75	0.04
Pupa	51	656 (133)	<i>T. sokolowskii</i>	16.32	209.92	32.00			
			Fail to emerge	4.68	52.08	7.94	0.60	1.71	0.23
			Sub total	21.00	262.00	39.94			
Moth	30	394 (6)	Sex= 48.15%					1.48	
Female x 2	30								
GS	0.024								
Generation total				859		96.91		Total K = 0.52	

LP1 – Larval period I

LP2 – Larval period II

LP3 – Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 15: Life table for the second generation of *P. xylostella* in the fourth crop in winter season during 2006-07

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	1436	Infertility	17	244.00	16.99	0.83	2.00	0.08
LP1	83	1192* (936)**	Unknown causes	8.00	120	10.07	0.90	1.92	0.04
LP2	75	1072 (684)	<i>C. plutellae</i>	19.50	278.72	26.00	0.70	1.88	0.16
			Unknown causes	3.50	42.28	3.94			
			Sub total	23.00	321.0	29.94			
LP3	52	751 (296)	<i>T. sokolowskii</i>	4.00	61.0	8.12	0.92	1.72	0.04
Pupa	48	690 (298)	<i>T. sokolowskii</i>	23.84	331.2	48.00	0.44	1.68	0.36
			Fail to emerge	3.16	55.8	8.09			
			Sub total	27.00	387.0	56.09			
Moth	21	303 (9)	Sex= 48.15%					1.32	
Female x 2	22								
GS	0.15								
Generation total				1133		121.21	Total K = 0.68		

LP1 – Larval period I

LP2 – Larval period II

LP3 – Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 16: Mean life table for four generations of *P. xylostella* in rainy season during 2005-07

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	282	Infertility	17.00	45.25	16.03	0.84	2.00	0.08
LP1	83	237* (172)**	Unknown causes	8.75	27.75	11.71	0.88	1.92	0.05
LP2	74.25	209 (90)	<i>C. plutellae</i>	28.68	72.67	34.73	0.62	1.87	0.25
			Unknown causes	4.32	6.33	3.03			
			Sub total	30.5	79	37.75			
LP3	41.25	130 (24)	<i>T. sokolowskii</i>	3.75	11.25	8.64	0.91	1.62	0.05
Pupa	37.50	119 (21)	<i>T. sokolowskii</i>	3.48	12.68	10.66	0.82	1.57	0.08
			Fail to emerge	3.02	8.49	7.13			
			Sub total	6.5	22	18.49			
Moth	31.00	97 (2.75)	Sex= 48.15%	1.25	3.5	3.61		1.49	
Female x 2	30.00								
GS	0.11								
Generation total				188.75		96.23		Total K = 0.51	

LP1 – Larval period I

LP2 – Larval period II

LP3 – Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

Table 17: Mean life table for four generations of *P. xylostella* in winter season during 2005-07

Age interval (x)	No. alive at beginning of x (Ix)		Factors responsible	No. dying during x (dx)		dx as percentage (100 qx)	Survival rate (Sx)	Log (Ix)	k's
	Lab	Field		Lab	Field				
Egg	100	1030.25	Infertility	13.25	141.25	13.71	0.86	2.00	0.06
LP1	86.75	889* (701)**	Unknown causes	8.5	84.02	9.48	0.91	1.94	0.05
LP2	78.25	804 (490)	<i>C. plutellae</i>	18.45	197.03	24.48	0.71	1.89	0.15
			Unknown causes	5.05	38.48	4.78			
			Sub total	23.50	235.5	29.26			
LP3	54.75	569 (132)	<i>T. sokolowskii</i>	5.75	53.75	9.44	0.86	1.74	0.05
Pupa	49.00	490 (132)	<i>T. sokolowskii</i>	17.83	195.05	39.77	0.56	1.69	0.26
			Fail to emerge	4.43	45.21	9.12			
			Sub total	22.25	240.25	48.98			
Moth	26.75	275 (4)	Sex= 48.15%	0.5	3.5	1.27		1.43	
Female x 2	26.5								
GS	0.026								
Generation total				758.5		112.14		Total K = 0.57	

LP1 – Larval period I

LP2 – Larval period II

LP3 – Larval period III

GS – Generation survival

* - Expected population in the field

** - Actual field population

The moth emerged from the pupal case and came out of the cocoon through the opening present at the anterior end.

Adult moths are small slender, \square ermin \square brown in colour, when at rest the antennae were extended foreword and wings were folded on the abdomen. The mid dorsal line where the anal ends of the wings meet, a diamond shaped design of three creamy yellow or white patches is formed (Plate 5f). Males and females could be easily distinguished by the darker and slender body of male and lighter and moderately stout body of the female. The average life span of mated and fed males and females were 9.7 and 11.77 days, respectively.

Fecundity

Newly emerged female moved about for some time and then copulated with the males. While copulating they faced opposite directions and mild disturbance did not deter the process. The female mated only once in her life and mated females rejected the attempts to mate by males. Fecundity ranged from 123-260 eggs per female with an average of 195.43 eggs (averages based on 30 observations during 3 seasons). Large number of eggs were laid on first day after mating. There was no distinct difference in the number of eggs laid in different seasons.

4.1.1.2 Life cycle under field conditions

For determining the total life cycle the pest under field conditions, the probable dates of peak egg laying, hatching, pupation and moth emergence of each generation studied in life table construction were considered. Since the sampling done for each of these generations in field was based on the age structure of the egg obtained from egg sampling and rearing, these generations were considered to be distinct from the overlapping field generations. The probable dates of peak egg laying, hatching, pupation and moth emergence along with the duration of each stage have been furnished in Table 7.

Egg

The moth laid eggs mostly on the upper surface of leaf along the mid rib and lateral veins of the outer whorl of thick leaves and rarely on lower surface. Eggs were laid mostly singly or in groups of 2-14. The duration of egg period lasted for 3 days in rainy season and 4 days in winter during both the years.

Larvae

The larvae emerging from the eggs were found to get dispersed well on the leaves. They were found to confine themselves on thick outer whorl of leaves. In young plant (before head formation) the larvae was found at the growing region and found feeding on the tender leaves around. The final instar larvae were found to confine themselves to outer whorl of leaves. The fully fed fourth instar larvae moved to the base of the leaf and built cocoons on lower surface. The pre pupal period lasted for one day in all the generation during both the seasons, of two years of study. Total larval period including the pre pupal period lasted for 13-14 days during rainy season and 14-15 days in winter.

Pupa

Pupae were found mostly on the lower surface of leaves. This stage lasted for 4 days in rainy and 5 days in winter during both the years.

Total life cycle of the pest was found to range between 20-21 days in rainy and 23-24 days in winter seasons.

4.1.2 Interpretations on life table data

Life tables prepared for eight generations of *P. xylostella* in main field are furnished in Table 8 to 15 and mean life tables for 4 generations each of cold and rainy seasons in Tables 16 and 17. The details of the major mortality factors identified have been furnished individually.

Parasitoids

Only two species of parasitoids were found to parasitize *P. xylostella* in Dharwad region. Among these, the solitary larval parasitoid *Cotesia plutellae* (L.) and gregarious larval pupal parasitoid *Tetrastichus sokolowskii* (Kurdj.) were recorded in many population sampling for specific stages of life table study.

1. The larval parasitoid, *Cotesia plutellae* (L.)

The parasitoid was recorded from larval period 2 (LP2) in both seasons during 2005-06 and 2006-07 (Plate 6 and 7). However, the percentage parasitization was more during rainy season when compared to winter in both the years. The per cent parasitization ranged from 19 to 42.32 during rainy season and 18 to 28 during winter. These results are evident from the dates furnished in the life tables for 8 generations and mean life tables for rainy and cold seasons. Parasitization by this parasitoid was a major mortality factor in LP2 and the parasitization occurred in all the generations.

2. The larval pupal parasitoid, *Tetrastichus sokolowskii* (Kurdj)

This species was the dominant parasitoid during winter season of both the years. The parasitism by this parasitoid was a major mortality factor in larval period 3 (LP3) and pupa (P). Adults of the parasitoid emerged from pupa (Plate 8). Per cent parasitism of the pupa in life table studies varied from 4 to 16 in rainy season and 24 to 48 in cold season. The higher percentage of parasitism by this species being in cold season as seen in the data furnished in the life table for 8 generation and mean life tables for rainy and cold season.

3. Predator

Only one spider predator (an unidentified species) was observed in the field, the predators were found feeding on the early stages of larva. However, the counts of these could not be taken.

4. Infertility

This was a mortality factor in the egg stage in all the generations of the pest during the period of study. No parasitoid was recorded on the egg stage.

5. Sex ratio

This was a mortality factor in adult stage. The normal sex ratio of *P. xylostella* is 50:50 when the sex ratio was distorted in favour of males, the number of males over and above the number of females was considered as the number dying at the adult stage. Mortality due to this factor was more in rainy season as seen from the mean life tables for rainy and cold seasons.

6. Unknown causes

The pest mortality which could not be included under any of the above mentioned heads (i.e., the causes being not known) was considered unknown causes. The mortality due to this factor ranged from 6.01 to 15.95, 2.13 to 8.08 and 3.66 to 11.91 per cent in LP1, LP2, and P stages, respectively.

4.1.2.1 Survivorship curves

The survivorship curves for the 8 generations as well as for the average of 4 generations in each year and average of all 8 generations are depicted in Fig. 1, 2 and 5.

On comparison with Slobodkin's (1962) curves, it was observed that the curves obtained in the present studies were almost similar to type III curves indicating that the mortality rate was constant in all the stages. Hence the mortality at later stage of development like pupa or adult would have greater impact on population reduction.

4.1.2.2. Death rate curves

Death rate curves for each of the 8 generation as well as for the average of all generations of both the years and average of 8 generations are furnished in Fig. 3, 4 and 5.

Visual observations were made on these curves along with the details in life tables on mortality factors. The force of mortality was found to act in different pattern in different generations on the 5 age intervals of the pest. In general the force of mortality was high in age intervals LP2 and pupa. Mortality in LP2 and P was similar during both the years. Major mortality factor in LP2 was parasitization by *C. plutellae*. The mortality factor in LP2 was operating with greater force in rainy season when compared to cold season. Mortality of pupa due to parasitization by *T. sokolowskii* was higher in cold season (in I and II generations of crop II and IV) compared to rainy season. This mortality factor was found to operate with greater force in the later stage of the crop when the population of *P. xylostella* was low.

Mortality in eggs was due to infertile eggs only and this was found to be higher in rainy season compared to cold season, because of the drenching of eggs in rain water.



Plate 6. Newly formed cocoon of *C. plutella* with host larva



Plate 7. Cocoons and adult of *C. plutella*



Plate 8. *Sokolowskii* emerging out of host pupa

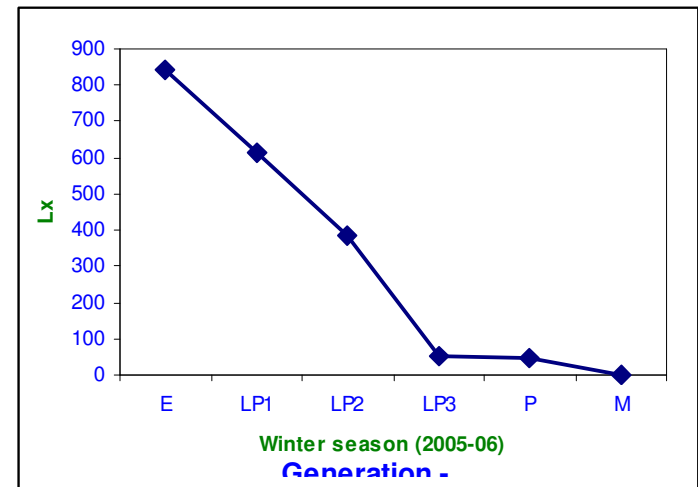
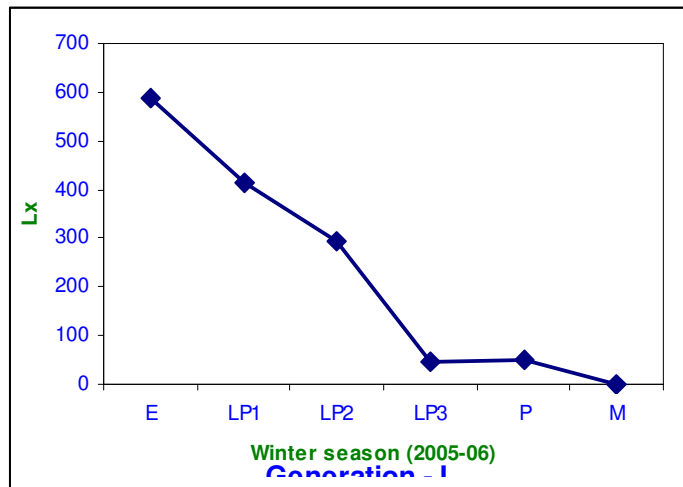
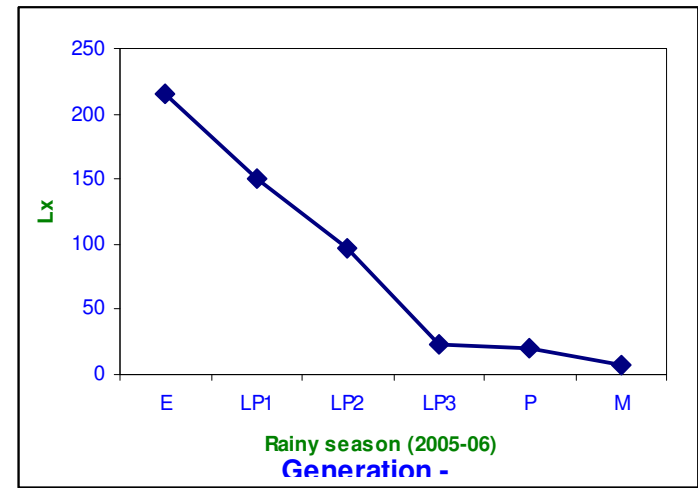
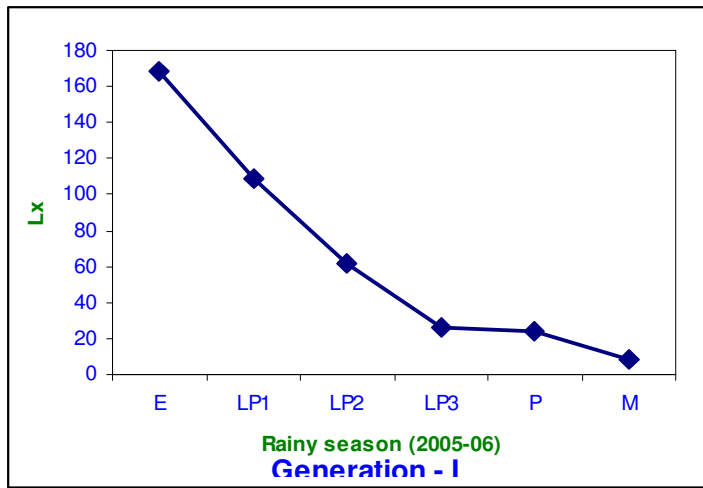


Fig. 1 : Survivorship curves for *P. xylostella* during 2005-06

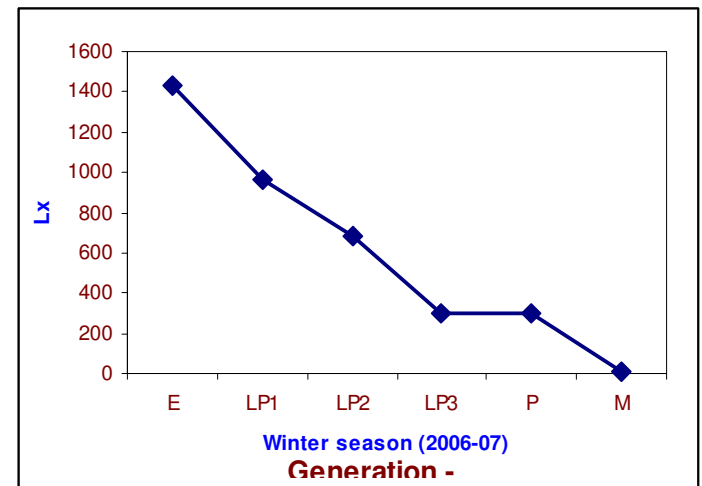
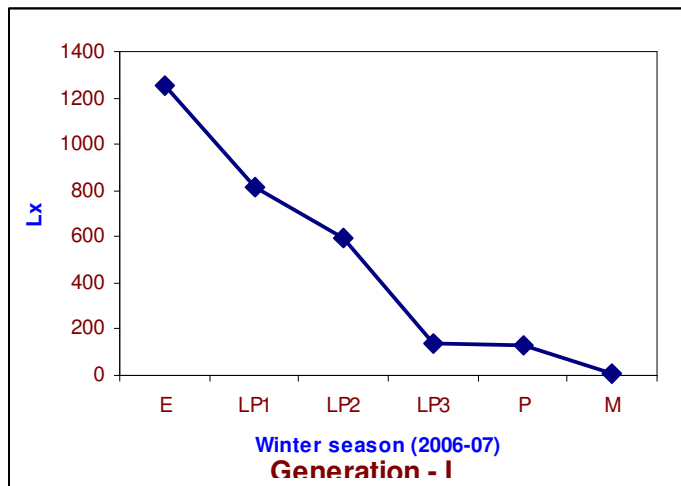
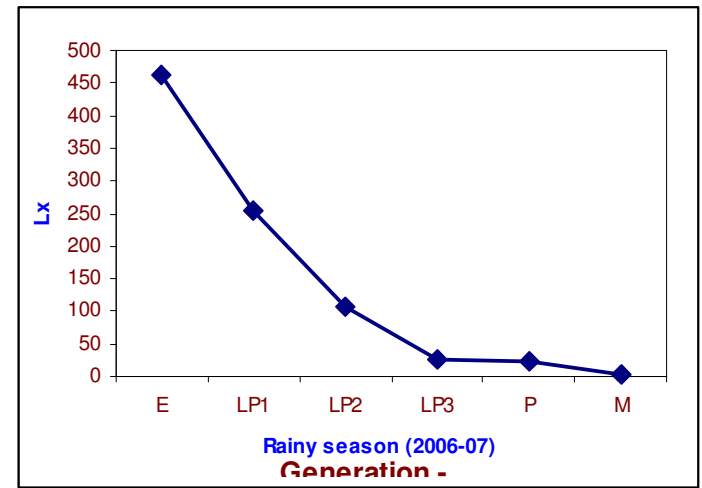
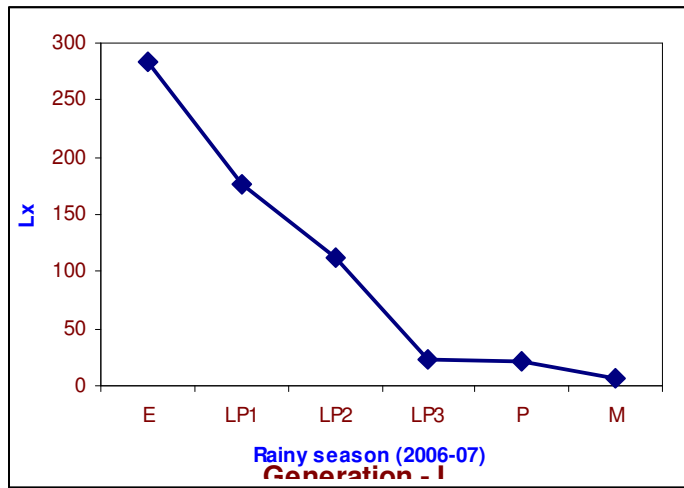


Fig. 2 : Survivorship curves for *P. xylostella* during 2006-07

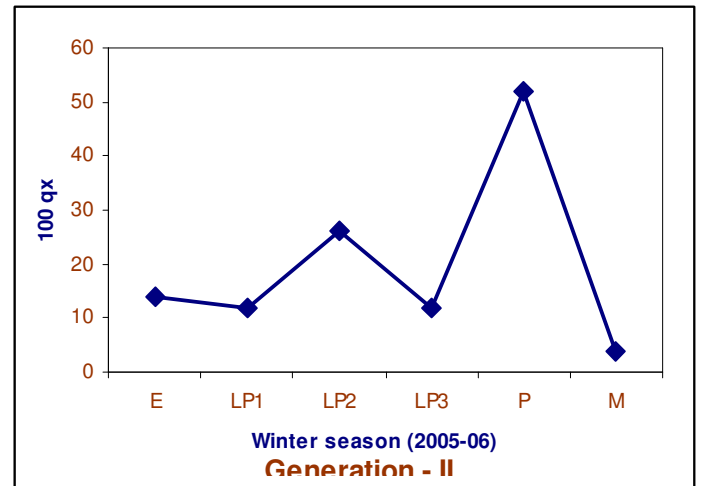
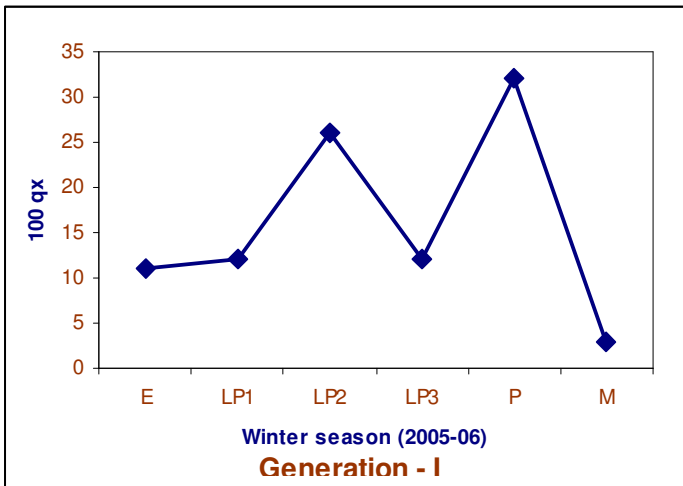
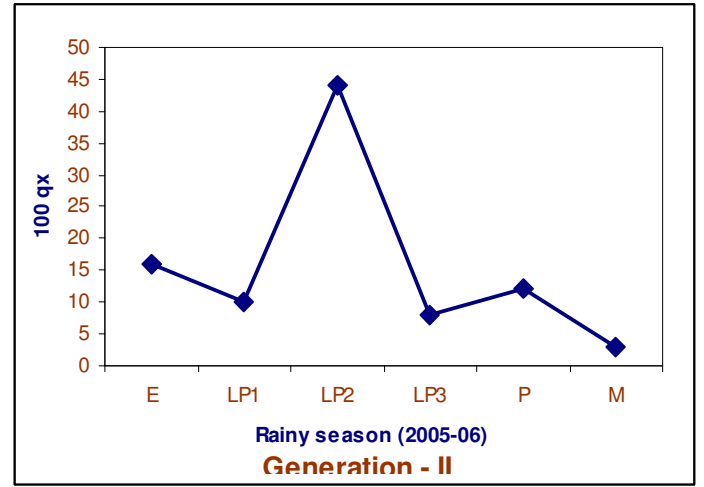
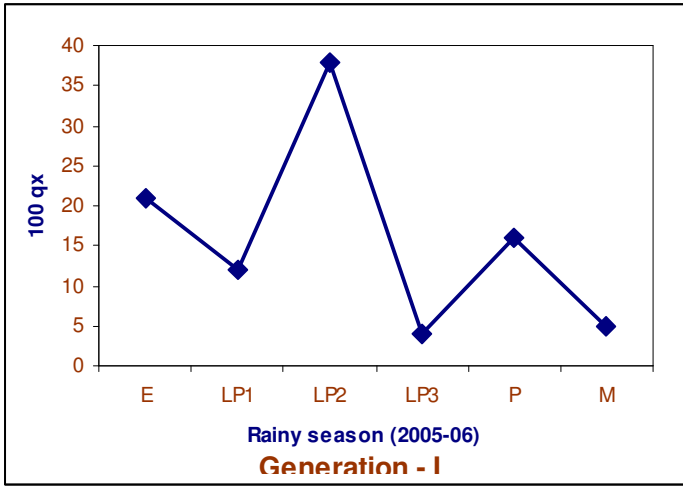


Fig. 3 : Death rate curves for *P. xylostella* during 2005-06

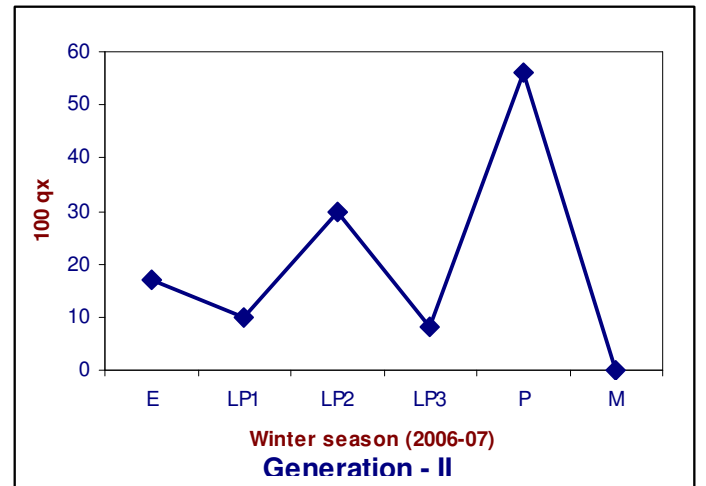
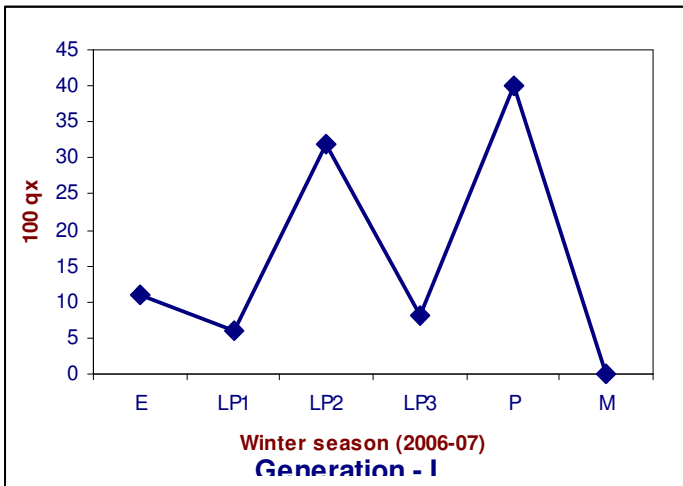
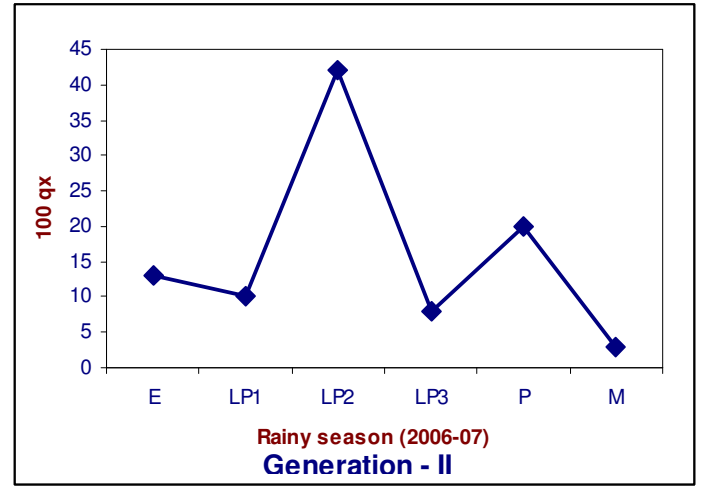
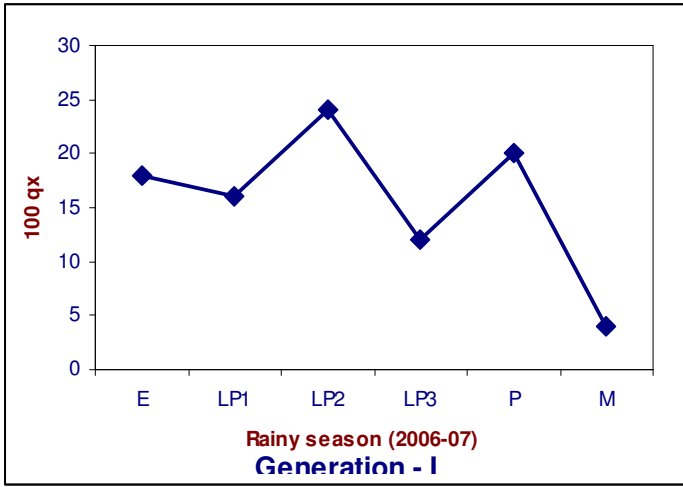


Fig. 4 : Death rate curves for *P. xylostella* during 2006-07

Mortality factor in LP1 was due to unknown causes and that in LP₃ was also the same along with parasitization by *T. sokolowskii*. Hence the force of mortality in LP3 acted in the same pattern as in P but at lower intensity. Mortality in adults was number of males in excess of the number of females.

4.1.2.3 Average survivorship and death rate curves

The average survivorship curve of eight generations (Fig. 5) clearly indicated that the survival rate was reduced to a greater extent between LP2 to LP3. There after the slope of the curve was reduced gradually indicating the lower survival rate of the later stages of the pest.

Similarly the average death rate curve for eight generations revealed mortality rate in pupal stage to be highest followed by that in LP2. However the average death rate curves for four generations each during rainy and winter seasons, clearly demarcated the seasonal activity of the parasitoids. The activity of larval parasitoid, *C. plutellae* was maximum during rainy season and that of larval pupal parasitoid, *T. sokolowskii* in winter.

4.1.2.4 Generation survival

During 2005-06, the generation survival value for the I, II, III and IV generations were 0.2, 0.14, 0.05 and 0.02, respectively, indicating that the pest survivability declined from generation to generation. Similarly the respective figures for the second year were 0.09, 0.069, 0.024 and 0.015. Pest survivability was lower in the second year than the 1st year.

4.1.2.5 Key factors causing population fluctuation of *P. xylostella*

The method suggested by Varley and Gradwell (1960) was employed and the data are presented graphically Fig. 6.

A close perusal of the curves for various stages against total mortality curves (K), it is evident that fluctuation in curve for kp follows more or less similar pattern as in generation mortality (K). The other curve which resembles second best the curve for generation mortality is KLP3. This indicates that the key factors influencing the over all mortality (K) was due to the mortality in P and larval mortality in LP3 age-interval. The killing power of mortality factor in LP3 and P stage well explains the generation mortality. The killing power of mortality factor in LP3 also contributed for generation mortality. The factor mainly responsible for mortality in LP3 and P stage was parasitization by *T. sokolowskii*. This revealed that the key factors influencing the overall mortality was pupal parasitization by *T. sokolowskii* and thus it is the key mortality factor of *P. xylostella* in Dharwad region.

4.2 MANAGEMENT OF DBM THROUGH ORGANIC APPROACH

4.2.1 Evaluation of organic soil amendments

Eight treatments comprising of various organic soil amendments along with recommended package of practices and an untreated control were evaluated for their efficacy on activity of DBM in cabbage.

For the convenience of presenting results, treatment details listed in Table 3 are used with notations as given below.

T₁ – VC – 1250 – SS (spray schedule)

T₂ – VC – 2500- SS

T₃ – NC – 250 –SS

T₄ – NC – 500 –SS

T₅ – PC – 250 –SS

T₆ – PC – 500 –SS

T₇ – PM – 1000 –SS

T₈ – PM – 2000 –SS

T₉ – RPP

T₁₀ – UTC

Activity of pests

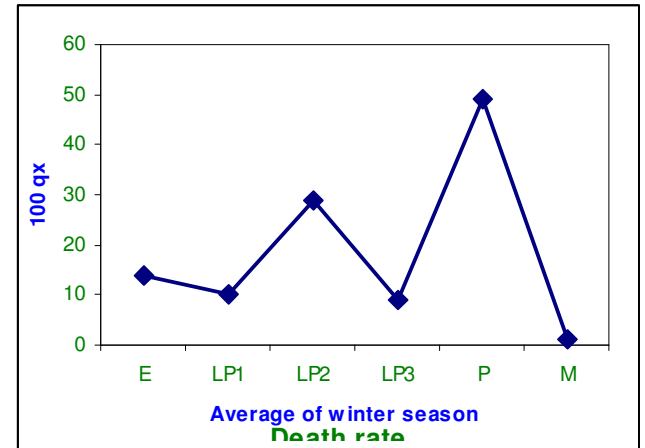
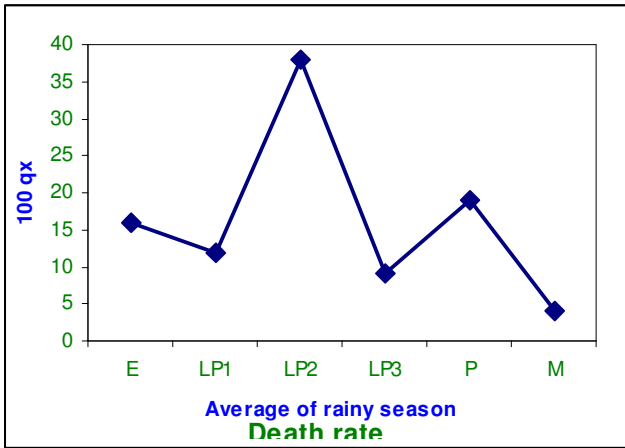
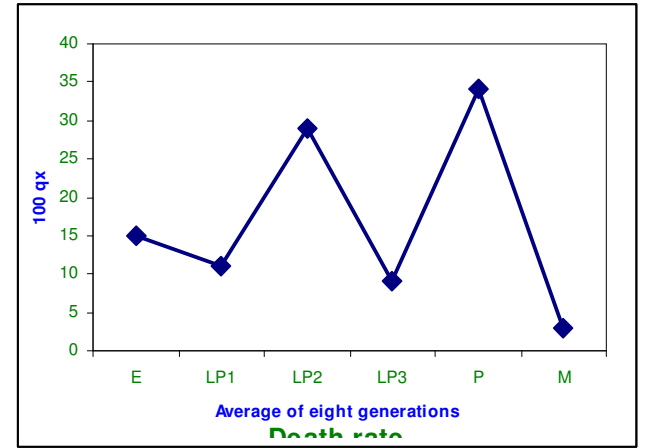
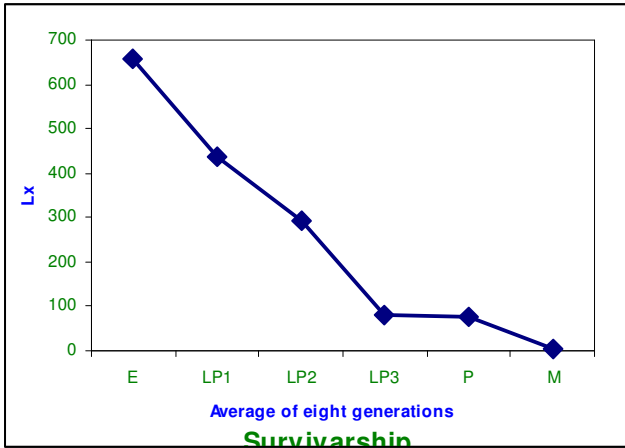


Fig. 5 : Average survivorship and death rate curves of *P. xylostella*

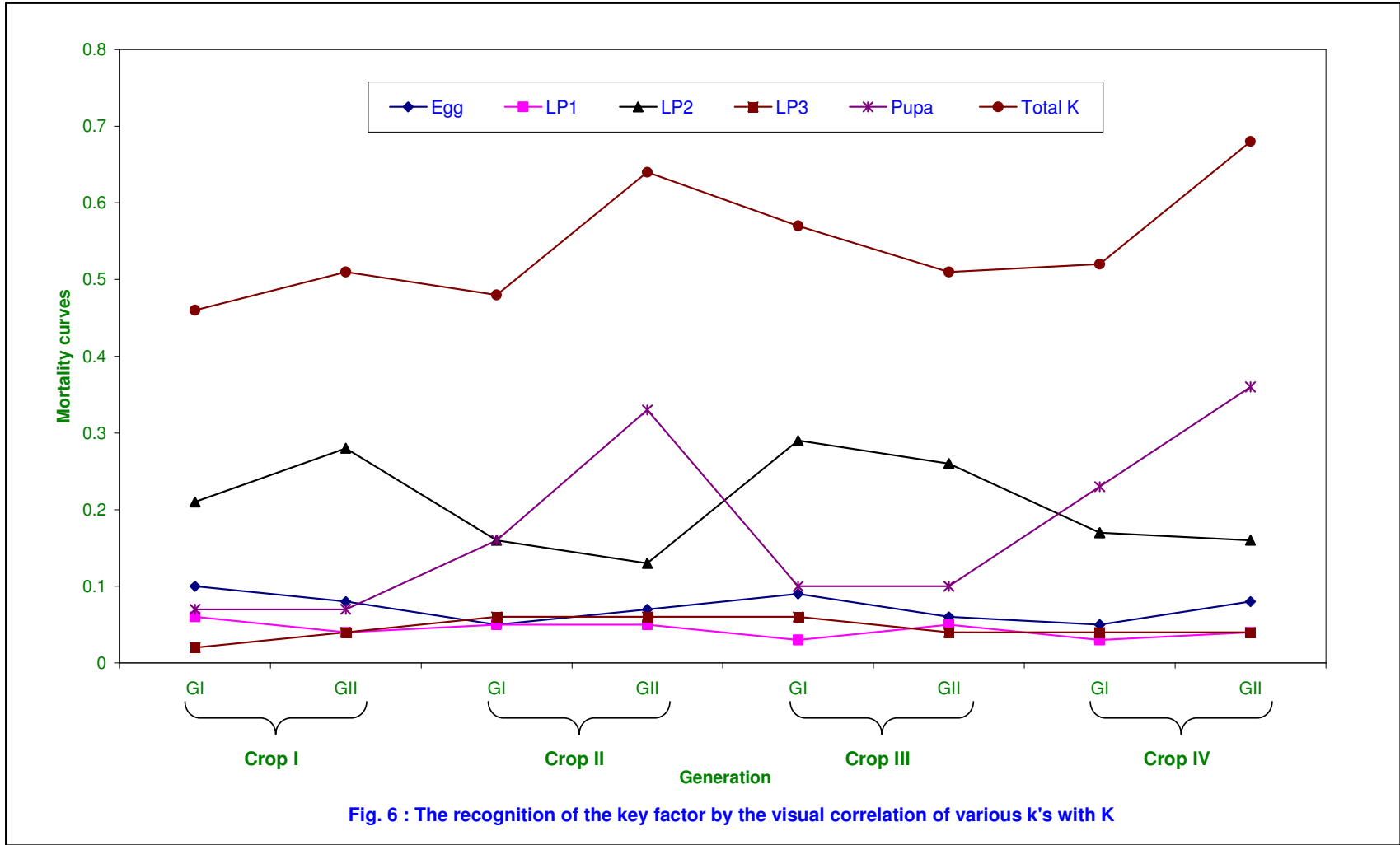


Fig. 6 : The recognition of the key factor by the visual correlation of various k's with K

Table 18 : Effect of organic amendments and spray sequence on *P. xylostella* population in cabbage

Treatments	Larvae/plant											
	2005						2006					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	1.30dc (1.34)	2.93bcd (1.85)	2.90cde (1.84)	2.83cde (1.75)	2.73de (1.793)	2.54de	1.47cd (1.38)	2.50bc (1.73)	2.50bc (1.73)	2.47cd (1.72)	2.37cd (1.69)	2.26bc
T ₂ – Vermicompost 2.5 t/ha- SS	1.07c (1.25)	2.63ab (1.77)	2.63bcd (1.78)	2.57bcd (1.75)	2.47cd (1.72)	2.27cd	0.77bc (1.12)	2.20b (1.64)	2.13b (1.62)	2.07bc (1.60)	1.97bc (1.57)	1.83b
T ₃ – Neem cake 250kg/ha- SS	0.57b (1.03)	2.37ab (1.69)	2.27abc (1.66)	2.17bc (1.63)	1.97bc (1.57)	1.87bc	0.67b (1.07)	1.93ab (1.56)	1.87ab (1.54)	1.80bc (1.52)	1.70abc (1.48)	1.59ab
T ₄ – Neem cake 500kg/ha –SS	0.47b (0.98)	2.10ab (1.61)	2.03ab (1.59)	2.00ab (1.58)	1.77ab (1.50)	1.67ab	0.37ab (0.93)	1.80ab (1.52)	1.70ab (1.48)	1.60ab (1.45)	1.47ab (1.40)	1.39ab
T ₅ – Pongamia cake 250 kg/ha- SS	2.30c (1.67)	3.70de (2.04)	3.63ef (2.03)	3.50e (2.00)	3.37ef (1.16)	3.30e	2.13d (1.62)	3.47de (1.99)	3.47cd (1.99)	3.43de (1.98)	3.33e (1.95)	3.17de
T ₆ – Pongamia cake 500 kg/ha – SS	1.47c (1.40)	3.43cd (1.98)	3.37de (1.96)	3.30de (1.95)	3.10de (1.90)	2.93de	1.90d (1.54)	3.23cd (1.93)	3.20cd (1.92)	3.20de (1.92)	3.13de (1.90)	2.93cd
T ₇ – Poultry manure 1 t/ha- SS	3.57de (2.02)	5.33f (2.42)	5.37g (2.42)	5.33f (2.42)	4.83g (2.31)	4.89g	3.83 ^e (2.08)	5.07f (2.36)	5.33de (2.41)	5.30f (2.41)	5.17g (2.28)	4.94f
T ₈ – Poultry manure 2 t /ha- SS	2.90de (1.84)	4.53ef (2.24)	4.53fg (2.04)	4.50f (2.23)	4.20fg (2.16)	4.13fg	3.13 ^e (1.90)	4.20ef (2.17)	4.20de (2.16)	4.00e (2.12)	3.93e (2.10)	3.89ef
T ₉ – Recommended package of practice	0.10 ^a (0.77)	1.83 ^a (1.53)	1.67 ^a (1.47)	1.47 ^a (1.39)	1.23 ^a (1.31)	1.26^a	0.10 ^a (0.77)	1.37 ^a (1.36)	1.23 ^a (1.31)	1.07a (1.25)	1.03a (1.23)	0.96a
T ₁₀ – Untreated check	5.07f (2.35)	6.60g (2.65)	8.33h (2.96)	11.63g (3.48)	12.17h (3.55)	8.76h	6.13f (2.57)	6.67g (2.67)	7.97f (2.90)	10.37g (3.29)	12.53g (3.60)	8.73g

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%) DAT – Days after transplanting SS – Spray Sequence

Table 19 : Effect of organic amendments and spray sequence on *P. xylostella* population in cabbage (pooled data of two years)

Treatments	Larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	1.38de (1.37)	2.72d (1.79)	2.70d (1.79)	2.65d (1.77)	2.55abc (1.74)	2.40d
T ₂ – Vermicompost 2.5 t/ha- SS	0.92cd (1.19)	2.42cd (1.71)	2.38cd (1.69)	2.32cd (1.68)	2.22abc (1.65)	2.05cd
T ₃ – Neem cake 250kg/ha- SS	0.62bc (1.05)	2.15ab (1.63)	2.07bc (1.60)	1.98bc (1.58)	1.83ab (1.53)	1.73ab
T ₄ – Neem cake 500kg/ha –SS	0.42ab (0.95)	1.95ab (1.56)	1.87b (1.54)	1.80b (1.52)	1.62ab (1.46)	1.53ab
T ₅ – Pongamia cake 250 kg/ha – SS	2.22f (1.65)	3.58e (2.02)	3.55e (2.01)	3.47e (1.99)	3.35bcd (1.96)	3.23ef
T ₆ – Pongamia cake 500 kg/ha – SS	1.68ef (1.47)	3.33e (1.96)	3.28e (1.94)	3.25e (1.94)	3.12bc (1.90)	2.93e
T ₇ – Poultry manure 1 t/ha- SS	3.70g (2.05)	5.20g (2.39)	5.35g (2.42)	5.32g (2.41)	5.00d (2.34)	4.91g
T ₈ – Poultry manure 2 t /ha- SS	3.02g (1.87)	4.37f (2.20)	4.37f (2.20)	4.25f (2.18)	4.07cd (2.14)	4.01f
T ₉ – Recommended package of practice	0.10a (0.77)	1.60a (1.45)	1.45a (1.40)	1.27a (1.33)	1.13a (1.27)	1.11a
T ₁₀ – Untreated check	5.60h (2.46)	6.63h (2.67)	8.15h (2.94)	11.00h (3.93)	12.35e (3.58)	8.75h

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

DAS – Days after spray SS _ Spray Sequence

The results on the effect of organic soil amendments on activity of diamondback moth, tobacco caterpillar and cabbage leaf webber, in general indicated the effectiveness of organics in suppressing the pest activity vis-à-vis comparison treatment. The details are presented here under.

4.2.1.1 Diamondback moth (*Plutella xylostella*)

The larval density of *P. xylostella* recorded at varied intervals during 2005 and 2006 is given in Table 18.

At 15 days after transplanting, significantly less larval density (0.47 larvae/plant) was registered in T₄ (NC 500- SS). This was followed by T₃ (NC 250- SS) with 0.57 larvae/plant which was found to be on par with T₄. Next best treatments to follow these were T₂ (1.07 larvae/plant), T₁ (1.30 larvae/plant) and T₆ (1.47 larvae/plant). All the treatments were superior over control which supported a significantly higher larval density on the crop and were inferior to the standard check (RPP).

At 30 days after transplanting (DAT), larval density as influenced by various treatments ranged from 1.83 to 6.6 larvae/plant. Treatments T₃, T₄ and T₂ followed T₉ (RPP) in registering low larval density and were on par with each other (2.10, 2.37 and 2.63 larvae/plant, respectively). Treatment with VC 1250 –SS, was next to follow the treatments with neem cake application. In rest of the treatment the larval density ranged from 3.43 to 6.6 larvae/plant with significantly higher larval load in control (6.6 larvae/plant).

At 45 DAT, larval number ranged from 1.67 to 8.33 larvae/plant. NC 500- SS and NC 250-SS were found to be highly promising against DBM by recording least larval population of 2.27 and 2.63 per plant, respectively. These were found to be on par with RPP which recorded 1.67 larvae/plant. The trend of treatment significance for other intervention was same as that of 30 DAT.

At 60 DAT, treatment with NC-500-SS was found to be significantly superior than rest of the treatments, by recording lowest larval density. And this was comparable with RPP. NC-250-SS, VC-2500-SS were next best followed by VC-1250-SS, PC-500-SS, PC-250-SS, PM-2000-SS and PM-1000-SS which were found to be significantly superior to control.

Similarly at 75 DAT also T₄ (NC-500-SS) maintained its supremacy, followed by NC-250-SS and VC-2500-SS. At this interval of observation treatments with poultry manure were found to be least effective.

Mean larval population also revealed similar trend of treatment significance against *P. xylostella* and it was of the order, T₄ < T₃ < T₂ < T₁ < T₆ < T₄ < T₈ < T₇ among the treatments with application of organic soil amendments. T₄ was found to be significantly superior to rest of the treatments and was on par with RPP.

Larval density of diamondback moth as influenced by different treatments during 2006 are also presented in Table 18.

The DBM population was slightly more during 2006 compared to previous year with mean population varying from 0.96 to 8.73 larvae/plant. The larval density of DBM at all the intervals of observations exhibited similar trend as in the case of 2005. The mean data revealed superiority of T₃ and T₄ which were comparable to RPP. All the treatments were found to be significantly superior over control which harbored higher larvae per plant.

Pooled data of two years has been presented in table 19. At all the intervals of observation treatments with NC (T₃ and T₄) were found to be most effective which recorded least larval population and were comparable with T₉ (RPP). UTC was found to have highest larval population. Among rest of the treatments VC-2500-SS was significantly superior at all the intervals followed by VC-1250-SS. However, at 75 DAT all the treatments with NC-SS and VC-SS were found to be on par with each other. Treatments including PC-SS were next in the order of efficacy. The mean values revealed the superiority of treatments in the order of T₄ = T₃ > T₂ = T₁ > T₆ > T₅ > T₈ > T₇ > T₁₀ which reiterated the result of two years of experimentation.

4.2.1.2 Tobacco caterpillar (*S. litura*)

During first year of study (2005), significantly less number of *S. litura* larvae per plant was noticed in T₄ (0.1/plant) at 15 DAT followed by T₃ (1.17) and T₂ (0.23). These were found to be on par with each other and were comparable with the standard check T₉ (Table 20).

Table 20 : Effect of organic amendments and spray sequence on *Spodoptera litura* population in cabbage

Treatments	Larvae/plant											
	2005						2006					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	0.30bc (0.89)	0.63bc (1.67)	1.57cd (1.44)	1.47cd (1.40)	1.33c (1.35)	1.06cd	0.47ab (0.98)	1.33b (1.35)	2.33b (1.68)	1.83b (1.52)	1.57bcd (1.42)	1.51cd
T ₂ – Vermicompost 2.5 t/ha- SS	0.23ab (0.86)	0.50abc (1.00)	1.33bc (1.35)	1.20bc (1.30)	0.80b (1.14)	0.81bc	0.43ab (0.96)	1.30b (1.33)	2.17b (1.63)	1.67b (1.46)	1.10bc (1.25)	1.33bc
T ₃ – Neem cake 250kg/ha- SS	0.17ab (0.82)	0.37ab (0.93)	1.13bc (1.27)	1.03abc (1.23)	0.67ab (1.08)	0.67ab	0.37ab (0.93)	1.13ab (1.27)	2.03b (1.59)	1.50b (1.41)	0.90ab (1.18)	1.19bc
T ₄ – Neem cake 500kg/ha –SS	0.10a (0.77)	0.33ab (0.91)	0.93ab (1.19)	0.83ab (1.15)	0.53ab (1.02)	0.55ab	0.23a (0.85)	0.97ab (1.21)	1.80b (1.50)	1.37b (1.36)	0.80ab (1.13)	1.03ab
T ₅ – Pongamia cake 250 kg/ha-SS	0.43cd (0.96)	1.13d (1.27)	2.47ef (1.72)	2.37ef (1.69)	2.10de (1.61)	1.70e	0.87bc (1.16)	2.47c (1.72)	3.43cd (1.98)	2.93cd (1.85)	2.43de (1.71)	2.43ef
T ₆ – Pongamia cake 500 kg/ha – SS	0.33bc (0.91)	0.93cd (1.19)	2.03de (1.59)	2.03de (1.59)	1.83cd (1.52)	1.43e	0.80bc (1.14)	1.50b (1.41)	2.60bc (1.76)	2.07bc (1.60)	1.77cd (1.50)	1.75de
T ₇ – Poultry manure 1 t/ha- SS	0.80e (1.13)	1.93e (1.56)	2.97f (1.86)	2.90e (1.84)	2.80d (1.81)	2.28g	1.60de (1.45)	3.17cd (1.91)	4.53d (2.24)	4.17e (2.61)	3.93f (2.10)	3.48f
T ₈ – Poultry manure 2 t /ha- SS	0.60de (1.05)	1.67e (1.47)	2.80f (1.81)	2.77ef (1.80)	2.67ef (1.77)	2.10f	1.23cd (1.31)	2.80c (1.81)	4.17d (2.16)	3.77de (2.06)	3.17ef (1.91)	3.03f
T ₉ – Recommended package of practice	0.07a (0.75)	0.23a (0.86)	0.57a (1.03)	0.53a (1.01)	0.30a (0.89)	0.34a	0.17a (0.82)	0.67a (1.08)	0.90a (1.16)	0.53a (1.01)	0.20a (0.83)	0.49a
T ₁₀ – Untreated check	1.53f (1.42)	2.93f (1.84)	4.93g (2.32)	6.83g (2.70)	7.47g (2.82)	4.74h	2.10e (1.60)	3.93d (2.10)	7.00e (2.73)	7.73f (2.86)	8.97g (3.07)	5.95g

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%) DAT – Days after transplanting SS _ Spray Sequence

Among rest of the treatments VC-1250-SS and PC-2000-SS were superior and were on par. All the treatments recorded significantly lower larval population density compared to control.

At 30 DAT, T_4 , T_3 and T_2 excelled over rest of the treatments by registering 0.33, 0.37 and 0.50 larvae/plant, respectively. These were followed by T_1 (VC-1250-SS) (0.63 larvae/plant). Treatments in the order of efficacy were T_6 (PC-500-SS) and T_5 (PC-250-SS).

At 45 DAT, NC 500-SS was significantly superior treatment followed by NC-250-SS and VC-2500-SS. Next in the order of efficacy was VC-1250 SS. At 60 DAT the order of efficacy of treatments were as follows $T_4 = T_3 > T_2 > T_1 > T_6 > T_5 = T_8 = T_7 > T_{10}$. However, at 75 DAT similar trend as that of 15 DAT was followed. Mean values also indicated similar pattern of performance of amendments.

During 2006, similar trend was followed at all the intervals of observations except at 45 and 60 DAT where in all the treatments with neem cake and vermicompost application were significantly superior over rest of the treatments, but were inferior to RPP. In all cases UTC registered highest pest population. However, observation at 75 DAT and mean values reiterated the results of 2005.

Pooled data on effect of organic amendments and spray sequence has been presented in table 21. Pooled data revealed similar trend as that of first year results, at all the intervals of observations.

4.2.1.3 Leaf webber (*Crocidolomia binotalis*)

At 15 DAT, NC-500-SS and NC-250-SS recorded significantly lowest leaf webber population (0.17 and 0.27 larvae/plant) and were on par with RPP (0.07 larvae/plant) (Table 22). VC-1250-SS and VC-2500-SS were next follow the treatments with NC-SS. Untreated control at all the intervals of observations recorded highest larval load per plant and was inferior to rest of the treatments.

However, at 30 DAT, all the treatments were found to be on par with each other. At 45 DAT, NC-500-SS was found to as effective as RPP by having recorded (0.77 larvae/plant). This was followed by NC-250-SS and VC-2500-SS which were on par with each other. For rest of the treatments, the values ranged from 0.90 to 2.77 larvae/plant. At 60 DAT there was slight increase in the larval numbers with similar trend as in case of 45 DAT. However, at 75 DAT the larval population in all the treatments reduced when compared to 60 DAT with NC-500-SS maintaining its supremacy by recording least larval number (0.33/plant) followed by NC-250-SS. Next best treatment was VC-2500-SS, VC-1200-SS followed by PC-2000-SS and PC-1000-SS, which were on par with each other. The mean values of larval numbers density during 2005 exhibited the pattern of $T_4 < T_3 = T_2 = T_1 < T_6 < T_5 < T_8 = T_7 < T_{10}$.

The values on the larval population during 2006 had quite different trend when compared to the previous year. At 15 DAT all the treatments were found to be statistically on par with each other. However, at 30 DAT, NC-500-SS and NC-250-SS registered least larval population and were comparable to RPP. These were followed by VC-2500-SS with (1.43 larvae/plant) and VC-1250-SS with (1.83 larvae/plant). Treatments with pongamia cake were next to follow the treatments with \square ermin compost. Among the remaining treatments larval density ranged between 2.6 to 3.00 larvae per plant, with significantly higher larval load in control (4.23). At 45 DAT, larval density ranged from 0.83 to 5.20. NC 500- SS was found to be highly promising against *C. binotalis* by recording least larval population of 1.33 larvae per plant which was comparable to RPP. The trend of treatment significance for other intervention were similar to that of 30 DAT.

At 60 DAT, NC-500-SS maintained its superiority which was followed by, NC-250-SS, VC-2500-SS, VC-1250-SS, PC-500-SS, PC-250-SS, PM-2000-SS and PM-1000-SS. These were found to be significantly superior over control by recording low larval density.

Similarly at 75 DAT also NC-500-SS maintained its supremacy which was comparable with RPP. NC-250-SS was found to be on par with NC-500-SS. At this interval of observation also PM-2000-SS and PM-1000-SS were found to be least effective.

Whereas in the pooled data (Table 23) at 15 DAT all the treatments were found to be on par with each other except PM-1000-SS. NC-500-SS recorded least number of larva per plant and UTC with highest larval number. In rest of the intervals of observations including the mean value similar trend was noticed as in 2006.

Table 21 : Effect of organic amendments and spray sequence on *S. litura* population in cabbage (pooled data)

Treatments	Larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	0.38bcd (0.94)	0.98bc (1.21)	1.95ab (1.57)	1.65cd (1.47)	1.45c (1.39)	1.28c
T ₂ – Vermicompost 2.5 t/ha- SS	0.33abc (0.91)	0.90bc (1.18)	1.75ab (1.50)	1.43bc (1.39)	0.95b (1.20)	1.07bc
T ₃ – Neem cake 250kg/ha- SS	0.27abc (0.88)	0.75ab (1.12)	1.58ab (1.44)	1.27bc (1.32)	0.78b (1.13)	0.93ab
T ₄ – Neem cake 500kg/ha –SS	0.17ab (0.82)	0.65ab (1.07)	1.37ab (1.36)	1.10ab (1.26)	0.67ab (1.08)	0.79ab
T ₅ – Pongamia cake 250 kg/ha- SS	0.65de (1.07)	1.80d (1.51)	2.95ab (1.85)	2.65ef (1.77)	2.27d (1.66)	2.06de
T ₆ – Pongamia cake 500 kg/ha – SS	0.57cde (1.03)	1.22 ^e (1.31)	2.32abc (1.68)	2.05de (1.60)	1.80cd (1.52)	1.59cd
T ₇ – Poultry manure 1 t/ha- SS	1.20f (1.30)	2.55 ^e (1.74)	3.75bc (2.06)	3.53g (2.01)	3.37 ^e (1.97)	2.88^e
T ₈ – Poultry manure 2 t /ha- SS	0.92ef (1.18)	2.23de (1.65)	3.48bc (2.00)	3.27fg (1.94)	2.92e (1.85)	2.56e
T ₉ – Recommended package of practice	0.12a (0.78)	0.45a (0.97)	0.73a (1.11)	0.53a (1.02)	0.25a (0.87)	0.42a
T ₁₀ – Untreated check	1.82g (1.51)	3.43f (1.97)	5.97c (2.53)	7.28h (2.78)	8.22f (2.95)	5.34g

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%) DAT – Days after transplanting SS _ Spray Sequence

Table 22 : Effect of organic amendments and spray sequence on *Crocidolomia binotalis* population in cabbage

Treatments	Larvae/plant											
	2005						2006					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	0.30b (0.89)	0.40a (0.94)	0.93c (1.19)	1.30bcd (1.34)	0.83c (1.15)	0.94bc	1.33a (1.35)	1.83cde (1.53)	2.27cde (1.66)	2.37cde (1.69)	1.90cd (1.55)	1.75c
T ₂ – Vermicompost 2.5 t/ha- SS	0.30b (0.89)	0.37a (0.93)	0.90c (1.18)	1.20bc (1.30)	0.80c (1.14)	0.93bc	1.37a (1.36)	1.43bcd (1.37)	1.83bcd (1.53)	1.93bcd (1.56)	1.43bc (1.39)	1.39bc
T ₃ – Neem cake 250kg/ha- SS	0.27ab (0.87)	0.37a (0.91)	0.83bc (1.15)	1.17bc (1.29)	0.67bc (1.08)	0.88b	1.23a (1.31)	1.47abc (1.38)	1.67bc (1.46)	1.73bcd (1.49)	0.93ab (1.19)	1.19ab
T ₄ – Neem cake 500kg/ha –SS	0.17ab (0.82)	1.10a (1.15)	0.47ab (0.98)	0.77ab (1.13)	0.33ab (0.91)	0.62ab	0.93a (1.19)	1.37ab (1.31)	1.33ab (1.35)	1.40ab (1.37)	0.63a (1.06)	1.08ab
T ₅ – Pongamia cake 250 kg/ha- SS	0.57cd (1.02)	0.53a (1.01)	1.53d (1.42)	1.87de (1.53)	1.47de (1.39)	1.35d	1.33a (1.35)	2.23ef (1.65)	2.63def (1.77)	2.77def (1.81)	2.27cd (1.66)	2.09de
T ₆ – Pongamia cake 500 kg/ha – SS	0.40bc (0.95)	0.43a (0.96)	1.20cd (1.30)	1.67cd (1.47)	1.20cd (1.29)	1.14cd	1.23a (1.31)	1.97de (1.57)	2.43cde (1.71)	2.47cde (1.72)	2.07cd (1.60)	1.87cd
T ₇ – Poultry manure 1 t/ha- SS	1.07e (1.25)	1.03a (1.20)	2.13ef (1.62)	2.70f (1.79)	2.37f (1.69)	2.01ef	1.77a (1.47)	3.00f (1.87)	3.70f (2.05)	3.83f (2.08)	3.43c (1.98)	3.00e
T ₈ – Poultry manure 2 t /ha- SS	0.70d (1.09)	0.73a (1.09)	1.63de (1.46)	2.33ef (1.68)	1.93f (1.56)	1.63e	1.57a (1.43)	2.60ef (1.76)	3.13ef (1.90)	3.30ef (1.95)	2.83de (1.82)	2.52d
T ₉ – Recommended package of practice	0.07a (0.75)	0.37a (0.89)	0.37a (0.93)	0.40a (0.94)	0.20a (0.83)	0.43a	0.77a (1.12)	1.13a (1.23)	0.83a (1.13)	0.80a (1.11)	0.40a (0.93)	0.63a
T ₁₀ – Untreated check	1.73f (1.49)	1.80a (1.83)	2.77f (1.79)	6.00g (2.54)	4.27h (2.17)	3.55g	2.97a (1.74)	4.23g (2.17)	5.20g (2.38)	6.30g (2.60)	5.63f (2.47)	4.63g

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%) DAT – Days after transplanting SS _ Spray Sequence

Table 23: Effect of organic amendments and spray sequence on *C.binotalis* population in cabbage (pooled data)

Treatments	Larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	0.35ab (0.92)	1.38c (1.37)	1.80abc (1.51)	1.83bcd (1.53)	1.37bcd (1.36)	1.35cd
T ₂ – Vermicompost 2.5 t/ha- SS	0.33ab (0.91)	1.13b (1.27)	1.63abc (1.45)	1.57abc (1.44)	1.12abcd (1.27)	1.16bc
T ₃ – Neem cake 250kg/ha- SS	0.32ab (0.91)	1.03b (1.23)	1.57ab (1.43)	1.45abc (1.39)	0.80abc (1.13)	1.03bc
T ₄ – Neem cake 500kg/ha –SS	0.63ab (1.02)	0.70a (1.09)	1.35ab (1.34)	1.08ab (1.25)	0.48ab (0.99)	0.85ab
T ₅ – Pongamia cake 250 kg/ha- SS	0.55ab (1.02)	1.88de (1.54)	1.98bc (1.57)	2.32bcd (1.68)	1.87cde (1.54)	1.72d
T ₆ – Pongamia cake 500 kg/ha – SS	0.42ab (0.96)	1.58cd (1.45)	1.83abc (1.53)	2.07bc (1.60)	1.63cde (1.46)	1.51cd
T ₇ – Poultry manure 1 t/ha- SS	1.05bc (1.24)	2.57f (1.75)	2.73c (1.79)	3.27d (1.94)	2.90e (1.84)	2.50ef
T ₈ – Poultry manure 2 t /ha- SS	0.72ab (1.10)	2.12e (1.62)	2.35bc (1.68)	2.82cd (1.82)	2.38ab (1.70)	2.08e
T ₉ – Recommended package of practice	0.22a (0.83)	0.57a (1.03)	0.98a (1.21)	0.60a (1.04)	0.30a (0.89)	0.53a
T ₁₀ – Untreated check	1.77c (1.49)	3.50g (2.00)	4.08d (2.13)	6.15e (2.58)	4.95f (2.33)	4.09g

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

DAT – Days after transplanting SS _ Spray Sequence

Table 24 : Yield and cost economics as influenced by different organic amendments and spray sequence

Treatment	Yield (t/ha)		Yield pooled (t/ha)	Net returns (Rs.)	Incremental returns (Rs.)	Treatment cost (Rs.)	IBCR
	2005	2006					
T ₁ – Vermicompost 1.25 t/ha-SS	14.83cd	14.24cde	14.54e	24350	19100	4200	4.54
T ₂ – Vermicompost 2.5 t/ha- SS	16.61bc	15.90bc	16.26cd	28650	23400	5450	4.29
T ₃ – Neem cake 250kg/ha- SS	18.11ab	16.57abc	17.34bc	31350	26100	3950	6.60
T ₄ – Neem cake 500kg/ha –SS	19.60ab	18.19ab	18.90ab	35250	30000	4950	6.06
T ₅ – Pongamia cake 250 kg/ha- SS	13.63de	13.90cde	13.76ef	22400	17150	5200	3.30
T ₆ – Pongamia cake 500 kg/ha – SS	15.47cd	14.87cd	15.17de	25925	20675	7450	2.78
T ₇ – Poultry manure 1 t/ha- SS	11.37ef	11.74de	11.56fg	16900	11650	3950	2.35
T ₈ – Poultry manure 2 t /ha- SS	12.67de	12.00e	12.33g	18825	13575	4950	2.74
T ₉ –Recommended package of practice	19.61a	19.20a	19.41a	36525	31275	4523	6.91
T ₁₀ – Untreated check	7.41f	6.40f	6.90h	5250	-	-	-

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

SS – Spray sequence

Table 25 : Effect of organic amendments and spray sequence on *Cotesia plutellae* population in cabbage

Treatments	No. of cocoons /10 plants											
	2005						2006					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	8.00d (2.92)	9.67c (3.19)	12.67de (3.62)	12.00d (3.53)	5.67d (2.48)	9.60bc	11.33de (3.44)	13.33de (3.72)	15.67cde (4.02)	12.33d (3.58)	8.33def (2.97)	12.20c
T ₂ – Vermicompost 2.5 t/ha- SS	8.00d (2.92)	9.00c (3.08)	12.00 ^e (3.53)	11.33d (3.43)	5.00de (2.35)	9.07bc	10.67de (3.34)	13.33de (3.72)	15.00def (3.94)	11.67de (3.49)	7.67efg (2.86)	11.67cd
T ₃ – Neem cake 250kg/ha- SS	8.00d (2.92)	9.00c (3.08)	10.67ef (3.34)	10.33de (3.28)	4.33de (2.19)	8.47c	10.33e (3.29)	13.00de (3.67)	14.00ef (3.81)	10.67ef (3.34)	7.00fg (2.74)	11.00cd
T ₄ – Neem cake 500kg/ha –SS	7.33d (2.80)	8.33c (2.97)	9.67f (3.18)	9.00c (3.08)	3.67e (2.04)	7.60c	10.33e (3.29)	12.00e (3.54)	13.33f (3.72)	10.33fg (3.29)	6.33g (2.61)	10.47d
T ₅ – Pongamia cake 250 kg/ha-SS	9.33c (3.13)	11.67b (2.49)	15.33c (3.98)	15.33c (3.98)	9.33c (3.13)	12.20b	12.67bc (3.63)	15.67de (4.02)	17.67c (4.26)	13.00cd (3.69)	9.67cd (3.19)	13.73bc
T ₆ – Pongamia cake 500 kg/ha – SS	9.00c (3.08)	11.33b (2.44)	14.33cd (3.85)	14.00c (3.81)	8.00c (2.19)	11.33b	11.67cd (3.49)	14.00cd (3.81)	16.00cd (4.06)	12.67d (3.63)	8.67de (3.03)	12.60bc
T ₇ – Poultry manure 1 t/ha- SS	10.67ab (3.34)	14.67a (3.10)	18.67b (4.38)	18.33b (4.34)	12.00ab (3.53)	14.87b	13.67ab (3.76)	16.67ab (4.14)	20.00b (4.53)	15.00b (3.94)	11.67b (3.49)	15.40b
T ₈ – Poultry manure 2 t /ha- SS	10.33b (3.29)	12.33b (3.58)	15.67c (4.08)	15.33c (3.98)	10.00bc (3.24)	12.73b	13.33b (3.72)	15.67bc (4.02)	17.67c (4.26)	14.33bc (3.85)	10.33bc (3.29)	14.27b
T ₉ – Recommended package of practice	6.33e (2.61)	5.67d (2.48)	6.00g (2.55)	6.33f (2.61)	1.67f (1.46)	5.20g	9.00f (3.08)	7.67f (2.85)	8.33g (2.97)	9.33g (3.13)	3.00h (1.86)	7.47g
T ₁₀ – Untreated check	11.33a (3.44)	15.67a (4.02)	21.67a (4.71)	20.67a (4.60)	14.33a (3.85)	16.73a	14.67a (3.90)	18.33a (4.34)	24.67a (5.02)	26.33a (5.18)	15.33a (3.97)	19.87a

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

DAS – Days after spray SS _ Spray sequence

Table 26 : Effect of organic amendments and spray sequence on *C. plutellae* population in cabbage (pooled data)

Treatments	No. Of Cocoons/10 plants					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
T ₁ – Vermicompost 1.25 t/ha-SS	9.67cde (3.19)	11.50de (3.46)	13.83de (3.78)	12.50ef (3.61)	7.00 ^e (2.74)	10.90c
T ₂ – Vermicompost 2.5 t/ha- SS	9.33deg (3.13)	11.17ef (3.42)	13.17ef (3.70)	11.83f (3.51)	6.33ef (2.62)	10.37cd
T ₃ – Neem cake 250kg/ha- SS	9.17def (3.11)	11.00ef (3.39)	12.17fg (3.56)	10.67g (3.34)	5.67fg (2.48)	9.73cd
T ₄ – Neem cake 500kg/ha –SS	8.83ef (3.05)	10.17f (3.27)	11.17g (3.42)	10.00g (3.24)	5.00g (2.35)	9.03d
T ₅ – Pongamia cake 250 kg/ha- SS	11.00abcd (3.39)	13.67bc (3.76)	16.50c (4.12)	14.17cd (3.83)	9.50c (3.16)	12.97bc
T ₆ – Pongamia cake 500 kg/ha – SS	10.33bcde (3.29)	12.67cd (3.63)	15.00d (3.94)	13.50de (3.74)	8.33d (2.97)	11.97c
T ₇ – Poultry manure 1 t/ha- SS	12.17ab (3.56)	15.67a (4.02)	19.17b (4.43)	16.83b (4.16)	11.83b (3.51)	15.13b
T ₈ – Poultry manure 2 t /ha- SS	11.83abc (3.51)	14.00b (3.81)	16.50c (4.12)	15.00c (3.94)	10.17c (3.27)	13.50b
T ₉ – Recommended package of practice	7.67f (2.86)	6.67g (2.68)	7.33h (2.80)	7.67h (2.86)	2.33h (1.68)	6.33f
T ₁₀ – Untreated check	13.00a (3.67)	17.00a (4.18)	22.67a (4.81)	24.00a (4.95)	14.83a (3.91)	18.30a

Figures in parantheses are square root transformed values ($\sqrt{x+0.5}$)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

DAT – Days after transplanting SS _ Spray Sequence

4.2.1.4 Yield

Treatment effect was manifested on yield in both the years of study

The pooled data of yield indicate significantly higher yield of cabbage in the treatment with NC-500-SS (18.9 t/ha) which was as good as RPP (19.41 t/ha). This was followed by application of NC-250-SS (17.34 t/ha). While others were next in the order, significantly less yield (6.9 t/ha) was recorded in control (Table 24).

4.2.1.5 Cost effectiveness

Cost effectiveness of each treatments could be analyzed based on benefit cost ratio. Among the treatments maximum B:C ratio was recorded in NC-250-SS (6.6) which was next best to RPP (6.91). NC-500-SS (6.06) was next in the order where as, lowest IBCR was recorded by PM-1-SS (2.35). However, rest of the treatments recorded moderate IBCR ranging between 2.74 and 4.54. But highest net returns was recorded by NC-500-SS (Rs. 35,250) which was next to RPP [Rs. 36,525]. This was followed by NC-250-SS (Rs. 31,350). Where as lower net returns was recorded by control (Rs. 5,250). However, rest of the treatments T_7 T_8 T_5 T_6 , T_1 and T_2 recorded net returns ranging from Rs. 16,900 to Rs. 28,650.

4.2.1.6 Effect on larval parasitoid of DBM (*Cotesia plutellae*)

During 2005, at 15 DAT, UTC recorded highest number of parasitoid cocoons (11.33/10 plants). Least was observed in case of RPP (6.33/10 plants) (Table 25). Rest of the treatments had values ranging between 7.33 to 10.33 cocoons/10 plants.

At 30 DAT the parasitoid population increased in all the treatments following similar trend of superiority of the treatments with respect to number of parasitoid cocoons. The number continued to increase even at 45 DAT with UTC maintaining supremacy of having maximum number of parasitoid cocoons compared to other treatments followed by PM 1t-SS > PM 2t-SS = PC 250-SS > PC-500-SS > VC-1250-SS > VC-2500-SS > NC-250-SS > NC-500-SS > RPP. However there was reduction on the number of parasitoid cocoons at 60 and 75 DAT owing to the reduced number of host larvae. But similar trend was maintained at all the intervals of observations. The mean data also revealed the supremacy of UTC in recording highest number of larval parasitoid cocoons followed by $T_7 > T_8 > T_5 > T_6 > T_1 > T_2 > T_3 > T_4 > T_9$.

During 2006 the parasitoid numbers varied between 7.47 to 19.87. Lowest parasitoid population was recorded in RPP (7.47). Significantly highest population (19.87) was registered in control, whereas remaining treatments exhibited moderate activity of the parasitoid. At all the intervals of observations the effect of different treatments on the larval endoparasitoid was similar as that of previous year. Pooled data (Table 26) also revealed similar pattern of treatment significance, which was in the order of $T_{10} > T_7 > T_8 > T_5 > T_6 > T_1 > T_2 > T_3 > T_4 > T_9$ in having the number of parasitoid.

4.2.2 Evaluation of ecofriendly insecticides

Eight ecofriendly insecticides along with malathion as chemical check and an untreated control were screened for their efficacy to control diamondback moth in two consecutive years (2005 and 2006). Effect of these insecticides on the larval load of tobacco caterpillar, cabbage leaf webber and one natural enemy of DBM *Cotesia plutellae* have also been recorded.

4.2.2.1 Diamondback moth (*Plutella xylostella* L.)

Field experiments were carried out for two years to evaluate the efficacy of botanicals and microbial based new insecticide molecules. Treatments were imposed in the experimental area after larval buildup. Subsequent sprays were taken up at 10 days interval. Totally 4 sprays were given during the cropping season. Larval load was uniform (8.43 to 9.1) through out the field before initiation of spray during 2005 (Table 27). Variation in the larval density was recorded at 1, 3, 7 and 10 days after each of four sprays and the data analyzed for variance to discriminate the treatment effects is given in Table 27.

I spray

One day after application of insecticides, highest per cent larval reduction over pre treatment was observed in case of spinosad (61.15%) which was on par with emamectin benzoate (56.41%). This was followed by indoxacarb (48.11% reduction). Novaluron (30.16%) and Dipel (26.28%) were next in the order of efficacy and were on par with each

Table 27 : Bioefficacy of eco-friendly insecticides against *P. xylostella* on cabbage during 2005

Treatments	Dosage (g a.i/ha)	Per cent larval reduction over pre treatment								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	8.73a	61.15 a (51.45)	96.11a (79.43)	89.76a (71.69)	88.72a (70.82)	46.10a (42.75)	92.99a (75.98)	93.86a (75.69)	87.30a (70.46)
T ₂ – Emamectin benzoate 5 SG	7.5	9.10a	56.41a (48.69)	87.59a (74.24)	83.11a (66.13)	81.27a (65.58)	40.26ab (39.37)	88.04ab (70.06)	81.84ab (68.01)	75.70a (63.02)
T ₃ – Novaluron 10 EC	50	8.90a	30.16c (33.27)	40.31c (39.39)	69.30b (56.52)	67.80b (55.52)	33.26bc (35.19)	62.19c (52.15)	67.79c (55.47)	49.61b (44.77)
T ₄ – Indoxacarb 14.5 SC	35	8.97a	48.11b (43.91)	74.46b (60.03)	73.26b (59.07)	71.82b (58.10)	35.19bc (36.38)	80.16b (64.36)	79.11bc (62.94)	62.19b (52.07)
T ₅ – Bt (Dipel 8L)	60	9.00a	26.28cd (30.80)	34.55cd (35.97)	38.62c (38.39)	36.53c (37.14)	30.76c (33.65)	53.43cd (46.98)	45.93d (42.64)	33.44c (35.30)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	8.53a	7.82g (16.08)	11.94fg (20.21)	19.76d (26.37)	6.02f (14.18)	5.24e (13.10)	11.97f (20.24)	18.24fg (24.29)	5.99e (14.16)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	8.43a	13.36f (21.41)	22.18e (28.04)	19.09d (25.87)	14.81e (22.40)	12.78d (20.61)	31.50e (34.11)	28.39ef (32.05)	19.71d (26.32)
T ₈ – NSKE	5%	8.47a	22.01de (27.97)	28.09de (31.99)	28.13d (31.85)	26.42d (30.77)	28.85e (32.46)	44.51de (41.84)	36.59de (37.19)	27.94cd (31.91)
T ₉ – Malathion 50 EC	250	8.73a	18.63e (25.55)	24.88e (29.91)	23.17d (28.75)	21.60de (27.65)	10.17d (18.46)	40.92de (39.76)	29.87e (33.03)	25.23cd (30.14)
T ₁₀ – Untreated control	-	8.47a	-3.57h (-10.82)	-3.90g (-11.34)	-5.29e (- 13.05)	-7.02g (-15.07)	-4.18g (- 11.69)	-6.18g (-14.34)	-8.95g (-17.09)	-1.42f (- 6.79)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Contd....

Treatments	Dosage (g a.i/ha)	Per cent larval reduction over pre treatment							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	52.44a (46.44)	93.67a (75.99)	91.98a (74.76)	73.66a (59.13)	93.36a (76.21)	94.86a (77.84)	96.94a (81.77)	95.99a (81.69)
T ₂ – Emamectin benzoate 5 SG	7.5	45.57a (42.43)	85.82a (68.16)	82.59a (69.79)	65.53ab (54.11)	90.30a (71.89)	91.96a (73.73)	92.50a (74.48)	88.91a (73.70)
T ₃ – Novaluron 10 EC	50	26.68b (31.08)	62.34c (52.27)	68.08b (55.65)	45.42cd (42.36)	52.33bc (46.34)	74.32b (59.85)	77.90b (62.16)	54.38c (47.53)
T ₄ – Indoxacarb 14.5.SC	35	42.18a (40.44)	73.30b (59.47)	73.69b (49.42)	56.71bc (48.94)	60.18b (51.10)	83.19b (56.24)	81.11b (64.64)	80.12b (64.12)
T ₅ – Bt (Dipel 8L)	60	22.68b (28.35)	53.69cd (47.15)	50.63c (45.36)	39.13de (38.68)	46.63c (43.06)	61.44c (51.72)	51.67c (45.96)	44.09cd (41.60)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	6.98c (15.20)	10.22g (18.49)	25.19e (29.97)	6.21g (14.42)	10.37e (18.64)	33.79e (35.53)	32.98d (35.02)	27.21 ^e (31.37)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	14.14c (22.01)	23.10f (28.02)	33.00de (35.05)	14.26g (21.11)	27.24d (31.42)	35.87e (36.77)	39.70cd (39.03)	44.12cd (41.60)
T ₈ – NSKE	5%	14.11c (22.02)	45.96d (42.68)	42.13cd (40.46)	27.89ef (31.87)	33.27d (35.22)	50.55cd (45.31)	44.47cd (41.82)	39.10cde (38.7)
T ₉ – Malathion 50 EC	250	9.59c (17.89)	34.91e (36.19)	33.28de (35.23)	23.41f (28.93)	30.20d (33.33)	42.71de (40.79)	38.07d (38.09)	32.68de (74.85)
T ₁₀ – Untreated control	-	-8.81d (16.83)	-3.17h (- 9.82)	-6.43f (- 14.39)	-1.12i (-6.04)	-1.00f (-5.70)	-3.16f (-9.95)	-2.97e (9.52)	-5.41g (-13.40)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 28 : Bioefficacy of eco-friendly insecticides against *P. xylostella* on cabbage during 2006

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	8.50a	58.35a (49.81)	92.11a (74.01)	85.33a (67.56)	83.75a (66.27)	55.68a (48.29)	96.09a (78.78)	92.24a (74.46)	65.34a (53.94)
T ₂ – Emamectin benzoate 5 SG	7.5	8.33a	50.50a (46.28)	82.34a (69.23)	78.43a (62.51)	73.18a (62.86)	47.62ab (43.62)	88.11a (74.18)	88.04a (71.00)	59.74a (50.63)
T ₃ – Novaluron 10 EC	50	8.20a	30.06c (33.22)	40.27c (39.35)	60.18b (50.94)	58.58b (49.99)	33.38c (35.28)	51.72c (46.00)	67.03b (55.07)	35.15c (36.32)
T ₄ – Indoxacarb 14.5 SC	35	8.50a	41.95b (40.32)	68.06b (55.89)	66.65b (54.86)	63.52b (52.90)	43.26b (41.11)	73.35b (59.39)	74.55b (60.19)	45.77b (42.55)
T ₅ – Bt (Dipel 8L)	60	8.47a	21.55d (27.61)	30.01d (33.19)	35.38c (36.47)	40.22c (39.32)	26.43cd (30.90)	45.60c (42.46)	42.67c (40.76)	28.89cd (32.37)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	7.80a	15.55e (22.97)	15.66f (23.02)	17.40d (24.65)	6.25f (14.28)	7.89e (16.09)	19.66f (26.22)	23.79e (29.09)	14.72f (22.56)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	8.03a	15.54e (23.20)	18.26ef (25.29)	24.54d (29.33)	18.09e (25.12)	9.71e (18.15)	30.81e (33.69)	28.12de (32.00)	18.86ef (25.73)
T ₈ – NSKE	5%	8.37a	19.93de (26.49)	24.59de (29.70)	22.50d (28.28)	31.34d (34.00)	24.38d (29.51)	42.78cd (40.84)	38.70cd (38.43)	23.66de (29.07)
T ₉ – Malathion 50 EC	250	7.87a	18.45de (25.41)	21.98def (27.93)	21.18d (27.39)	22.75 ^e (28.46)	19.75d (26.04)	35.38de (36.49)	32.09def (34.49)	21.57e (27.65)
T ₁₀ – Untreated control	-	8.50a	-4.29f (- 11.89)	-3.84g (- 11.28)	-5.62e (-13.64)	-6.94g (- 15.23)	-2.89f (-9.74)	-6.24g (- 14.38)	-9.58f (- 17.92)	-1.53h (- 6.91)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Contd....

Treatments	Dosage (g a.i/ha)	Per cent larval reduction over pre treatment							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	47.24a (43.41)	98.46a (85.86)	94.75a (79.37)	68.93a (56.14)	98.96a (86.61)	97.33a (84.52)	97.33a (84.52)	96.00a (80.68)
T ₂ – Emamectin benzoate 5 SG	7.5	39.95ab (39.19)	92.10a (78.40)	90.21a (73.67)	65.11a (53.84)	90.47a (80.67)	89.47a (75.69)	91.58a (76.30)	87.30a (72.22)
T ₃ – Novaluron 10 EC	50	36.32bc (37.02)	55.84c (48.37)	69.80b (56.92)	41.10c (39.86)	53.70bc (47.15)	69.46bc (56.84)	77.76b (62.32)	64.98cd (53.93)
T ₄ – Indoxacarb 14.5 SC	35	37.31bc (37.62)	77.94b (62.71)	72.29b (58.54)	50.79b (42.45)	62.02b (52.07)	80.73b (64.34)	82.27b (65.96)	78.69bc (62.62)
T ₅ – Bt (Dipel 8L)	60	30.52cd (33.54)	50.86cd (45.51)	43.07c (41.01)	36.09c (36.89)	47.58c (43.60)	59.58c (50.57)	64.38c (53.56)	51.15de (45.70)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	8.46f (16.67)	21.45f (27.57)	26.12e (30.70)	6.60e (14.83)	10.77e (18.73)	29.79d (33.08)	22.06f (28.01)	16.26g (23.76)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	10.08ef (18.50)	30.99ef (33.80)	28.05de (31.96)	22.05d (28.00)	26.67d (31.08)	29.95d (32.92)	43.03d (40.99)	38.44ef (38.20)
T ₈ – NSKE	5%	26.81d (31.14)	44.60cde (41.89)	39.05cd (38.64)	27.87d (31.84)	32.76d (34.90)	42.96d (40.83)	36.53de (37.08)	32.19f (34.46)
T ₉ – Malathion 50 EC	250	15.02e (22.78)	37.18de (37.57)	37.20cde (37.53)	24.02d (29.34)	29.17d (32.67)	32.69d (34.65)	27.13ef (31.34)	21.97fg (27.94)
T ₁₀ – Untreated control	-	-6.94g (- 15.11)	-3.01g (-9.78)	-6.26f (14.30)	-0.84f (-7.15)	-0.40f (-6.63)	-4.82e (- 11.83)	-1.78g (- 10.75)	-5.59h (-13.67)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

other. Least larval reduction was noticed in case of treatments with *N. rileyi* (7.852%). Similar trend was noticed at all the intervals of observation after I spray. However, from 7 DAS, all the insecticides exhibited reduced efficacy over 3 DAS except novaluron which had reduced effect only on 10 DAS.

II spray

Larval population was reduced at 10 days after the second spray in all the treatments, in contrast to increase in the untreated control. Extent of reduction varied significantly among the treatments. Similar trend as seen in the case of I spray was followed in II spray also, at all the intervals of observation. Spinosad and emamectin benzoate maintained their superlative efficacy by having maximum per cent larval reduction.

III and IV spray

In both of these sprays, the plots sprayed with spinosad and emamectin benzoate recorded significantly maximum per cent larval reduction at all the intervals of observation and thus distinguished as best treatments. This was followed by indoxacarb. Treatments that were next in the order of superiority were than novaluron and dipel which suppressed the larval population at 10 days after each spray. At all the intervals of observation during III and IV spray, *N. rileyi* was poorest in controlling the larval population of the pest.

In the succeeding year of experimentation pest load was 8.43 to 9.1 on one day before imposition of treatments indicating the uniformity in distribution (Table 28). Steady increase in larval population in untreated plots from the beginning of trial till 10 days after second spray (as in the case of 2005) suggested that prevalence of most favourable environmental conditions for pest build up.

The superiority of spinosad and emamectin benzoate was confirmed there were followed by the second year studies. Next best treatment was indoxacarb which was followed by the efficacy of novaluron and dipel.

Pooled analysis of the data on larval load indicated supremacy of spinosad (96% larval reduction) followed by emamectin benzoate (88.1%) which were on par with each other (Table 29). These were followed by the of indoxacarb, novaluron and dipel in the descending order of their toxicity at all the intervals of observation. *N. rileyi* was found to be the least effective of all the treatments.

4.2.2.2 Tobacco caterpillar (*Spodoptera litura*)

The second spray taken up on the crop during both the years was the first spray for tobacco caterpillar as this pest appeared late at numbers exceeding ETL during both years of study. Pre treatment pest population did not differ significantly between treatments to indicate uniform distribution of pest, however the pest density was above ETL. During 2005 the population ranged from 2.87 to 3.77 (Table 30) on a day before treatment imposition.

I spray

There was significant variation in the pest population at 1, 3, 7 and 10 DAS and all the treatments excelled over untreated control. At 7 and 10 days after 1st spray the efficacy of the insecticides reduced but for novaluron and *N. rileyi*, where in the reduced efficacy was noticed only after 10 DAS. Spinosad and emamectin were found to be the most effective of all treatments with 73.69 and 65.57 per cent larval reduction over pre treatment at 10 DAS. The other insecticides which followed them with respect to superiority were indoxacarb, novaluron and dipel in the mentioned order.

II spray

Similar trend as in the I spray was followed in II spray also at all the intervals of observations. Spinosad and emamectin benzoate maintained their supremacy by having maximum per cent larval reduction of 92.52 and 88.19, respectively at 10 DAS, *N. rileyi* was found to be least effective treatment by registering 5.02 per cent larval reduction.

III spray

Emamectin benzoate proved statistically at par to the spray of spinosad at 7 and 10 days after third spray. Rest of the treatments followed the above two in the order of toxicity and were significantly superior to UTC. However, spinosad and emamectin benzoate were most effective at all the intervals of observations.

Table 29 : Bioefficacy of eco-friendly insecticides against *P. xylostella* on cabbage (Pooled data)

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	8.62a	59.75a (0.63)	94.11a (76.72)	87.55a (69.63)	86.24a (68.55)	50.89a (45.52)	94.54a (77.38)	93.05a (75.08)	76.32a (62.20)
T ₂ – Emamectin benzoate 5 SG	7.5	8.72a	53.45a (47.99)	84.97a (71.98)	80.77a (64.72)	77.23a (64.72)	43.94ab (41.80)	88.07a (71.62)	84.94a (69.21)	67.72b (57.17)
T ₃ – Novaluron 10 EC	50	8.55a	30.11c (33.25)	40.29cd (30.37)	64.74b (53.73)	63.19b (52.75)	33.32cd (35.24)	56.96c (49.08)	67.41c (55.27)	42.38d (40.55)
T ₄ – Indoxacarb 14.5 SC	35	8.73a	45.03b (42.11)	71.26b (57.96)	69.95b (56.96)	67.67b (55.50)	39.23bc (38.75)	76.76b (61.87)	76.83b (61.57)	53.98c (47.31)
T ₅ – Bt (Dipel 8L)	60	8.73a	23.91d (29.20)	32.28c (34.58)	37.00c (37.43)	38.38c (38.23)	28.59de (32.27)	49.52cd (44.72)	44.30d (41.70)	31.17e (33.84)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	8.17a	11.69f (19.53)	13.80e (21.61)	18.24d (25.26)	6.14g (14.23)	7.47g (15.62)	15.82g (23.23)	21.02f (26.69)	10.35g (18.36)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	8.23a	14.45f (22.31)	20.22d (26.67)	22.15d (27.85)	16.45f (23.76)	10.33g (26.00)	31.15f (33.90)	28.26ef (32.03)	19.28f (26.02)
T ₈ – NSKE	5%	8.42a	20.97de (27.23)	26.34cd (30.85)	25.32d (30.06)	28.88d (32.38)	26.62e (30.98)	43.65de (41.34)	37.64de (37.81)	25.80ef (34.49)
T ₉ – Malathion 50 EC	250	8.30a	18.54e (27.48)	23.43d (28.92)	22.17d (28.07)	22.17e (28.06)	14.96f (22.25)	38.15ef (38.13)	30.98e (33.76)	23.40f (28.90)
T ₁₀ – Untreated control	-	8.48a	-3.93g (11.36)	-3.87f (11.31)	-5.46e (13.35)	-6.98h (15.15)	-3.54h (10.71)	-6.21h (14.36)	-9.27g (17.51)	-1.48h (6.85)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Contd.....

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ - Spinosad 2.5 SC	15	49.84a (44.92)	96.06a (80.93)	93.37a (77.06)	71.30a (7.63)	96.91a (82.22)	95.35a (85.27)	97.14a (83.15)	96.00a (81.18)
T ₂ - Emamectin benzoate 5 SG	7.5	42.76a (41.01)	87.35a (74.64)	88.01a (71.71)	65.32a (53.98)	90.38a (77.28)	90.72a (74.71)	92.04a (76.74)	88.10a (76.71)
T ₃ - Novaluron 10 EC	50	31.50c (34.05)	59.09c (50.32)	68.94b (56.29)	43.26c (41.11)	53.02bc (46.74)	71.89c (58.34)	77.83b (62.24)	59.68c (50.73)
T ₄ - Indoxacarb 14.5 SC	35	39.75b (39.03)	75.62b (61.09)	72.99b (58.98)	53.75b (47.20)	61.10b (51.59)	81.96b (65.29)	81.69d (65.30)	79.41b (63.37)
T ₅ - Bt (Dipel 8L)	60	26.60c (30.94)	52.27cd (46.33)	46.85c (43.19)	37.61c (37.79)	47.10c (43.33)	60.51d (51.15)	58.02c (49.76)	47.62d (43.65)
T ₆ - <i>Nomuraea rileyi</i>	2 g/l	8.53ef (16.85)	15.83g (23.03)	25.66f (30.33)	6.41f (14.63)	10.57e (18.68)	31.79f (34.30)	27.52e (31.52)	21.73f (27.57)
T ₇ - <i>Beauveria bassiana</i>	5 g/l	11.30ef (19.34)	27.04f (30.91)	30.52ef (33.50)	18.15e (24.56)	26.96d (31.25)	32.91f (34.84)	41.36d (40.01)	41.28de (39.90)
T ₈ - NSKE	5%	20.46d (26.58)	45.28de (42.28)	40.59cd (39.55)	27.88d (31.86)	33.02d (35.06)	46.75e (43.07)	40.50d (39.45)	35.64e (36.58)
T ₉ - Malathion 50 EC	250	12.30e (20.33)	36.04ef (36.88)	35.24de (36.38)	23.72de (29.13)	29.68d (33.00)	37.70ef (37.72)	32.60de (34.71)	27.32f (31.40)
T ₁₀ - Untreated control	-	-7.87f (-15.97)	-3.09h (-9.80)	-6.35g (-14.35)	-0.98g (-6.63)	-0.70f (-6.17)	-3.99g (-10.89)	-2.37f (-10.14)	-0.09g (-13.53)

In a column means followed by the same alphabet donot differ significantly by DMRT (0.05)

PT - Pretreatment DAS - Days after spray

Figures in paranthesis are angular transformed values

Table 30: Bioefficacy of eco-friendly insecticides against *S. litura* on cabbage during 2005

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.70a	34.09a (35.65)	84.74a (57.16)	77.91a (62.06)	73.69a (59.80)	38.74a (38.49)	93.74a (78.11)	92.52a (74.62)	89.94a (71.66)	87.11a (77.18)	97.33a (84.52)	93.17a (77.62)	90.33a (75.24)
T ₂ – Emamectin benzoate 5 SG	7.5	3.67a	27.13a (31.85)	77.79a (61.99)	71.23a (57.65)	65.57a (54.13)	32.00ab (34.86)	88.19a (73.47)	82.47a (67.83)	69.62a (64.08)	67.22a (65.36)	89.08ab (77.78)	84.44a (77.14)	81.94a (65.18)
T ₃ – Novaluron 10 EC	50	2.90a	17.21bc (24.46)	43.04c (40.94)	62.43a (52.27)	48.33c (44.01)	24.02c (29.30)	59.20bc (50.35)	65.24b (54.00)	37.22bc (37.58)	35.90bc (36.80)	72.92c (58.81)	74.22bc (59.63)	53.91b (47.27)
T ₄ – Indoxacarb 14.5 SC	35	3.47a	21.61b (27.58)	65.78b (54.34)	64.88a (53.74)	55.41bc (48.12)	28.04bc (28.87)	75.17b (50.47)	75.17b (60.47)	43.02b (40.95)	53.36b (36.95)	81.62bc (54.99)	81.31b (65.05)	61.69b (51.79)
T ₅ – Bt (Dipel 8L)	60	3.77a	14.47cd (22.36)	34.38cd (35.76)	31.68b (33.94)	26.02d (30.32)	17.90d (24.99)	41.27cd (39.94)	38.11c (38.11)	27.18cd (31.03)	26.81c (31.15)	63.35c (52.89)	53.00d (46.73)	46.25b (42.84)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	3.10a	3.41e (10.64)	5.56f (13.55)	8.98c (17.41)	6.05f (13.87)	4.61e (12.34)	6.69e (14.90)	11.01e (19.36)	5.02fg (12.75)	7.02de (15.33)	11.93e (20.19)	16.83f (24.20)	12.81c (20.91)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	3.23a	12.02cd (20.28)	24.28e (29.49)	23.45bc (28.93)	16.15de (23.67)	15.57d (23.23)	30.57d (33.55)	29.48cd (32.88)	12.21ef (20.45)	23.52c (29.00)	34.78d (36.12)	31.74e (34.27)	23.16c (28.60)
T ₈ – NSKE	5%	2.97a	10.91d (19.27)	20.96e (27.24)	19.74bc (26.36)	11.18ef (19.46)	13.29d (21.37)	27.79d (31.80)	25.88d (30.52)	8.49efg (16.84)	19.90cd (36.49)	30.19d (33.31)	28.16ef (32.03)	21.33c (27.37)
T ₉ – Malathion 50 EC	250	3.53a	13.15cd (21.25)	26.28de (30.80)	26.12bc (30.64)	17.22de (24.48)	16.69d (24.10)	32.39d (34.67)	31.18cd (33.94)	17.08de (24.22)	25.72c (30.44)	35.70d (36.68)	34.41e (35.88)	24.52c (29.59)
T ₁₀ – Untreated control	-	2.87a	-3.07e (-9.73)	-4.61g (-12.27)	-28.77d (- 29.83)	-10.87g (- 18.93)	-3.03f (- 9.56)	-3.43f (- 10.42)	-3.06f (-9.29)	-4.11g (- 11.59)	-4.49e (- 12.12)	-5.11f (- 12.81)	-3.84g (- 10.84)	-3.71d (- 10.50)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

During 2006, the density of tobacco caterpillar was 2.23 to 4.17 per plant at the beginning of experimentation (Table 31). This went on reducing till 10 DAS of III spray. Data presented in Table 31 indicated that spinosad and emamectin benzoate proved significantly superior over rest of the treatments at all the intervals of observation during the three sprays. Next best treatment was indoxacarb followed by novaluron and Bt. In all the sprays, *N. rileyi* was found to be least effective which could provide maximum of 12.28 per cent larval reduction when three sprays were considered.

On analysis of the data after pooling, trend in superiority of treatments did not deviate from year to year (Table 32). The order of per cent larval reduction at 10 DAS after III spray was spinosad > emamectin benzoate > indoxacarb > novaluron = Bt > malation = *B. bassiana* = NSKE > *N. rileyi*.

4.2.2.3 Cabbage leaf webber (*Crociodolomia binotalis*)

The results of the bioefficacy trials with ecofriendly insecticides for the years 2005 and 2006 are presented in tables 33 and 34. During the period of study the second spray taken up on the crop was the first spray for cabbage leaf webber as this pest crossed ETL during this time.

Experimental results of 2005 presented in Table 33 revealed uniformity on leaf webber incidence before the intervention with treatments.

I spray

However, there was significant difference among the treatments on 1, 3, 7 and 10 days after I spray with respect to per cent larval reduction over pre treatment and all the treatments were found to be significantly superior over control. Spinosad recorded highest mortality of larva followed by emamectin benzoate which was on par with it. However, NSKE and *N. rileyi* were least effective in reducing the pest population. Similar trend was maintained in 3, 7 and 10 DAS, but with increased efficiency of all the treatments than 1 DAS.

II spray

Second spray was taken up ten days after first spray and the data recorded on 1, 3, 7 and 10 DAS revealed similar pattern of toxicity as that in the I spray but with increased efficiency. All the treatments were found to be significantly superior over control with highest per cent mortality in spinosad and emamectin benzoate and least mortality in case of *N. rileyi*.

III spray

The plots sprayed with spinosad and emamectin benzoate recorded significantly maximum per cent larval reduction at all the intervals of observations and thus discriminated as best v/s other treatments. This was followed by indoxacarb, novaluron and dipel in suppressing the pest population at 10 days after spray. *N. rileyi* was the poorest of the treatment which registered maximum of 15.07 per cent reduction on 7 DAS.

The results of experiment conducted in 2006 were no different in the effectiveness of treatments as explained above (Table 34) and so in pooled analysis (Table 35). These results confirmed the effectiveness of treatments which was in the order of spinosad = emamectin benzoate > indoxacarb > novaluron > dipel > malathion > *B. bassiana* = NSKE > *N. rileyi*.

4.2.2.4 Yield

Pest reduction in various treatments clearly reflected and translated in yield (Table 36). Yield of cabbage which ranged from 37.54 to 33.96 t/ha in 2005 and 33.02 to 32.38 t/ha in 2006 did not vary significantly among plots treated with spinosad and emamectin benzoate. By virtue of good protection offered by these insecticides the yield increased significantly (37.54 t/ha and 33.02 t/ha in spinosad and 33.96 t/ha and 32.28 t/ha in emamectin benzoate treated plots (Plate 9 and 10).

Pooled analysis of data also confirmed the superiority of all the treatments over UTC. Superiority of spinosad and emamectin benzoate over other inputs was also reiterated.

4.2.2.5 Cost effectiveness

On an average, indoxacarb, novaluron, Bt sprayed cabbage produced yield of 28.76, 25.69 and 23.71 t/ha respectively. But, this increase was spectacular with spinosad (33.17) and emamectin benzoate (Table 36). The cost of intervention of these treatments ranged from

Table 31 : Bioefficacy of eco-friendly insecticides against *S.litura* on cabbage during 2006

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	4.17a	33.33a (5.26)	85.89a (68.01)	83.72a (66.30)	78.67a (62.58)	59.01a (51.61)	97.53a (83.35)	94.15a (76.79)	76.09a (64.86)	81.00a (64.59)	93.00a (77.42)	89.57a (71.30)	88.24a (70.00)
T ₂ – Emamectin benzoate 5 SG	7.5	3.97a	29.55a (32.92)	78.95a (63.78)	76.60a (61.27)	73.06ab (58.90)	42.95ab (42.40)	90.73a (74.61)	85.94a (69.56)	55.19a (53.98)	68.52a (59.93)	85.57ab (68.92)	81.21a (66.28)	76.82a (65.38)
T ₃ – Novaluron 10 EC	50	4.13a	16.75c (24.14)	42.97c (40.93)	61.29b (51.59)	49.34c (44.62)	28.66cd (32.24)	66.45b (54.91)	60.79b (51.64)	37.57b (37.65)	45.45c (42.36)	67.26cd (55.24)	70.14b (56.96)	40.48c (39.48)
T ₄ – Indoxacarb 14.5 SC	35	4.13a	24.20b (29.39)	66.71b (54.91)	66.29b (54.62)	62.82b (52.47)	35.78bc (36.51)	78.43b (62.97)	71.64b (58.13)	47.27b (43.42)	60.29b (51.00)	76.62bc (61.31)	74.52b (59.78)	50.55b (45.32)
T ₅ – Bt (Dipel 8L)	60	2.97a	15.80cd (23.39)	31.87d (34.32)	31.91c (34.39)	25.32d (30.09)	24.49cd (29.56)	50.10c (45.18)	36.62c (37.21)	18.78c (25.36)	32.90d (34.97)	55.52d (48.21)	39.26c (38.76)	30.67d (33.58)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	2.93a	3.47f (10.62)	4.24f (11.85)	8.81e (17.22)	4.21f (9.18)	4.47e (12.14)	6.34e (14.57)	10.07d (18.48)	2.62e (7.60)	7.70f (51.98)	10.33f (18.74)	12.28e (20.49)	4.58g (12.31)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	3.53a	11.62de (19.93)	23.62e (29.07)	25.66cd (30.40)	13.90 ^e (21.83)	19.63d (26.22)	30.12d (33.26)	28.02c (31.90)	10.95cd (19.31)	25.46de (30.27)	31.17 ^e (33.93)	28.79d (32.43)	17.43ef (24.61)
T ₈ – NSKE	5%	3.10a	9.96 ^e (18.35)	19.81 ^e (26.42)	20.89d (27.18)	11.96e (20.17)	17.26d (24.46)	27.60d (31.64)	25.59c (30.30)	6.33de (14.53)	20.30e (26.76)	27.81e (31.81)	26.48d (30.94)	12.66f (20.73)
T ₉ – Malathion 50 EC	250	3.77a	12.41cde (20.62)	26.39de (30.88)	26.89cd (31.21)	16.49de (23.92)	20.37cd (26.77)	36.05cd (36.75)	32.77c (34.84)	14.02cd (21.70)	27.61de (31.66)	34.68e (36.07)	30.74cd (33.65)	19.62e (26.26)
T ₁₀ – Untreated control	-	2.23a	-5.99g (-13.45)	-6.94g (-14.82)	-18.92f (- 24.90)	-11.57g (- 19.27)	-4.65f (- 11.95)	-9.29f (- 17.07)	-5.59e (-13.31)	-15.72f (- 22.89)	-1.49g (- 6.90)	-3.69f (-10.55)	-5.59f (- 13.31)	-5.78h (-13.51)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 32: Bioefficacy of eco-friendly insecticides against *S. litura* on cabbage (Pooled)

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.93a	33.71a (5.45)	85.32a (67.59)	80.81a (64.18)	76.18a (61.19)	48.87a (45.05)	95.63a (80.73)	93.33a (75.70)	83.01a (66.26)	84.06a (70.89)	95.17a (80.97)	91.37a (74.46)	89.29a (72.62)
T ₂ – Emamectin benzoate 5 SG	7.5	3.82a	28.34a (33.14)	78.37a (62.88)	73.92ab (59.46)	69.32a (56.53)	37.48b (39.93)	89.46a (73.44)	84.21a (70.09)	62.41a (60.53)	67.87b (63.15)	85.01b (73.03)	85.14a (68.78)	79.38a (66.43)
T ₃ – Novaluron 10 EC	50	3.52a	16.98c (24.30)	43.00c (40.93)	61.86b (51.93)	48.83c (44.32)	26.34cd (30.77)	62.82c (52.63)	63.01c (52.82)	37.40b (37.61)	40.68d (39.58)	70.74cd (57.43)	71.53b (57.88)	47.20bc (43.37)
T ₄ – Indoxacarb 14.5 SC	35	3.80a	22.90b (28.48)	66.25b (54.62)	65.59b (54.18)	59.12b (50.29)	31.91c (34.19)	76.80b (61.72)	73.40b (59.30)	45.15b (42.19)	56.83c (48.97)	78.97bc (63.18)	78.07b (62.38)	56.12b (48.55)
T ₅ – Bt (Dipel 8L)	60	3.37a	15.14cd (22.88)	33.12d (35.04)	31.80c (34.17)	25.67d (30.21)	21.20de (27.28)	45.68d (42.56)	37.36d (37.66)	22.98c (28.19)	29.85de (33.06)	59.44d (50.55)	46.13c (42.75)	38.46c (38.21)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	3.02a	3.44f (10.63)	4.90f (12.70)	8.89d (17.31)	5.13f (11.53)	4.54f (12.24)	6.52f (14.74)	10.54f (18.92)	3.82f (10.18)	7.36f (15.65)	11.13f (19.46)	14.55e (22.34)	8.70e (16.61)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	3.38a	11.82e (20.10)	23.95e (29.28)	24.55c (29.66)	15.03e (22.75)	17.60e (24.72)	30.34de (33.41)	28.75de (32.39)	11.58de (19.88)	24.49e (29.63)	32.97e (35.02)	30.26d (33.35)	20.30d (26.61)
T ₈ – NSKE	5%	3.03a	10.43e (18.81)	20.38e (26.83)	20.32c (26.77)	11.57e (19.81)	15.27e (22.91)	27.70e (31.72)	25.74e (30.41)	7.41ef (15.69)	20.10e (26.63)	29.00e (32.56)	27.32d (31.48)	17.00d (24.05)
T ₉ – Malathion 50 EC	250	3.65a	12.78de (20.94)	26.33de (30.84)	26.50c (30.92)	16.86e (24.20)	18.53de (25.43)	34.22de (35.71)	31.98de (34.29)	15.55cd (22.96)	26.67e (31.05)	35.19e (36.37)	32.58d (34.76)	22.07d (27.92)
T ₁₀ – Untreated control	-	2.55a	-4.53g (-11.59)	-5.78g (-13.54)	-23.84e (- 27.37)	-11.22g (- 19.10)	-3.84g (- 10.76)	-6.36g (-13.75)	-4.33g (-11.30)	-9.91g (- 17.24)	-2.99g (-9.51)	-4.40g (-11.68)	-4.72f (- 12.07)	-4.75f (- 12.00)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 33: Bioefficacy of eco-friendly insecticides against *C.binotalis* on cabbage during 2005

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.13a	33.92a (35.62)	91.63a (73.48)	77.69a (62.04)	65.21a (53.90)	50.89a (45.52)	95.76a (79.76)	94.34a (78.22)	72.27a (58.64)	63.13a (52.72)	97.33a (84.52)	97.33a (84.52)	97.33a (84.52)
T ₂ – Emamectin benzoate 5 SG	7.5	3.20a	31.83a (34.34)	82.74a (68.84)	71.20ab (57.64)	63.09a (52.64)	40.42b (40.857)	89.42a (71.25)	87.51ab (70.21)	55.79a (52.34)	53.78a (48.48)	91.70a (75.85)	87.36a (75.14)	86.67a (76.55)
T ₃ – Novaluron 10 EC	50	3.37a	19.82c (26.42)	39.86c (39.14)	41.59c (40.14)	36.73c (37.24)	23.98c (29.31)	54.48c (47.61)	66.58c (55.08)	35.17bc (36.37)	34.90c (36.14)	71.19b (58.34)	78.27b (62.93)	29.47c (32.70)
T ₄ – Indoxacarb 14.5 SC	35	2.97a	25.79b (30.49)	68.83b (56.30)	63.88b (53.10)	53.22b (46.85)	34.99b (36.22)	78.68b (63.33)	76.70bc (62.39)	46.57b (43.00)	44.15b (41.63)	81.26b (65.07)	75.06b (60.99)	47.66b (43.64)
T ₅ – Bt (Dipel 8L)	60	3.17a	15.14d (22.86)	35.80cd (36.70)	29.29d (32.70)	28.79d (32.24)	21.24c (27.42)	45.33cd (42.31)	36.27d (37.00)	31.35c (34.02)	23.83d (29.19)	53.42c (46.98)	51.70c (45.99)	23.94c (29.16)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	2.77a	3.76f (11.12)	8.44g (16.89)	9.37f (17.78)	(9.56f 17.83)	5.57f (13.46)	10.96f (19.32)	11.81ef (20.08)	6.03ef (14.11)	7.07f (15.37)	11.54e (19.85)	15.07e (22.83)	6.99e (15.29)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	2.87a	10.06e (18.35)	22.38ef (28.16)	22.56de (28.23)	14.48ef (.04)	12.78de (20.76)	30.18e (33.25)	26.98d (31.19)	12.34de (20.43)	18.24de (25.25)	31.22d (33.91)	26.00de (30.65)	12.25de (20.26)
T ₈ – NSKE	5%	2.93a	8.32e (16.69)	18.96f (25.80)	16.94e (24.26)	12.48ef (0.49)	9.18ef (17.61)	23.84e (29.20)	21.66de (27.70)	9.89de (18.19)	15.26e (22.96)	24.86d (29.90)	24.16de (29.41)	8.60de (17.02)
T ₉ – Malathion 50 EC	250	3.07a	11.94de (20.17)	28.29de (32.11)	24.89de (29.86)	16.91e (23.92)	18.12cd (25.18)	33.24de (35.18)	30.51d (33.47)	14.95d (22.69)	19.72de (26.32)	37.94cd (37.96)	34.19d (35.75)	18.45cd (25.38)
T ₁₀ – Untreated control	-	2.87a	-2.88g (-9.38)	-6.59h (-14.80)	-4.60g (- 11.73)	-14.89g (-22.43)	-1.90g (-7.84)	-5.12g (-12.80)	-7.11f - (14.74)	-2.38f (-8.74)	-3.26g (-10.17)	-5.06f (-12.08)	-5.82f (-13.30)	-7.61f (- 14.81)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 34: Bioefficacy of eco-friendly insecticides against *C.binotalis* on cabbage during 2006

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.47a	30.30a (33.39)	90.08a (71.85)	74.55a (59.83)	61.89a (51.88)	44.58a (41.89)	96.55a (80.11)	90.81a (72.65)	62.74a (52.42)	69.46a (56.46)	97.79a (83.15)	96.50a (79.50)	96.79a (81.55)
T ₂ – Emamectin benzoate 5 SG	7.5	3.07a	25.33ab (30.18)	81.56a (64.65)	66.60b (55.23)	58.44a (49.86)	41.78a (40.26)	87.07b (72.86)	87.07a (69.46)	53.44a (46.99)	62.67a (52.35)	93.00a (74.86)	93.53a (75.39)	79.11a (71.48)
T ₃ – Novaluron 10 EC	50	2.87a	18.41cd (25.39)	42.68c (40.70)	43.4c (34.12)	35.49b (36.22)	21.18c (27.37)	51.90d (46.11)	53.48c (47.01)	32.68bc (32.82)	37.57c (37.78)	70.80b (57.64)	74.13c (59.71)	36.56bc (37.17)
T ₄ – Indoxacarb 14.5 SC	35	3.00a	22.93bc (28.59)	66.51b (54.81)	63.03b (52.56)	51.68a (45.97)	32.31b (34.59)	77.33c (62.51)	76.89b (61.36)	41.91b (40.34)	51.52b (45.87)	87.64b (69.82)	76.54b (61.89)	54.46b (47.58)
T ₅ – Bt (Dipel 8L)	60	3.13a	14.95de (22.72)	34.58cd (35.80)	21.30d (27.44)	22.21c (27.98)	18.66c (25.58)	44.33d (41.72)	41.57d (40.12)	28.72cd (32.23)	29.90d (33.09)	48.68c (44.24)	38.62d (38.40)	24.58cd (29.44)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	2.87a	3.86g (11.20)	7.04f (14.86)	6.76g (15.03)	9.57e (17.35)	4.25f (11.81)	5.23f (13.20)	9.47f (17.91)	10.50g (18.31)	8.82g (17.20)	10.12e (15.28)	17.19f (24.48)	7.18ef (15.24)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	2.83a	10.04f (18.43)	17.73ef (24.85)	13.36ef (21.22)	15.14cde (22.84)	11.72de (20.00)	28.05e (31.94)	27.45e (31.56)	19.65def (26.23)	20.06ef (26.58)	32.24cd (34.59)	30.30de (33.37)	12.82def (20.93)
T ₈ – NSKE	5%	3.20a	7.40f (15.78)	12.38ef (20.57)	10.15fg (18.49)	13.21de (21.06)	10.19e (18.59)	23.54e (29.01)	22.46e (28.29)	15.48efg (23.07)	14.44f (22.30)	24.71ef (29.80)	22.73d (28.29)	10.69def (19.04)
T ₉ – Malathion 50 EC	250	2.93a	11.67ef (19.95)	21.24de (27.42)	17.07de (24.37)	18.37cd (25.20)	16.31cd (23.79)	28.99e (32.56)	28.79e (32.43)	21.22de (27.31)	21.86e (27.85)	33.91cd (35.60)	32.41de (34.65)	17.53de (24.67)
T ₁₀ – Untreated control	-	2.87a	-9.45h (-17.38)	-12.95g (-20.29)	-14.58h (-21.97)	-15.39f (-22.71)	-5.97g (-12.85)	-7.41g (-15.21)	-9.68g (-16.69)	-13.49h (-20.80)	-8.23h (-16.52)	-4.30f (-9.19)	-5.74g (-13.24)	-5.66f (-13.08)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 35 : Bioefficacy of eco-friendly insecticides against *C. binotalis* on cabbage pooled

Treatments	Dosage (g a.i./ha)	Per cent larval reduction over pre treatment												
		First spray					Second spray				Third spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.30a	32.11a (34.51)	90.86a (72.66)	76.12a (60.93)	63.55a (52.89)	47.73a (43.70)	95.45a (79.16)	93.28a (76.21)	67.50a (55.53)	66.30a (54.59)	97.56a (83.84)	96.92a (82.01)	97.06a (83.04)
T ₂ – Emamectin benzoate 5 SG	7.5	3.13a	28.58a (32.26)	82.15a (66.79)	68.90a (56.99)	60.77a (51.25)	41.10a (40.87)	88.25b (72.36)	87.29a (69.83)	54.61a (51.67)	58.22a (51.27)	92.62a (75.47)	90.18a (73.95)	82.89a (76.07)
T ₃ – Novaluron 10 EC	50	3.12a	19.11c (25.90)	41.27c (39.92)	42.57c (37.13)	36.11c (36.73)	22.58c (28.34)	53.19d (46.86)	60.03c (51.05)	33.93c (35.59)	36.23c (36.96)	70.99b (57.99)	76.20b (61.32)	33.01c (34.94)
T ₄ – Indoxacarb 14.5 SC	35	2.98a	24.36b (29.54)	67.67b (55.56)	63.45b (52.83)	52.45b (46.41)	33.65b (35.40)	78.00c (62.92)	76.79b (61.88)	44.24b (41.67)	47.83b (43.75)	84.45b (67.44)	75.80b (61.44)	51.06b (45.61)
T ₅ – Bt (Dipel 8L)	60	3.15a	15.05d (22.79)	35.19c (36.25)	25.30d (30.09)	25.50d (30.11)	19.95cd (26.50)	44.83d (42.02)	38.92d (38.56)	30.03c (33.13)	26.86d (31.14)	51.05c (45.61)	45.16c (42.19)	24.26cd (29.30)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	2.82a	3.81g (11.16)	7.74g (15.87)	8.06g (16.41)	9.56f (17.59)	4.91f (12.64)	8.09f (16.26)	10.64f (19.00)	8.26e (16.21)	7.95g (16.29)	10.83e (17.57)	16.13e (23.65)	7.09f (15.27)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	2.85a	10.05ef (18.39)	20.05de (26.50)	17.96ef (24.72)	14.81e (22.44)	12.25e (20.38)	29.11e (32.60)	27.21de (31.38)	15.99d (23.33)	19.15ef (25.91)	31.73d (34.25)	28.15dd (32.01)	12.54ef (20.59)
T ₈ – NSKE	5%	3.07a	7.86f (16.23)	15.67ef (23.18)	13.54f (25.38)	12.85ef (20.77)	9.69e (18.10)	23.15e (28.75)	22.60e (28.35)	12.68d (20.63)	14.85f (22.63)	24.43de (29.61)	23.79d (29.09)	9.65ef (18.03)
T ₉ – Malathion 50 EC	250	3.00a	11.80e (20.06)	24.76d (29.76)	20.98de (27.11)	17.64e (24.56)	17.22d (24.48)	31.12e (33.87)	29.65de (32.93)	18.09d (25.00)	20.79e (27.08)	35.18cd (36.30)	34.05cd (35.68)	17.99de (25.02)
T ₁₀ – Untreated control	-	2.87a	-6.16h (-13.38)	-9.77h (-17.55)	-9.59h (-16.85)	-15.14g (-22.58)	-3.93g (- 10.34)	-6.27g (-14.00)	-8.39g (-15.71)	-7.94f (-14.79)	-5.75h (-13.34)	-4.68f (-10.63)	-5.78f (-13.27)	-6.64g (-13.94)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are angular transformed values

Table 36 : Effect of different eco friendly insecticides on yield of cabbage

Treatment	Dosage (g ai/ha)	Yield (t/ha)			Net returns (Rs.)	Incremental returns (Rs.)	Treatment cost (Rs)	IBCR
		2005	2006	Pooled				
T ₁ – Spinosad 2.5 SC	15	37.54a	33.02a	35.28a	72700	51025	3720	13.71
T ₂ – Emamectin benzoate 5 SG	7.5	33.96ab	32.38a	33.17a	67425	48250	6038	7.99
T ₃ – Novaluron 10 EC	50	27.74cd	23.65b	25.69bc	48725	29500	5600	5.28
T ₄ – Indoxacarb 14.5 SC	35	29.06bc	28.44b	28.76b	56400	37225	3600	10.34
T ₅ – Bt (Dipel 8L)	60	23.29d	24.13b	23.71c	43775	24600	4795	5.13
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	11.68ef	9.89de	10.79e	11475	-	1400	-
T ₇ – <i>Beauveria bassiana</i>	5 g/l	15.86e	13.15cd	14.51d	20775	1600	3100	1.45
T ₈ – NSKE	5%	14.43e	15.76c	15.10d	22250	3075	1200	2.50
T ₉ – Malathion 50 EC	250	17.22e	15.77c	16.50d	25750	6575	1690	3.89
T ₁₀ – Untreated control	-	8.52f	6.82e	7.67e	-	-	-	-

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05 %)



Plate 9. Spinosad treated plot showing completely protected plants

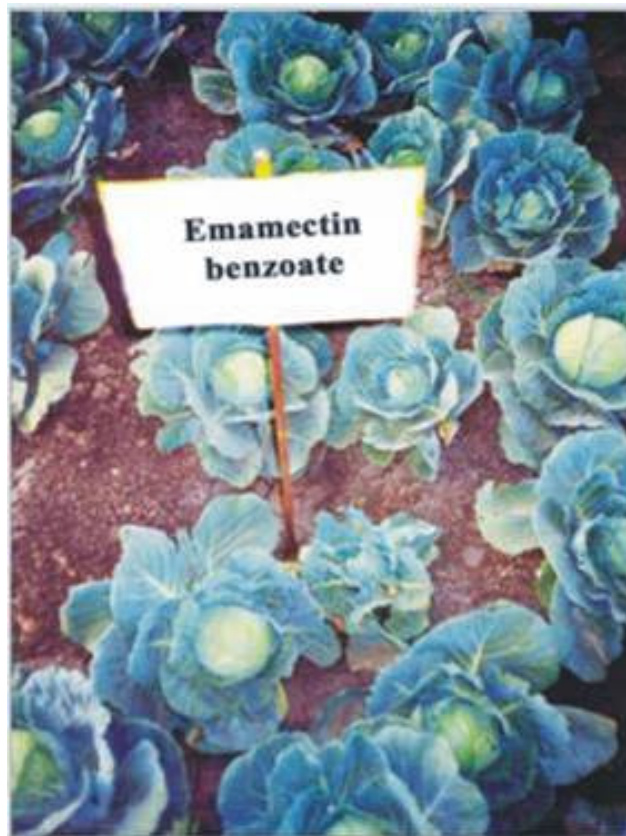


Plate 10. Emamectin benzoate treated plot showing completely protected plants

zero in untreated control to Rs. 6038 per hectare in emamectin benzoate treated plots. The benefit cost ratio (B:C ratio) was maximum in spinosad followed by indoxacarb. Proportion of investment to benefit was so close between novaluron (5.28) and dipel (5.13) that option can be in favour of any one depending on availability.

4.2.2.6 Effect on larval parasitoid, *Cotesia plutellae*

The impact of different ecofriendly insecticides on natural population of *C. plutellae* under field conditions was recorded for two seasons. Activity of solitary larval parasitoid of DBM, *C. plutellae* was uniform a day before spray during 2005 (Table 37).

After I spray

At 3 days after imposition of treatment the number varied significantly. Higher toxicity of malathion to the parasitoid till 3 DAS was evident from significantly lower number of cocoons (1.6/10 plant) followed by indoxacarb (4.67/10 plant) and spinosad (4.3/10 plants). *N. rileyi*, *B. bassiana*, NSKE and Bt spared the beneficial agent totally by recording at par number of cocoons with UTC. The number of parasitoid cocoons in emamectin benzoate and novaluron were (5.67 and 7.67 cocoons/10 plants) which were statistically on par with each other.

At 7 DAS the parasitoid number further reduced in all the treatments except *B. bassiana* and NSKE indicating the effectiveness of the chemical on the host of the parasitoid till 7 DAS. However, at 10 DAS the parasitoid density increased in all the treatments.

After II spray

Similar trend as in the case of I spray was noticed at all the intervals of observations. After second spray, significantly highest parasitoid cocoons were recorded in untreated check (27.33/ 10 plants) followed by *N. rileyi*, *B. bassiana*, NSKE and Bt. which were on par, on all occasions. Other tested insecticides reduced parasitoid cocoons to significantly lowest numbers ranging from 3.0 to 14.67/10 plants.

After III spray

Number of *C. plutellae* cocoons after 3 days of III spray was in the order of UTC = *N. rileyi* = *B. bassiana* = NSKE = dipel > novaluron > spinosad = emamectin benzoate > indoxacarb = malathion. However, at 7 DAS, the number of parasitoid cocoons were further reduced in all the chemical treated plots unlike in case of first two sprays. At 10 DAS there was increase in the density of cocoons in all the treatments along with UTC.

After IV spray

Similar trend as in III spray was observed in case of 4th spray, at all the intervals of observations. In the absence of any intervention to check the pest population, the parasitoid density continued to increase. In treatments with *N. rileyi*, *B. bassiana*, NSKE and Bt even after IV spray higher number of cocoons were recorded which indicates the safety of these treatments to the parasitoid. These were followed by treatments with novaluron (11.33 cocoons/10 plants), spinosad (0.67 cocoons /10 plants) and emamectin benzoate (0.67 cocoons /10 plants) which were on par with each other. Indoxacarb and malathion ranked least by recording least number of parasitoid cocoons per plant.

Analysis of data during the second year of study (2006) (Table 38) and pooled data (Table 39) reiterated the safety of Bt along with NSKE, *N. rileyi* and *B. bassiana* to the larval endoparasitoid. It was interesting to note that population in the UTC was significantly higher than in pathogen applied plots.

4.3 EVALUATION OF IPM MODULES

Based on the results of previous experiments, organic soil amendments and new molecules were integrated in two field trials to develop an IPM module against DBM. Two modules of integrated pest management were evaluated in comparison with recommended package of practice (RPP) and Indian Institute of Horticulture Research (IIHR) module, for their effectiveness in the control of diamondback moth. Effect of these modules on other cabbage pests viz., tobacco caterpillar, cabbage leaf webber and a natural enemy (*Cotesia plutellae*) were also evaluated. Following were the different treatments tried.

T₁ – Recommended package of practices (RPP)

T₂ – Indian Institute of Horticulture Research (IIHR module)

Table 37 : Bioefficacy of eco-friendly insecticides against *C. plutellae* on cabbage during 2005

Treatments	Dosage (g a.i/ha)	Number of cocoons/10 plants								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	10.33a (3.21)	8.67ab (2.92)	4.33d (2.03)	6.00cd (2.44)	6.33d (3.51)	4.67d (2.15)	4.33d (2.07)	4.33de (2.07)	4.67d (2.16)
T ₂ – Emamectin benzoate 5 SG	7.5	10.67a (3.26)	9.67a (3.10)	5.67cd (2.35)	4.67de (2.14)	5.33d (2.30)	5.00d (2.24)	5.00d (2.24)	4.67d (2.16)	4.67d (2.16)
T ₃ – Novaluron 10 EC	50	11.33a (3.36)	10.67a (3.26)	7.67cd (2.38)	6.00cd (2.45)	10.33c (3.22)	10.00c (3.17)	9.33c (3.06)	9.33c (3.22)	10.00c (3.17)
T ₄ – Indoxacarb 14.5 SC	35	10.00a (3.16)	9.33a (3.06)	4.67d (2.78)	4.00e (2.11)	4.33e (2.07)	4.00e (2.00)	3.33de (1.84)	3.00e (1.73)	3.33e (1.84)
T ₅ – Bt (Dipel 8L)	60	12.33a (3.51)	12.00a (3.16)	11.67a (3.42)	7.33c (2.71)	10.33c (3.22)	10.00c (3.17)	9.67c (3.11)	13.33b (3.66)	14.67b (3.83)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	12.33a (3.51)	12.00a (3.47)	12.33a (3.52)	11.67b (3.57)	13.67b (3.70)	13.67b (3.70)	14.00b (3.75)	14.67b (3.83)	15.67b (3.96)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	10.67a (3.26)	10.00a (3.16)	10.67ab (3.27)	11.33b (3.36)	12.33bc (3.51)	12.33bc (3.51)	12.67b (3.56)	13.00b (3.61)	14.33b (3.79)
T ₈ – NSKE	5%	11.33a (3.36)	11.00a (3.31)	11.00ab (3.31)	11.67b (3.42)	12.67bc (3.56)	12.33bc (3.52)	12.33b (3.52)	12.67b (3.57)	14.33b (3.79)
T ₉ – Malathion 50 EC	250	10.67a (3.26)	5.67b (2.38)	1.67e (1.30)	3.33e (1.81)	3.67e (1.92)	3.00e (1.73)	2.67e (1.63)	3.00e (1.73)	3.00e (1.73)
T ₁₀ – Untreated control	-	10.33a (3.22)	11.33a (3.37)	13.67a (3.70)	17.33a (4.17)	20.33a (4.51)	21.67a (4.60)	23.67a (4.87)	24.67a (4.97)	27.33a (5.23)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray Figures in paranthesis are square root transformed values

Contd...

Treatments	Dosage (g a.i./ha)	Number of cocoons/plants							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	4.67c (2.16)	3.67d (1.92)	2.33cd (1.49)	4.33c (2.09)	4.00c (2.00)	2.00c (1.40)	1.33cd (1.16)	0.67cd (0.76)
T ₂ – Emamectin benzoate 5 SG	7.5	4.00d (2.00)	2.67de (1.64)	2.67c (1.64)	3.67c (1.92)	3.00c (1.73)	2.00c (1.40)	1.00cd (1.02)	0.67cd (0.76)
T ₃ – Novaluron 10 EC	50	6.67c (2.59)	4.67c (2.16)	3.67c (1.91)	4.33c (2.09)	2.67c (1.64)	1.67cd (1.30)	1.67c (1.30)	1.33c (1.16)
T ₄ – Indoxacarb 14.5 SC	35	3.33d (1.82)	2.00e (1.40)	1.33de (1.16)	2.33d (1.54)	0.67d (0.76)	0.67de (0.76)	0.67d (0.76)	0.33d (0.49)
T ₅ – Bt (Dipel 8L)	60	14.33b (3.79)	13.67b (3.70)	16.33b (4.04)	16.67b (4.09)	15.33b (3.92)	14.67b (3.83)	15.00b (3.88)	14.33b (3.79)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	15.00b (3.88)	15.67b (3.96)	16.00b (4.00)	16.33b (4.04)	16.67b (4.09)	16.67b (4.09)	16.67b (4.09)	16.33b (4.04)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	14.33b (3.79)	14.67b (3.83)	15.33b (3.92)	15.33b (3.92)	15.67b (3.96)	16.33b (4.04)	16.67b (4.09)	16.67b (4.09)
T ₈ – NSKE	5%	14.00b (3.75)	14.67b (3.83)	15.67b (3.96)	16.00b (4.00)	16.00b (4.00)	16.33b (4.04)	16.67b (4.09)	16.33b (4.05)
T ₉ – Malathion 50 EC	250	1.67e (1.25)	1.33e (1.16)	1.00e (1.02)	1.33e (1.16)	1.00d (1.02)	0.33e (0.49)	0.67d (0.76)	0.33d (0.49)
T ₁₀ – Untreated control	-	29.33a (5.42)	32.00a (5.66)	33.67a (5.81)	35.67a (5.98)	37.33a (6.11)	40.33a (6.35)	35.00a (5.92)	34.33a (5.86)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are square root transformed values

Table 38 : Bioefficacy of eco-friendly insecticides against *C.plutellae* on cabbage during 2006

Treatments	Dosage (g a.i./ha)	Number of cocoons/10 plants								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	8.67a (2.94)	7.67cd (2.91)	3.67c (1.91)	5.33c (2.30)	6.33d (2.51)	5.33d (2.17)	2.67de (1.64)	4.00de (2.00)	4.33d (2.09)
T ₂ – Emamectin benzoate 5 SG	7.5	14.33a (3.79)	13.33a (3.66)	7.33c (1.59)	5.67c (2.38)	6.33d (2.51)	6.00d (2.45)	3.67d (1.90)	3.67d (2.07)	5.33d (2.30)
T ₃ – Novaluron 10 EC	50	10.33a (3.21)	9.00cd (3.01)	7.67b (2.78)	5.33c (2.32)	9.67c (3.11)	8.67c (2.94)	8.33c (2.89)	8.67c (3.11)	9.00c (2.99)
T ₄ – Indoxacarb 14.5 SC	35	9.00a (3.00)	6.67cd (2.71)	3.67c (1.91)	3.33d (1.81)	4.33e (2.09)	2.67e (1.64)	2.33de (1.54)	2.66e (1.64)	2.66e (1.64)
T ₅ – Bt (Dipel 8L)	60	11.33a (3.37)	11.67ab (3.42)	11.00a (3.32)	6.67c (2.58)	9.67c (3.11)	9.33c (3.05)	9.00c (3.00)	12.67b (3.57)	13.33b (3.66)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	10.33a (3.22)	10.67abc (3.27)	10.67a (3.27)	11.33b (3.37)	12.33bc (3.51)	12.67b (3.56)	12.67b (3.56)	13.33b (3.65)	14.33b (3.78)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	12.00a (3.46)	11.67ab (3.41)	12.33a (3.51)	12.33b (3.51)	13.33b (3.66)	13.67b (3.70)	14.33b (3.79)	14.33b (3.79)	16.33b (4.04)
T ₈ – NSKE	5%	12.33a (3.50)	12.00ab (3.46)	12.33a (3.50)	13.33b (3.64)	14.00b (3.74)	13.67b (3.70)	13.67b (3.70)	14.33b (3.79)	15.67b (3.96)
T ₉ – Malathion 50 EC	250	9.33a (3.06)	4.67e (2.16)	2.33e (1.54)	3.33d (1.81)	3.67e (1.91)	2.33e (1.54)	2.00e (1.40)	2.33e (1.54)	2.67e (1.64)
T ₁₀ – Untreated control	-	11.33a (3.36)	12.67a (3.56)	14.33a (3.79)	19.67a (4.44)	23.00a (4.80)	23.67a (4.87)	24.33a (4.94)	25.33a (5.04)	28.00a (5.29)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray Figures in paranthesis are square root transformed values

Contd...

Treatments	Dosage (g a.i./ha)	Number of cocoons/plant							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	2.33c (1.54)	2.33c (1.54)	3.67c (1.92)	3.00cd (1.73)	3.33c (1.84)	2.00c (1.40)	1.67cd (1.27)	1.33cd (1.16)
T ₂ – Emamectin benzoate 5 SG	7.5	2.00c (1.40)	2.00c (1.40)	3.00cd (1.73)	3.67cd (1.92)	2.67cd (1.64)	2.00c (1.40)	1.67cd (1.27)	1.00cde (1.02)
T ₃ – Novaluron 10 EC	50	3.33c (1.77)	3.00c (1.70)	3.67c (1.88)	4.67c (2.14)	2.00cd (1.40)	1.33c (1.16)	1.33c (1.16)	2.33c (1.54)
T ₄ – Indoxacarb 14.5 SC	35	2.33c (1.49)	1.67d (1.27)	1.67d (1.27)	2.67d (1.64)	1.00e (0.89)	0.67cd (0.76)	0.33d (0.49)	0.67de (0.76)
T ₅ – Bt (Dipel 8L)	60	12.00b (3.47)	14.67b (3.83)	15.33b (3.92)	13.00b (3.61)	14.67b (3.82)	13.33b (0.64)	13.67b (3.68)	13.33b (3.64)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	15.00b (3.87)	15.33b (3.92)	15.67b (3.96)	14.67b (3.83)	16.00b (4.00)	16.67b (4.08)	16.67b (4.08)	15.67b (3.96)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	15.00b (3.87)	15.33b (3.91)	17.33b (4.17)	16.33b (4.05)	17.67b (4.20)	17.67b (4.19)	18.67b (4.31)	15.67b (3.95)
T ₈ – NSKE	5%	15.67b (3.96)	15.67b (3.96)	16.33b (4.04)	14.33b (3.71)	17.00b (4.13)	17.33b (4.17)	17.67b (4.21)	17.00b (4.13)
T ₉ – Malathion 50 EC	250	2.00c (1.40)	1.67d (1.27)	1.67d (1.27)	2.33d (1.49)	1.33de (1.16)	0.33d (0.49)	0.33d (0.49)	0.33 ^e (0.49)
T ₁₀ – Untreated control	-	30.67a (5.53)	34.33a (5.86)	36.00a (6.00)	30.33a (5.50)	37.67a (6.14)	41.67a (6.45)	43.00a (6.55)	44.33a (6.65)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray

Figures in paranthesis are square root transformed values

Table 39 : Bioefficacy of eco-friendly insecticides against *C. plutellae* on cabbage (Pooled data)

Treatments	Dosage (g a.i/ha)	Number of cocoons/10 plants								
		First spray					Second spray			
		PT	1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	9.50a (3.08)	9.00cd (3.00)	6.33c (2.51)	5.67cd (2.37)	6.33d (2.51)	4.67cd (2.16)	4.00de (1.74)	4.17d (2.04)	5.50d (2.33)
T ₂ – Emamectin benzoate 5 SG	7.5	12.50a (3.52)	11.50ab (3.38)	7.50c (1.97)	5.83cd (2.42)	5.83de (2.41)	5.50cd (2.35)	4.33d (2.07)	4.33d (2.12)	5.00d (2.23)
T ₃ – Novaluron 10 EC	50	10.83a (3.29)	9.83bc (3.13)	6.67c (2.58)	5.67cd (2.39)	10.00c (3.16)	9.33c (3.05)	8.83c (2.97)	8.00c (3.16)	9.50c (3.08)
T ₄ – Indoxacarb 14.5 SC	35	9.50a (3.08)	8.00d (2.62)	4.17d (2.74)	5.17d (2.26)	5.17e (2.26)	3.50d (1.84)	3.00e (1.74)	3.00 ^e (1.74)	4.17e (2.04)
T ₅ – Bt (Dipel 8L)	60	11.83a (3.44)	11.83a (3.44)	11.33b (3.37)	7.00c (2.65)	10.00c (3.16)	9.67c (3.11)	9.33c (3.05)	13.00b (2.61)	14.00b (3.75)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	11.33a (3.37)	11.33ab (3.37)	11.50b (3.39)	12.00b (3.47)	13.00b (3.61)	13.17b (3.63)	13.33b (3.66)	14.00b (3.74)	15.00b (2.87)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	11.33a (3.36)	10.83ab (3.29)	11.50b (3.39)	11.83b (3.44)	12.83b (3.58)	13.00b (3.61)	13.50b (3.68)	13.67b (3.70)	15.33b (3.92)
T ₈ – NSKE	5%	11.83a (3.43)	11.50ab (3.39)	11.67b (3.41)	12.50b (3.53)	13.33b (3.65)	13.00b (3.61)	13.00b (3.61)	13.50b (3.68)	15.00b (3.88)
T ₉ – Malathion 50 EC	250	10.00a (3.16)	5.17e (2.27)	2.00e (1.42)	3.33e (1.81)	4.67e (2.16)	2.67e (1.63)	2.33e (1.51)	2.83e (1.65)	4.00e (2.00)
T ₁₀ – Untreated control	-	10.83a (3.29)	12.00a (3.49)	14.00a (3.75)	18.50a (4.30)	21.67a (4.66)	22.67a (4.76)	24.00a (4.90)	25.00a (5.00)	27.67a (5.26)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray Figures in paranthesis are square root transformed values

Contd...

Treatments	Dosage (g a.i/ha)	Number of cocoons/plant							
		Third spray				Fourth spray			
		1 DAS	3 DAS	7 DAS	10 DAS	1 DAS	3 DAS	7 DAS	10 DAS
T ₁ – Spinosad 2.5 SC	15	3.33de (1.82)	2.67cd (1.63)	2.17cd (1.46)	4.00c (2.01)	3.67c (1.92)	2.00c (1.40)	1.00cd (0.96)	1.33cd (1.16)
T ₂ – Emamectin benzoate 5 SG	7.5	3.83d (1.96)	2.83cd (1.92)	2.33cd (1.52)	3.33cd (1.83)	2.83cd (1.69)	2.00c (1.40)	0.67cd (0.76)	1.00cd (.96)
T ₃ – Novaluron 10 EC	50	5.67c (2.36)	4.00c (1.97)	3.33c (1.81)	4.00c (1.99)	2.33d (1.52)	1.50c (1.23)	1.50c (1.23)	1.83c (1.35)
T ₄ – Indoxacarb 14.5SC	35	3.50de (1.86)	2.17d (1.45)	1.33d (1.14)	1.50e (1.21)	0.83e (0.83)	0.67d (0.76)	0.50d (0.62)	0.50de (0.62)
T ₅ – Bt (Dipel 8L)	60	13.67b (3.70)	12.83b (3.59)	15.50b (3.94)	16.00b (4.00)	15.00b (3.87)	14.00b (0.73)	14.33b (3.78)	13.83b (3.72)
T ₆ – <i>Nomuraea rileyi</i>	2 g/l	14.83b (3.85)	15.33b (3.92)	15.67b (3.96)	16.00b (4.00)	16.33b (4.04)	16.67b (4.08)	16.67b (4.08)	16.00b (4.00)
T ₇ – <i>Beauveria bassiana</i>	5 g/l	15.33b (3.92)	14.83b (3.85)	15.33b (3.91)	16.33b (4.04)	16.67b (4.08)	17.00b (4.12)	17.67b (4.20)	16.17b (4.02)
T ₈ – NSKE	5%	14.17b (3.77)	15.17b (3.90)	15.67b (3.96)	16.17b (4.02)	16.50b (4.06)	16.83b (4.10)	17.17b (4.15)	16.67b (4.09)
T ₉ – Malathion 50 EC	250	2.50e (1.57)	2.17d (1.47)	1.50d (1.21)	2.50d (1.58)	1.17de (1.09)	0.33d (0.49)	0.33d (0.62)	0.50e (0.49)
T ₁₀ – Untreated control	-	29.83a (5.46)	31.33a (5.60)	34.00a (5.83)	35.83a (5.99)	37.50a (6.13)	41.00a (6.40)	39.00a (6.24)	39.33a (6.26)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

PT – Pretreatment DAS – Days after spray Figures in paranthesis are square root transformed values

T₃ – Adoptive module

T₄ – Bio intensive module

In all the four modules, mustard was sown as trap crop and dichlorvos at 0.1 per cent was used at an interval of 10-15 days for the control of pests on mustard. The results obtained in both the trials have been presented here under.

4.3.1 Diamondback moth : *Plutella xylostella*

The observations on larval number per plant were recorded at 15, 30, 45, 60 and 75 days after transplanting. Efficacy of IPM modules became visible at 15 DAT. This is mainly because of application of neem cake in module III and IV. The discrimination continued till 75 DAT during both the trials. Module III recorded significantly least pest population throughout the period of study (Table 40). Module IV which was bio-intensive, proved significantly superior to RPP (module I) but performed inferior to other modules. Larval population in the first trial remained lowest per plant (1.54) in module III. While module I (RPP) registered higher number of larvae per plant (6.27). Order of superiority of the modules was III > II > IV > I.

During second trial, trend in the efficacy of modules remained same as in the first trial, confirming the superiority of module III by recording lowest larval population at all the intervals of observations. The average larval population was lowest in module III (1.50) and was highest in module I (6.38).

Inference from pooled analysis of the data (Table 41) on the larval population of DBM was no different from the data of two trials. The order of superiority was module III > II > IV > I.

4.3.2 Tobacco caterpillar: *Spodoptera litura*

The observation recorded at 15 DAT revealed significant difference with respect to larval number per plant among the neem cake applied plots and plots without neem cake application during both the trials (Table 42).

Adoptable module was found to be the best treatment with least number of larvae at 30 DAT (0.88 larvae/plant) followed by IIHR module (1.8), biointensive module (3.74) and RPP which recorded highest number of larvae (5.80) and was least effective. Similarly at subsequent intervals of observations adoptable module maintained its supremacy. The lowest mean number of larvae was noticed in adoptable module followed by IIHR, biointensive modules and RPP with average values being 0.96, 1.95, 2.66 and 4.75 larvae per plant, respectively.

Similar was the trend during of second trial where in the adoptable module exhibited supremacy with average of 1.51 larvae per plant. This was followed by IIHR module (2.57 larvae/plant), biointensive module (3.44) and RPP (5.40).

The pooled data of two trials against the tobacco caterpillar indicated the superiority of adoptable module (Table 43). The order of superiority was, module III > II > IV > I with average number of larvae per plant being 1.24, 2.18, 3.05 and 5.04, respectively.

4.3.3 Cabbage leaf webber : *Crocidolomia binotalis*

In first trial, the population density of leaf webber, *C. binotalis* at different intervals 15, 30, 45, 60, and 75 DAT was significantly less in module III (1.32, 0.90, 0.20, 0.08 and 0.06, respectively) and was followed by module II (4.64, 1.49, 0.89, 0.69 and 0.62). Significantly more larval density (4.98, 4.34, 3.36, 3.14 and 2.26) was registered in module I (Table 44). Mean data of larval density was of the order module III < module II < module IV < module I.

Data from second trial suggested superiority of module III over others by recording significantly least larval number per plant. Also module II recorded lowest larval population compared to other two modules. Analysis of pooled data (Table 45) also confirmed the above findings.

4.3.4 Yield

Ultimate yard stick to measure superiority of any treatment is yield and its safety to natural enemies and environment. In the light of above facts, among IPM treatments evaluated against DBM, module III proved its superiority in suppression of the pest with

Table 40 : Effect of IPM modules on *P. xylostella* population in cabbage

Modules	No. of larvae/plant											
	I trial						II trial					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	10.32c (3.29)	7.50d (2.82)	5.64d (2.47)	4.72d (2.27)	3.18c (1.90)	6.27d (2.60)	10.42c (3.30)	7.52d (2.82)	5.82d (2.50)	4.98d (2.33)	3.16c (1.89)	6.38d (2.62)
M ₂ – IIHR Module	9.36c (3.14)	3.04b (1.87)	0.85b (1.16)	0.73b (1.11)	0.08ab (0.76)	2.81b (1.82)	10.19c (3.27)	2.64b (1.76)	0.94b (1.18)	0.62b (1.06)	0.71ab (1.10)	3.02b (1.88)
M ₃ – Adoptive Module	6.06a (2.56)	1.28a (1.33)	0.28a (0.88)	0.10a (0.77)	0.00a (0.71)	1.54a (1.43)	5.70a (2.49)	1.46a (1.40)	0.14a (0.80)	0.16a (0.81)	0.02a (0.72)	1.50a (1.41)
M ₄ - Bio intensive Module	7.44b (2.82)	5.02c (2.34)	3.12c (1.89)	1.56c (1.41)	0.78b (1.08)	3.58c (3.02)	6.80b (2.70)	4.62c (2.26)	3.22c (1.92)	1.54c (1.41)	1.40b (1.38)	3.52c (2.00)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

IIHR – Indian Institute of Horticultural Research

Table 41 : Effect of IPM modules on *P. xylostella* population in cabbage (pooled data of two trials)

Modules	No. of larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	10.37c (3.30)	7.51d (2.83)	5.73d (2.49)	4.85d (2.31)	3.17d (1.91)	6.33 d (2.57)
M ₂ – IIHR Module	10.19c (3.27)	2.84b (1.83)	0.88b (1.17)	0.44b (0.97)	0.27b (0.88)	2.92 b (1.87)
M ₃ – Adoptive Module	5.88a (2.50)	1.37a (1.37)	0.21 a (0.84)	0.13a (0.79)	0.01 a (0.71)	1.52 a (1.42)
M4 - Bio intensive Module	7.12b (2.76)	4.82c (2.30)	3.17c (1.91)	1.55c (1.42)	0.79c (1.12)	3.49c (2.00)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

IIHR – Indian Institute of Horticultural Research

Table 42 : Effect of IPM modules on *S. litura* population in cabbage

Modules	No. of larvae/plant											
	I trial						II trial					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	7.32b (2.79)	5.80d (2.50)	4.72d (2.28)	3.70d (2.04)	2.22d (1.64)	4.75d (2.29)	9.08b (3.09)	6.16d (2.57)	5.08d (2.35)	3.98d (2.10)	2.68d (1.76)	5.40d (2.43)
M ₂ – IIHR Module	6.16b (2.58)	1.80b (1.50)	0.67b (1.08)	0.71b (1.10)	0.40b (0.15)	1.95b (1.57)	8.80b (3.05)	2.64b (1.75)	0.89b (1.18)	0.60b (1.05)	0.67b (1.08)	2.57b (1.75)
M ₃ – Adoptive Module	3.58a (2.02)	0.88a (1.17)	0.16a (0.81)	0.16a (0.81)	0.02a (0.72)	0.96a (1.21)	5.78a (2.50)	1.46a (1.39)	0.22a (0.85)	0.10a (0.77)	0.00a (0.71)	1.51a (1.42)
M ₄ - Bio intensive Module	4.34a (2.20)	3.74c (2.05)	2.56c (1.74)	1.58c (1.42)	1.10c (1.25)	2.66 c (1.78)	6.54a (2.65)	4.08c (2.13)	3.12c (1.89)	1.98c (1.55)	1.46c (1.37)	3.44c (1.98)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

IIHR – Indian Institute of Horticultural Research

Table 43 : Effect of IPM modules on *S. litura* population in cabbage (pooled data of two trials)

Modules	No of larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	8.20c (2.95)	5.98d (2.54)	4.90d (2.32)	3.84d (2.07)	2.45d (1.71)	5.04d (2.35)
M ₂ – IIHR Module	7.62c (2.85)	2.22b (1.64)	0.63b (1.08)	0.60b (1.05)	0.46b (0.98)	2.18b (1.64)
M ₃ – Adoptive Module	4.68a (2.27)	1.17a (1.28)	0.19a (0.83)	0.13a (0.79)	0.01a (0.71)	1.25 a (1.32)
M ₄ - Bio intensive Module	5.44b (2.43)	3.91c (2.21)	2.84c (1.82)	1.78c (1.50)	1.28c (1.32)	3.05 c (1.88)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

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Table 44 : Effect of IPM modules on *C. binotalis* population in cabbage

Modules	No. of larvae/plant											
	I trial						II trial					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	4.98c (2.34)	4.34d (2.19)	3.36d (1.96)	3.14d (1.90)	2.26d (1.64)	3.62d (2.03)	6.20c (2.59)	5.02d (2.34)	4.14d (2.14)	3.12d (1.89)	2.40d (1.69)	4.18d (2.16)
M ₂ – IIHR Module	4.64c (2.27)	1.49b (1.41)	0.89b (1.18)	0.69b (1.09)	0.62b (1.06)	1.67b (1.47)	5.40c (2.43)	1.90b (1.55)	0.99b (1.22)	0.75b (1.12)	0.31b (0.90)	1.87b (1.54)
M ₃ – Adoptive Module	1.32a (1.35)	0.90a (1.17)	0.20a (0.83)	0.08a (0.76)	0.06a (0.75)	0.51a (1.00)	2.52a (1.73)	1.20a (1.30)	0.48a (0.98)	0.22a (0.84)	0.02a (0.72)	0.89a (0.71)
M ₄ - Bio intensive Module	2.72b (1.78)	2.58c (1.75)	2.00c (1.54)	1.70c (1.43)	1.00c (1.16)	2.00c (1.58)	3.76b (2.06)	2.98c (1.86)	1.94c (1.56)	1.16c (1.28)	0.72c (1.10)	2.67c (1.78)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

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Table 45 : Effect of IPM modules on *C. binotalis* population in cabbage (pooled data of two trials)

Modules	No. of larvae/plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	5.59c (2.47)	4.68d (2.27)	3.75d (2.05)	3.13d (1.90)	2.33d (1.67)	3.90d (2.10)
M ₂ – IIHR Module	5.07c (2.36)	1.54b (1.43)	0.80b (1.14)	0.62b (1.06)	0.40b (0.95)	1.57b (1.44)
M ₃ – Adoptive Module	1.92a (1.55)	1.05a (1.24)	0.34a (0.91)	0.15a (0.80)	0.04a (0.73)	0.70 a (1.09)
M ₄ - Bio intensive Module	3.24b (1.93)	2.78c (1.81)	1.97c (1.56)	1.43c (1.37)	0.86c (1.14)	2.06 c (1.60)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

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Table 46 : Yield of cabbage as influenced by IPM modules

IPM module	Yield (t/ha)		Pooled (t/ha)	Net returns (Rs.)	Treatment cost (Rs.)	B:C ratio
	Trial I	Trial II				
M ₁ – RPP Module	20.34d	20.17d	20.25d	20625	4200	4.91
M ₂ – IIHR Module	30.08b	32.27b	31.18b	47950	6300	7.61
M ₃ – Adoptive Module	37.1a	38.39a	37.75a	64375	6810	9.45
M ₄ - Bio intensive Module	24.11c	25.68c	24.89c	37225	5535	6.73

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moderate conservation of natural enemy and highest yield and B:C ratio during both the trials of experimentation. Module II and module IV were next best and recorded significantly higher yield than RPP (module I) (Table 46). Pooled analysis also confirmed superiority of module III by recording the highest yield of 37.75 t/ha followed by module II (31.18), module IV (24.89) and module I (20.25).

4.3.5 Benefit cost ratio

Among the different modules, highest benefit cost ratio (9.45) was observed in adoptable module which was followed by IHR module (7.61) and biointensive module (Table 46).

Results of both the trials and the pooled data indicated that module III comprising application of neem cake @ 500 kg/ha, new insecticide molecules and mustard trap crop proved consistently superior to all other modules by recording lowest larval population, higher yield and high benefit cost ratio.

4.3.6 Effect of IPM components on parasitoid (*C. plutellae*)

Number of parasitoid cocoons per plant differed significantly among the modules, at all the intervals of observation during both trials (Table 47). Significantly higher density of parasitoid cocoons was recorded by module IV with average value of 6.4 cocoons/plant during first trial. This was followed by module II (4.9 cocoon) and module III (3.8 cocoon) which were significantly superior over module I (RPP).

In the second trial also significantly least number of parasitoid cocoons were recorded in module I compared to rest of the modules at all the intervals of observation. Similar trend was noticed in the pooled data (Table 48).

On the strength of superiority of IPM treatments in lowering the pest activity and conserving or encouraging parasitoids to exert supplementary effect in the control of DBM, registering higher yield and benefit cost ratio, module III (Adoptable module) appeared to be the best IPM package (Plate 11) followed by module II (IHR module). Despite safety of module IV (bio intensive module) to parasitoids it was ineffective to suppress the target pest and increase yield and was ineffective costwise. However, it was superior than module I (RPP) which was least effective in controlling the pest and was harmful to natural enemies (Plate 12).

Table 47 : Effect of IPM modules on *C. plutellae* population in cabbage

Modules	No. of cocoons /10 plants											
	I trial						II trial					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	9.00d (3.08)	3.60d (2.02)	1.40c (1.35)	0.80d (1.12)	0.00c (0.71)	2.96c (1.86)	7.60b (2.74)	3.60d (2.01)	1.80c (1.50)	1.00c (1.19)	0.20c (0.81)	2.84c (1.83)
M ₂ – IIHR Module	11.60b (3.48)	6.00b (2.54)	3.60b (2.01)	2.40b (1.70)	1.20ab (1.30)	4.96ab (2.34)	13.40a (3.72)	5.80b (2.50)	3.80ab (2.07)	2.80ab (1.81)	1.40ab (1.37)	5.44ab (2.44)
M ₃ – Adoptive Module	10.20c (3.27)	4.60c (2.26)	2.20c (1.64)	1.40c (1.37)	0.60b (1.02)	3.80b (2.07)	11.00a (3.38)	4.80c (2.29)	3.00b (1.84)	2.00b (1.57)	1.00b (1.22)	4.36b (2.20)
M ₄ - Bio intensive Module	14.20a (3.83)	7.20a (2.77)	5.40a (2.42)	3.60a (2.01)	1.60a (1.43)	6.40a (2.63)	14.80a (3.91)	7.00a (2.73)	4.80a (2.30)	3.80a (2.07)	2.20a (1.60)	6.52a (2.65)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

RPP - Recommended Package of Practice

IIHR – Indian Institute of Horticultural Research

Table 48 : Effect of IPM modules on *C. pluteae* population in cabbage (pooled data of two trials)

Modules	No. of cocoons /10 plant					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	Mean
M ₁ – RPP Module	8.30c (2.94)	3.60d (2.02)	1.60d (1.44)	0.90d (1.17)	0.10c (0.77)	2.90 c (1.84)
M ₂ – IIHR Module	12.50ab (3.60)	5.90b (2.53)	3.70b (2.04)	2.60b (1.76)	1.30ab (1.33)	5.20ab (2.39)
M ₃ – Adoptive Module	10.60b (3.33)	4.70c (2.28)	2.60c (1.76)	1.70c (1.48)	0.80b (1.13)	4.08b (2.14)
M ₄ - Bio intensive Module	14.50a (3.87)	7.10a (2.76)	5.10a (2.36)	3.70a (2.04)	1.90a (1.53)	6.46a (2.64)

In a column means followed by the same alphabet do not differ significantly by DMRT (0.05%)

Figures in paranthesis are square root transformed values

DAT – Days after transplanting

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Plate 11. Adoptable module plot showing completely protected plants



Plate 12. RPP module plot showing damaged plants

V. DISCUSSION

The investigations on diamondback moth embodying the construction of life tables, analysis of key mortality factors, effect of organic amendments along with the sequential spray of indigenous technologies known (ITK's), botanicals on the pest population, evaluation of ecofriendly insecticides and comparison of different IPM modules in pest management have been carried out in order to formulate a sound management strategy against notorious pest species diamondback moth. The information on various aspects was investigated in detail. The findings are discussed in the light of earlier work and presented here under.

5.1 LIFE TABLE STUDIES

Construction of life tables for 8 generations during 2 years period was carried out to fill in the lacunae to harness the potentialities for the utilization of natural enemies which seem to be a safe approach for an organic cabbage cultivation. So far no work has been reported on life mortality tables for *P. xylostella* on cabbage from Dharwad region.

Studies on biology of the pest under laboratory and field conditions, the number of generations occupied by the pest in each cropping season, the total period for each generation, the population density of various stages of the pest in different generations, construction of life mortality tables and interpreting these tables by survivorship and death rate curves and finally determining the key mortality factors affecting the population fluctuation have been discussed here under.

5.1.1 Life cycle of the pest

Abraham and Padmanabhan (1968), Patil and Pokharkar (1971), Jayaratham (1977), Bhalla and Dubey (1986), Devjani and Singh (1999) and Chauhan *et al.* (1999) have studied the biology of this insect from different places of the country. During the present study, observations on the biology were recorded under laboratory and field conditions.

Egg

In the present study, the duration of egg period was found to be 3 days both in summer and rainy seasons and 3-4 days in winter under laboratory conditions. The incubation period was found to range from 3-11 days at temperatures ranging from 26-15°C (Kanervo, 1936), 4-6 day at Kodaikanal, (Abraham and Padmanabhan, 1968), 4-6 days in Maharashtra at 80-72°F (Patil and Pokharkar, 1971), 3-4 days at Bangalore (Jayarathnam, 1977) and 3-4 days in Himachal Pradesh (Chauhan *et al.*, 1997). The mean incubation period was 3.10 days (Bhalla and Dubey, 1986) and 2.18 days at Manipur (Devjani and Singh, 1999).

Larva

Morphological characters and habits of all the larval instars, more or less corroborated with the earlier observation. There were 4 larval instars which confirm the earlier reports. Including the pre pupal period, the total larval period lasted on an average of 10.81, 12.1 and 16.8 days in summer, rainy and winter seasons respectively under laboratory conditions.

But in the field it varied considerably over 2 seasons. On an average, total larval period occupied 20-21 days during rainy season and 23-24 days during winter. This variation can be attributed to the variation in climatic factors. These findings are in agreement with Abraham and Padmanabhan (1968), Patil and Pokharkar (1971) and Jayarathnam (1977).

Pupa

Mature IV instar larvae in majority of the cases were found to pupate on the lower side of leaves. The average pupal period lasted for 3.8, 4.2 and 4.9 days during summer, rainy and winter seasons, respectively in the laboratory and 4 days in rainy and 5 days in winter seasons under field conditions. However, earlier workers reported the pupal period at 6.5 – 11 days (Abraham and Padmanabhan, 1968), 4-5 day (Jayarathnam, 1977), 4-15 days (Chelliah and Srinivasan, 1986) and a mean pupal period of 6.86 days in Manipur (Devjani and Singh, 1999), 5.9 days in Solan (Chauhan *et al.*, 1999).

Adult

Morphological characters of adult moth during the present investigations were as described by earlier workers.

Under laboratory conditions the mated and fed male and female adults lived for 9.7 and 11.7 days with females living longer. These findings are in accordance with the previous studies.

Fecundity

In the laboratory females with food, laid 123-260 eggs, on an average of 195.43 eggs per female. Hassanein (1958) reported the fecundity per female to range from 0-252 under different temperatures under laboratory condition. Average of 284 (Patil and Pokharkar, 1971), 221.6 (Jayarathnam, 1977), 153 (Devjani and Singh, 1999) and 201 eggs (Sharma *et al.*, 1999) have been reported.

5.1.2 Interpretations of life table data

Life tables for 8 generations could be constructed (4 during rainy and 4 during cold seasons) on 4 crops employing the methods described by Morris and Miller (1954) and Harcourt (1969). Perusal of the life tables constructed for both the years of study revealed that only one mortality factor contributed towards the generation mortality of DBM. The different aspects of life table study are discussed here under.

Totally, 2 parasitoids and one spider predator species have been recorded on *P. xylostella* as natural enemies in Dharwad region during the present investigations. In general, parasitization by parasitoids was the major mortality influencing factor. Among the parasitoids, *T. sokolowskii* was dominant which caused heavy parasitization (upto 48.96%) on pupal stage on winter crop during both the years. It was *C. plutellae* which caused heavy mortality of the pest population in LP2 during rainy season of both years of study causing mortality to the tune of 37.75 per cent.

Though the parasitoids were major mortality factors, they were unable to regulate the pest population. This may be because inability of the parasites to multiply at higher rate than the pests and seasonality of action of these two parasitoids.

Reena (2000) also reported only two parasitoids on DBM viz., *C. plutellae* and *T. sokolowskii* in Dharwad. Several workers have reported parasitization ranging from 12.3 to 80 per cent and 28 to 98 per cent for *C. plutellae* and *T. sokolowskii*, respectively. Parasitoids appear to be the dominant group of natural enemies of DBM in the present investigation which is in agreement with Chiu *et al.*, 1974; Yaseen, 1974; Ooi, 1979, Velasco, 1983; Chua and Ooi, 1986; Joshi and Sharma, 1974; Yadav *et al.*, 1979; Yadav *et al.*, 1975; Nagarkatti and Jayanth, 1982; Jayarathnam, 1977; Chandramohan, 1994; Mustaque and Mohyuddin; 1987, Reena, 2000; Chauhan *et al.*, 1997; Reddy and Singh; 1998; Fan and Ho, 1971; Devi *et al.*, 2004; Badjena and Mandal, 2005 and Devjani and Singh, 2006.

Only one unidentified spider predator was found feeding on the early instar larvae of DBM in the field. Among the predators Jayarathnam (1977) recorded 3 species of spiders preying on DBM. However, during the present investigation only one spider species was found. As it was very rare, no observations could be recorded on its role as a mortality factor. As some of the mortality factors such as predators and weather factors did not leave clear evidence of death of the pest, these factors were pooled and collectively taken as unknown factors. Thus, apart from parasitization the other mortality factors included, infertility of egg stage and unknown causes in all the stages of DBM. The effect of meteorological factors on the population fluctuation has not been included in the life table preparation since the present studies were conducted inside the laboratory. However, the difference between the expected and actual counts in the field recorded in life table (Table 8 to 17) indicated the extent of adverse effect of these parameters on the insect population.

5.1.2.1 Survivorship and death rate curves

The survivorship and death rate curves drawn for all the generations in each year (Fig. 1 to 4) indicated that in general, the mortality rate was constant in all the stages and hence, mortality at later stage of development like LP3, pupa and adult contributed more for the population reduction.

The average survivorship and death rate curves of the pest is depicted in Fig. 5. The mean death rate curve for 8 generations indicated highest death rate in pupa followed by LP2. However, the average death rate curves for four generations each during rainy and winter seasons, clearly demarcated the seasonal activity of the parasitoids. The activity of larval

parasitoid, *C. plutellae* was maximum during rainy season and that of larval pupal parasitoid, *T. sokolowskii* in winter.

The seasonal activity of the parasitoids are in confirmation with the findings of Jayarathnam (1977) who reported that the activity of larval parasitoid *C. plutellae* to be more in rainy season and larval pupal parasitoid, *P. sokolowskii* during winter. The generation survivability declined from I generation in crop I to II generation in crop IV (0.2 to 0.015). It was also clear that the pest survivability was comparatively low during second year of study (2006-07).

5.1.3 Key mortality factors causing population fluctuation of DBM

Employing the graphical method of Varley and GradWell (1960), the mortality curves for various stages (k) were drawn against the total mortality (K) (Fig. 6). The curve which exhibited similar trend to that of K curve was considered to be containing the key factor. During the present investigation kP followed by kLP3 exhibited similarity. Thus, the key factor during the period of study included parasitization by *T. sokolowskii* in LP3 as well as in P stages of the pest. The role of parasitoids in causing mortality of DBM under field conditions has been emphasized by several workers as discussed in the early part of this chapter. The findings on the determination of key mortality factors affecting the population of DBM are in agreement with Jayarathnam (1977) and Reddy and Singh. (1998).

5.2 MANAGEMENT OF DBM THROUGH ORGANIC APPROACH

5.2.1 Evaluation of organic soil amendments

Insecticidal control of DBM has posed problems of resistance development and pesticide residues in cabbage and hence switching over to organic agriculture with development of a non-chemical package or a programme with least pesticide usage is need of the hour in cabbage production. In this context, use of organic soil amendments and botanical pesticides in crop production assume greater significance. With this idea in back ground an attempt has been made in the present study to know the effect of various organic amendments along with a non-chemical spray sequence on pest activity and management on cabbage in two field trials during 2005 and 2006.

5.2.1.1 Diamondback moth (*Plutella xylostella*)

From tables 18 and 19 it is clear that, least mean larval population of *P. xylostella* was recorded in NC-500-SS and NC-250-SS which were on par with recommended package of practices (RPP). Moderate larval density was noticed in rest of the treatments with VC, PC and PM. Whereas, UTC registered maximum larval population at all the intervals of observation during the period of experimentation (Fig. 7).

However, the literature pertaining to effect of organic soil amendments in DBM management appears scanty except the following reports. Krishnamoorthy *et al.* (2001) who reported soil application of neem cake @ 250 kg/ha revealed significant reduction in larval population of DBM to less than 2 per plant cent as compared to more than 5 per plant in check.

Similarly, Chakraborti (2001) reported that superiority of presowing application of neem cake @ 300 kg/ha, followed by foliar application of NSKE and 1-2 applications with phosphamidon to be effective against DBM which was significantly superior to chemical check. However, in the present study RPP was superior over other treatments with neem cake application. Perhaps the absence of any chemical in the spray sequence in the present study might be the reason for variation of these results. Further Krishnamoorthy *et al.* (1998) reported 3 applications of NSKE 4 per cent to be adequate to reduce DBM population from more than 40 per cent to negligible level.

5.2.1.2 Tobacco caterpillar (*Spodoptera litura*)

Neem cake treated plots proved its supremacy in reducing larval incidence which were comparable to with RPP (Table 21 and 22). This was followed by application of VC at two dosages over other treatments. UTC at all the intervals of observation recorded highest larvae per plant (Fig. 7).

LEGEND

Tr. No.	Treatment Details
T ₁	Vermicompost 1.25 t/ha-SS
T ₂	Vermicompost 2.5t/ha-SS
T ₃	Neem cake 250kg/ha-SS
T ₄	Neem cake 500kg/ha-SS
T ₅	Pongamia cake 250 kg/ha-SS
T ₆	Pongamia cake 500kg/ha-SS
T ₇	Poultry manure 1t/ha-SS
T ₈	Poultry manure 2t/ha-SS
T ₉	Recommended package of practice
T ₁₀	Untreated check

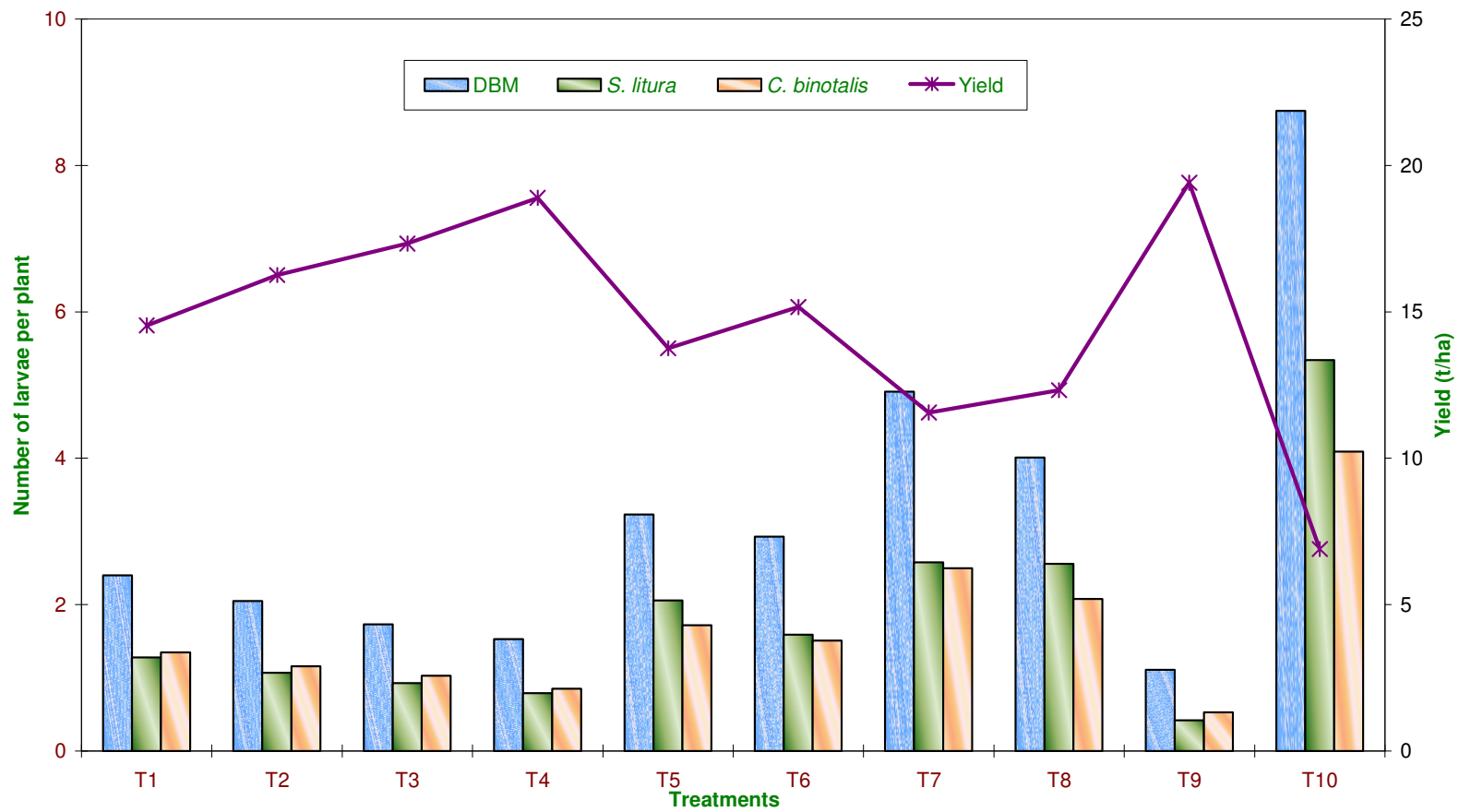


Fig. 7 : Efficacy of various organic amendments and spray sequence on larval population of cabbage pests and yield (pooled data)

Fig. 7 : Efficacy of various organic amendments and spray sequence on larval population of cabbage pests and yield (pooled data)

Relevant literature on this aspects is lacking. However, the report of Mallikarjun Rao *et al.* (1998) who showed the combined efficacy of soil application of neem cake @ 500 kg/ha and seedling root dip with 1 per cent neem oil and 1 per cent neem spray at weekly intervals to be effective against *S. litura* in chilli eco-system supports the present findings. Similarly Ravikumar (2004) reported the application of neem cake @ 1 t/ha to be as effective as RPP by recording significantly less larval population in chilli. The reports by Mallikarjun Rao *et al.* (1998) and Vijayalakshmi *et al.* (1996) revealed the effectiveness of neem, chilli in combination with cow urine which gave moderate control of *S. litura* upto 13 days of spraying lend some support to the present findings.

5.2.1.3 Cabbage leaf webber (*Crociodolomia binotalis*)

From Tables 22 and 23 it is evident that NC-500-SS at all the intervals of observations recorded significantly lowest leaf webber population followed by NC-250-SS. The treatments with vermicompost were next to follow these treatments with neem cake. UTC was found to record highest larval density throughout the period of experiment. However, rest of the treatments were found to be inferior to vermicompost but significantly superior to UTC.

Literature pertaining to the efficacy of organic amendments and botanicals in managing the cabbage leaf webber are lacking. Hence comparative analysis could not be made.

Neem cake is the important byproduct obtained after extraction of oil from kernels. Neem cake contains two per cent bitter terpenoids mainly azadirachtin which is responsible for the anti ovipositional, antifeedant, growth disrupting, fecundity and fitness reducing properties on insects. Pest suppressing activity of neem cake may be attributed primarily to certain phenolic compounds released during decomposition apart from stimulatory effect on root growth (Meerabai and Asha, 2001). Hence reduced activity of pests on cabbage crop receiving applications of neem cake could be attributed to these properties.

Vermicompost contains both major and minor plant nutrients in available forms, besides enzymes, antibiotics, vitamins and plant growth hormones which have definite advantage over organic manures. This would probably make plant system more defensive against pest infestation level and they might enhance tolerance level of the plant (Giraddi *et al.*, 2003).

On the other hand organic manures constitute a dependable source of both major and minor plant nutrients. Addition of organic manures improves soil physical, chemical and biological properties. During decomposition, these organic manures yield organic compounds, organic acids as well as antibiotic substances as intermediate products. These products on absorption by plants increase their resistance to pest and diseases (Meerabai and Asha, 2001). The present results throw light on the induced resistance through variation in chemistry of the plant as influenced by source of plant nutrition provided by different organic amendments.

However the increase in the larval population of all the pests at 30 DAT in treatments with organic amendments (Table 18 to 23) may be attributed to the dissipation of the product in environment and this is evident in the study of Krishnamoorthy *et al.* (2001) who reported superiority of split application of neem cake against vegetable pests.

Further at the remaining intervals of observation *viz.*, 45, 60 and 75 DAT the larval load of all the three pests went on reducing in organic amendments applied plots which can be attributed to the efficacy of NSKE in controlling the pest population. These results of the present study corroborated with the earlier works of Krishnamoorthy *et al.* (1998); Mallikarjun Rao *et al.* (1998); Vijayalakshmi *et al.* (1996) and Dhanraj (2000) who reported the moderate efficacy of NSKE in controlling cabbage pests.

5.2.1.4 Yield

Treatment effect was manifested on yield in both the years of study.

The pooled data of yield indicate significantly higher yield of cabbage in the treatment with NC-500-SS (18.9 t/ha) and NC-250-SS (17.34 t/ha). These were found to be on par with RPP (19.2 t/ha). While others were next in the order. Significantly less yield (6.9 t/ha) was recorded in control (Table 24). Relevant literature could not be traced to make comparative analysis.

5.2.1.5 Larval parasitoid (*Cotesia plutellae*)

The mean values of number of parasitoid cocoons/10 plants during both the years of study (Table 25) and pooled data (Fig. 8) indicated the supremacy of UTC followed by $T_7 > T_8 > T_5 > T_6 > T_1 > T_2 > T_3 > T_4 > T_9$ in having the number of parasitoids cocoons. RPP was found to have least number of cocoons.

There is lack of information on the effect of organic amendments on the solitary endo larval parasite of DBM (*Cotesia plutellae*) to compare with the present findings.

Earlier reports by Sannaveerappanavar (1995), Jyothi *et al.* (2001) and Reena (2000) indicated slight toxicity to complete safety of NSKE to *C. plutellae*. They are in accordance with the present findings where in all the treatments with organic amendments and non chemical spray sequence recorded significantly higher parasitoid cocoons than RPP. However, these were inferior to UTC. The reason for this might be the reduction in availability of number of host larvae thus indirectly lowering the parasitoid activity.

5.2.2 Evaluation of ecofriendly insecticides

Exploration of fauna for biocidal activity has been uninterrupted endeavour in search of ecofriendly insecticides for pest management. The pest management strategies envisage harmonious blending of effective components of pest control methods in the light of the importance of conserving natural enemies, while pesticides are being used as a tool for the control of DBM. Studies on bioefficacy of new molecules of insecticides *viz.*, spinosad, emamectin benzoate, novaluron, indoxacarb along with malathion, NSKE, *N. rileyi*, *B. bassiana* and *B. thuringensis* (dipel 8L) were tried against diamondback moth. Efficacy of these on other pests such as tobacco caterpillar, cabbage leaf webber and hazards of these on potential larval endoparasitoid of DBM *C. plutellae* were also recorded in two field trials during 2005 and 2006.

5.2.2.1 Diamondback moth (*Plutella xylostella*)

In the present study all the new molecules of insecticides gave good protection against DBM throughout the crop period with maximum population reduction on third day after spray except insect growth regulator (Novaluron) which exhibited maximum efficacy only on seventh day after spray indicating slow mode of action. In all the four sprays spinosad gave maximum per cent larval reduction which was on par with emamectin benzoate and were significantly superior over others. These were followed by the superiority of indoxacarb, novaluron and dipel.

LEGEND

Tr. No.	Treatment Details
T ₁	Vermicompost 1.25 t/ha-SS
T ₂	Vermicompost 2.5t/ha-SS
T ₃	Neem cake 250kg/ha-SS
T ₄	Neem cake 500kg/ha-SS
T ₅	Pongamia cake 250 kg/ha-SS
T ₆	Pongamia cake 500kg/ha-SS
T ₇	Poultry manure 1t/ha-SS
T ₈	Poultry manure 2t/ha-SS
T ₉	Recommended package of practice
T ₁₀	Untreated check

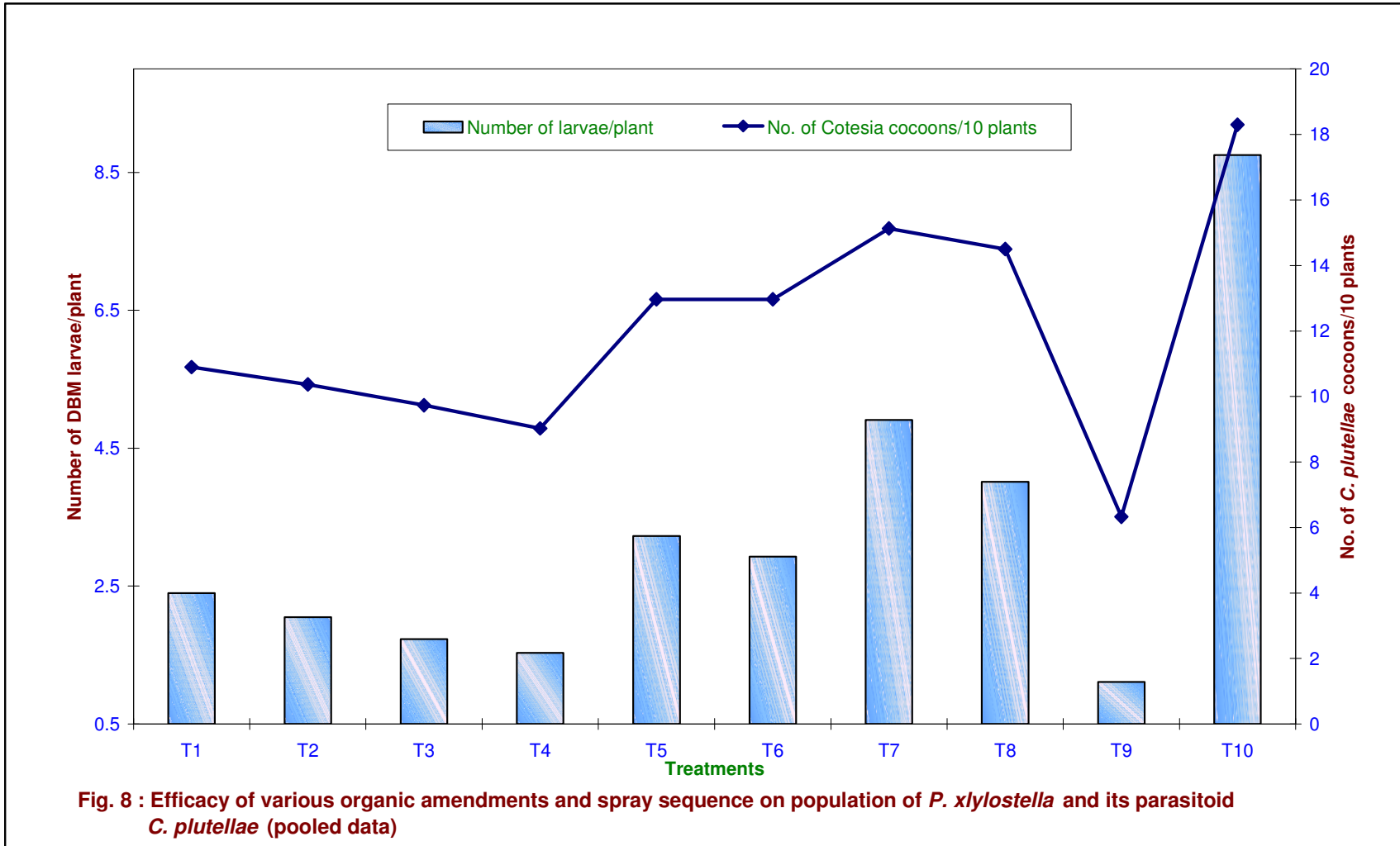


Fig. 8 : Efficacy of various organic amendments and spray sequence on population of *P. xylostella* and its parasitoid *C. plutellae* (pooled data)

This was also clearly indicated by the pooled data of two years with spinosad giving 96 per cent larval reduction followed by emamectin benzoate (88.1%) which was on par with it. Indoxacarb exhibited larval reduction of 79.4 per cent. While, novaluron and Bt gave moderate control with 59.68 and 47.62 per cent respectively. Next in the order of effectiveness were *B. bassiana* (41.28%), NSKE (35.64%) and malathion (27.32%). However, *N. rileyi* proved ineffective against DBM (Table 29).

During the present investigation, spinosad, a fermentation product of soil actinomycete, *Saccharopolyspora spinosa* with noval mode of action having strong larvicidal property and emamectin benzoate, to be excellent at 15 g a.i/ha and 7.5 g a.i/ha, respectively against DBM followed by indoxacarb at 35 g a.i/ha.

Several workers have reported the effectiveness of spinosad and emamectin benzoate against DBM (Peter *et al.*, 2000; Walunj *et al.*, 2001; Dey and Somchaudhary 2001, Rachappa *et al.*, 2004; Peter and Vedham, 2001; Arora *et al.*, 2003; Pramanik and Chatterjee, 2004; Wu *et al.*, 1998; Xiao *et al.*, 1999; Shi *et al.*, 2004; Kumar and Devappa, 2006 and Kanna *et al.*, 2005a and b). The superiority of indoxacarb against DBM are in accordance with the works of many of the earlier authors (Babu *et al.*, 2002a, Babu *et al.*, 2002b, Liu *et al.*, 2003 and Athira, 2002).

In the present study the insect growth regulator, novaluron exhibited maximum efficacy only after 7 DAS indicating slow mode of action which is in agreement with the findings of Dhanraj (2000), Thambe *et al.* (1997) and Harishkumar and Jaglan (2005b). However, moderate control of DBM was achieved with novaluron 50 g a.i/ha in the present investigation which is in accordance with Harishkumar and Jaglan (2005a and 2005b). However, with reports of Sangareddy *et al.* (1999), Maheshkumar *et al.* (1999), Dhanraj (2000) and Kulkarni (2001) revealed novaluron to be highly effective against DBM which is in variance with present findings. One possible reason for variation in the results during the present investigation may be attributed to development of resistance by the pest to the particular insecticide (Wu *et al.*, 1998).

Moderate control given by Bt against DBM are in agreement with several reports (Rajamohan and Jayaraj, 1978; Anon., 1989; Justin *et al.*, 1990; Panchabhavi and Sudhindra, 1994; Kulkarni *et al.*, 1995; Dhanraj, 2000; Jastotia and Suri, 2002 and Pokharkar *et al.*, 2002).

5.2.2.2 Tobacco caterpillar (*Spodoptera litura*)

In the present study all the new molecules of insecticides tested gave good protection to the crop from tobacco caterpillar during crop growth stage. IGR gave maximum protection only at seven days after spray while the remaining new insecticides gave maximum protection at three days after spray compared to one, seven and ten DAS. In all the four sprays taken on the crop spinosad resulted in maximum per cent larval reduction followed by emamectin benzoate and indoxacarb. However, novaluron, Bt and rest of the treatments improved in their efficacy against the pest with the subsequent sprays.

Pooled data of two years clearly indicated good efficacy of spinosad against tobacco caterpillar at 3 days after 3rd spray with 95.17 per cent in larval reduction which was on par with emamectin benzoate (85.01%). Rest of the treatments in the order of superiority were indoxacarb, novaluron and Bt with 78.97, 70.74 and 59.44 per cent larval reduction, respectively (Fig. 9). *N. rileyi* was the least effective. During the present investigation spinosad and emamectin gave higher protection to the crop followed by indoxacarb, novaluron and Bt. This is mainly attributed to strong larvicidal properties of the insecticides. The present findings revealed that spinosad and emamectin benzoate are superior against *S. litura*. Which are in accordance with the works of Paliwal (2000), Peter *et al.*, (2000), Dhanraj (2000), Dey and Somchaudhary (2001) and Pramanik and Chatterjee (2002).

Similarly, the toxicity of indoxacarb in the present study was supported by works of Srivastava and Pande (2003) and Ladaji (2004) against *S. litura* on chickpea in laboratory and field studies, respectively. The findings of Rao *et al.* (2001), Pramanik and Chatterjee (2004), Patil and Jamadagni (2006) who reported the effectiveness of various IGR's against *S. litura* in different crop ecosystems supported the good performance of novaluron against the target insect. Moderate control of Bt against *S. litura* was reported by Rajamohan and Jayaraj (1978), Amonkar *et al.* (1985), Nagamani *et al.* (1995), Zoz (1990) and Dhanraj (2000).

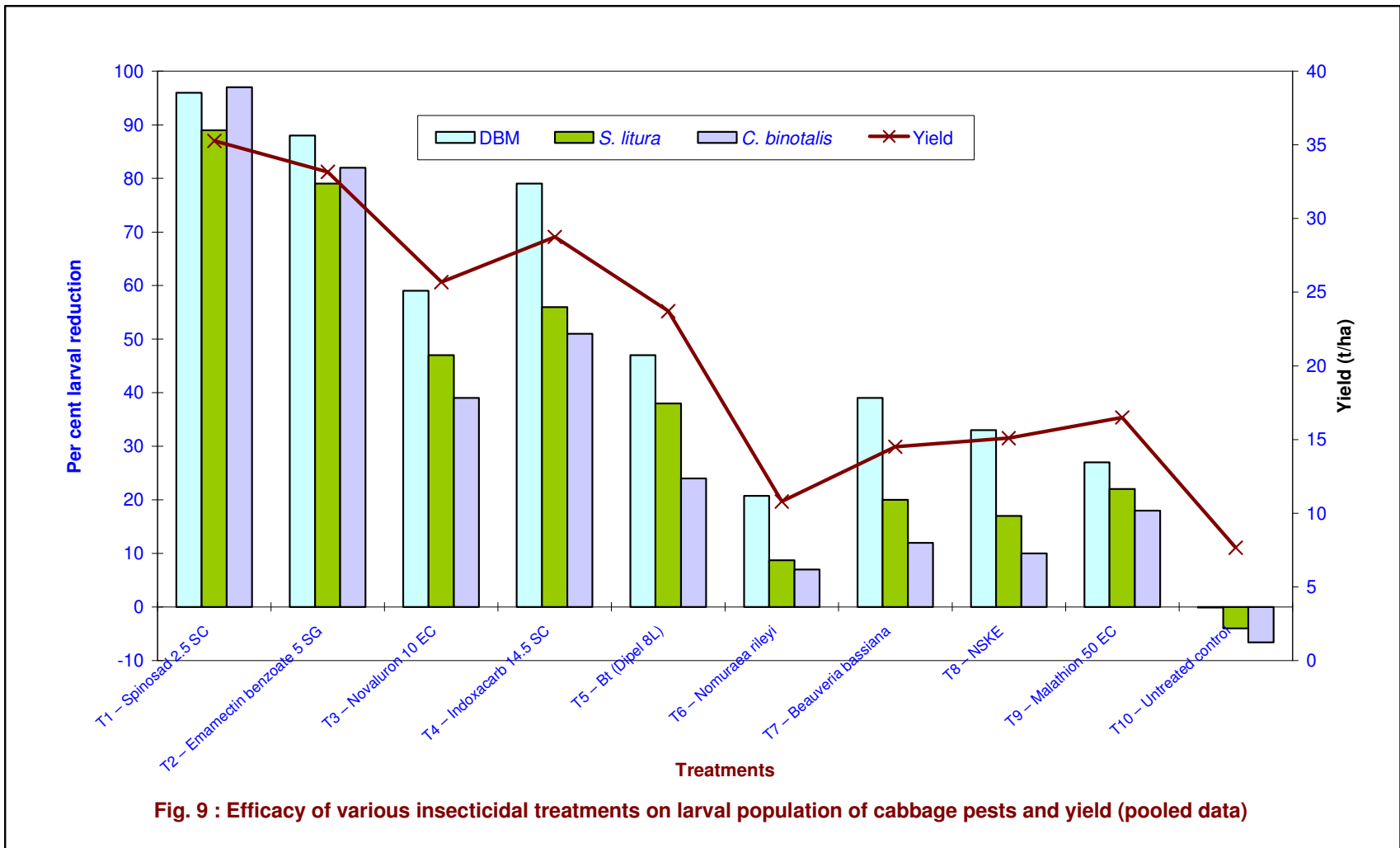


Fig. 9 : Efficacy of various insecticidal treatments on larval population of cabbage pests and yield (pooled data)

Fig. 9 : Efficacy of various insecticidal treatments on larval population of cabbage pests and yield (pooled data)

5.2.2.3 Cabbage leaf webber (*Crociodolomia binotalis*)

All the five molecules tested gave good protection to the crop by reducing the pest appreciably when compared to *N. rileyi*, *B. bassiana*, NSKE and malathion. Novaluron resulted in maximum larval reduction on seventh day after spray where as the rest of the ecofriendly molecules caused highest larval reduction three days after spray.

Spinosad resulted in maximum per cent larval reduction in all the three sprays imposed on the crop after the pest appeared. This was on par with emamectin. Indoxacarb was next best treatment followed by novaluron, dipel and other treated molecules which enhanced their efficacy in the subsequent sprays.

Pooled data of two years indicated the dominance of spinosad in controlling the cabbage leaf webber with 97.56 per cent reduction in larval numbers followed by emamectin benzoate (92.62%), indoxacarb (84.45%), novaluron (70.99%) and dipel (51.05%) at 1 and 3 days after III spray.

Literature pertaining to bioefficacy of indoxacarb against the pest is not available. The superiority of spinosad and emamectin benzoate in controlling the cabbage leaf webber in the present study is in conformity with work of Peter *et al.* (2000), Dhanraj (2000) and Ghosh *et al.* (2001). Similarly, better efficacy of IGRs against *C. binotalis* is in accordance with Bhavani and Punnaiah (2004) and Goud *et al.* (2006). Similarly the findings of Gopalkrishnan and Vishalakshi (2001) and Dhanraj (2000) endorses the present findings on Bt efficacy.

5.2.2.4 Incidence of larval parasitoid (*Cotesia plutellae*) of DBM

It is seldom borne in mind about implication of chemical spraying on the survival and development of natural enemies in or on the host body. Pesticides as they destroy the target species, can knock off the parasitoids as well. Conservation of natural enemies of pest species has been considered vital component in formulating the integrated control strategies. The consensus has been that such system would be fairly stable and lower the pesticide load in the environment.

DBM is attacked by mainly *C. plutellae* in its larval stage. The parasitization by this may go as high as 80 per cent (Jayarathnam, 1977). To take full advantage of these parasitoids, knowledge on the toxicity of chemicals to the parasitoids becomes essential in the integration of biological and chemical methods.

Considering the pooled data of two years, the safety of treatments was observed in recording higher number of pupae of *C. plutellae* which was in the order of UTC > *N. rileyi* = *B. bassiana* = NSKE = dipel > novaluron = spinosad = emamectin benzoate > indoxacarb > malathion based on their degree of toxicity (Fig. 10).

The insecticide treated plots invariably recorded lesser number of pupae of *C. plutellae* mainly due to direct toxicity of insecticides on natural enemies. The toxicity of insecticides to *C. plutellae* observed in the present study is in agreement with the findings of Reena (2000) who reported NSKE 2 per cent and neemark (2.0%) to be completely safe to *C. plutellae*. The safety of Bt to the parasitoid as revealed in the present study are in accordance with the findings of Asokan and Mohan (1996), Kao and Tzeng (1990), Rejesus and Soyaboc (1990), Lim *et al.* (1986) and Athira (2002) who observed no significant difference in per cent parasitism between Bt treated and untreated plots.

Novaluron in the present study ranked next to Bt in terms of its safety to *C. plutellae* followed by spinosad and emamectin benzoate at all the intervals of observations till third spray. These results are in agreement with the findings of Haseeb and Amano (2002) who reported 3 IGR's viz., chlorfluazuron (5%), flufenoxuron (10%) and diflubenzuron (5%) to be selective against the parasitoid *C. plutellae*. Also reports of Dey and Somchaudhary (2001) who observed, spinosad @ 15-25 g a.i./ha to show very little adverse effect on *C. plutellae* and Shi *et al.* (2004) who reported selectivity of emamectin benzoate to the parasitoid are in agreement with the present findings. At the end of fourth spray there was decline in number of parasitoid cocoons/plant in all these three treatments. This reduction in the parasitoid population in novaluron, spinosad and emamectin benzoate treated plots might be due to the reduction in availability of number of host larvae or due to killing of host larvae before the completion of parasitoid development and thus, indirectly lowering the parasitoid activity (Basappa, 1995 and Athira, 2002).

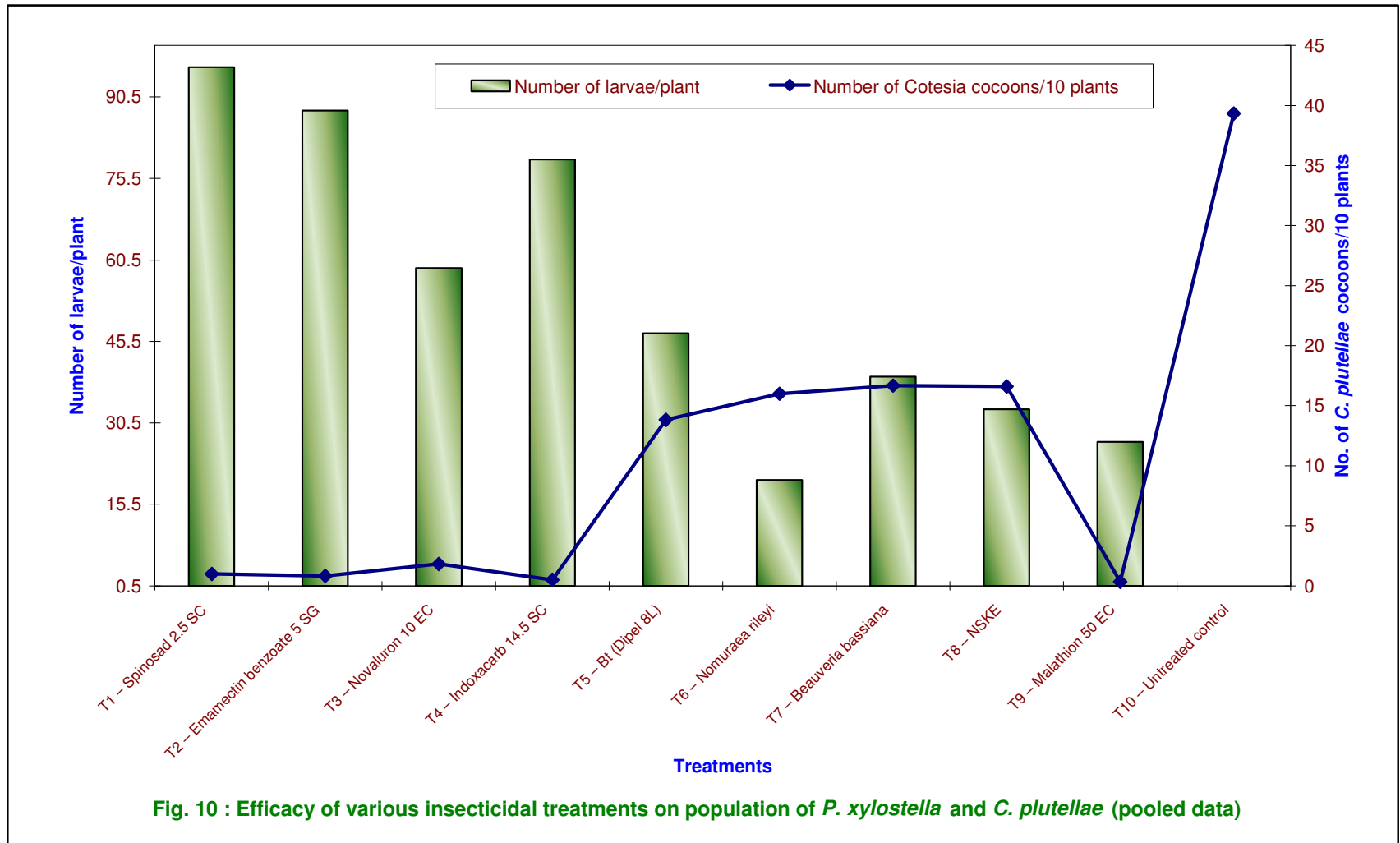


Fig. 10 : Efficacy of various insecticidal treatments on population of *P. xylostella* and *C. plutellae* (pooled data)

5.2.2.5 Yield

Among the treatments spinosad registered highest yield and proved as highly productive treatment (Table 36). This is in agreement with earlier reports (Dhanraj, 2000, Rachappa *et al.*, 2004, Walunj *et al.*, 2001 and Athira, 2002). This was found to be on par emamectin benzoate treated plots (33.17 t/ha). These findings corroborate with the results of (Kumar and Devappa, 2006 and Kanna *et al.*, 2005b).

Indoxacarb recorded 28.76 t/ha which was next to spinosad and emamectin benzoate. This is in agreement with findings of Athira (2002) who reported indoxacarb as next best treatment to spinosad with respect to yield.

Similarly, the higher yields registered in novaluron are in accordance with the results of Sangareddy *et al.* (1999) and Dhanraj (2000).

5.3 EVALUATION OF IPM MODULES

Investigations on the control of insect pests mostly have been focused on individual methods in almost all crops. Cabbage is no exception to this. Insecticides have been used extensively on combating pests of cabbage. However, their increased use has resulted in development of resistance in insect pests, fragile ecosystem, scoring low on sustainability, product quality and environment safety. Search for an environmentally acceptable tool in the management of DBM and other cabbage pest is a global attempt for reasons unknown beyond simple explanation. An attempt has been made in the present study to develop and evaluate two packages for the management of target pest and economic feasibility for adaptation by the growers.

First set included integration of neem cake application @ 500 Kg/ha, mustard trap crop and new insecticide molecules to develop IPM module and evaluated for effectiveness. In the second set neem cake application @ 250 Kg/ha, mustard trap crop, use of egg parasitoid and safer insecticide to non-target agents were integrated. These two were tried for their effectiveness vis-à-vis recommended package of practice and IIHR module.

5.3.1 Diamondback moth : *Plutella xylostella*

Significantly less mean population of DBM was recorded in M-III which was followed by M-II and M-IV. Significantly higher number of DBM larvae were noticed in M-I (Fig. 11a).

At 15 DAT significantly less number of DBM larvae were noticed in treatments with neem cake application. Effectiveness of organic amendments (neem cake) against DBM has been documented by various workers (Chakraborti, 2001; Krishnamoorthy *et al.*, 2001). However, in the subsequent intervals of observation module III maintained its supremacy which received spinosad, emamectin sprays and Bt sprays. This was followed by module II. However, bio-intensive module recorded less pest load than RPP.

The present findings are in confirmation with Peter *et al.* (2000), Dey and Somachaudhary (2001), Rachappa *et al.* (2004), Kumar and Devappa (2006). Kanna *et al.* (2005a and b) who reported spinosad and emamectin to show excellent efficacy against DBM.

5.3.2 Tobacco caterpillar : *S. litura*

The larval count at 15 DAT was significantly less in modules with neem cake application which is in accordance with works of Mallikarjun Rao *et al.* (1998) who reported soil application of neem cake in combination with 1 per cent neem spray at weekly interval was found to be effective against *S. litura* in chilli.

However, in rest of the intervals of observations, module III with neem cake, spinosad, emamectin benzoate and Bt application maintained its supremacy in maintaining the low population density followed by module II with Bt spray alone (Fig. 11c). Effectiveness of these chemicals against *S. litura*, has been documented by Dey and Somachaudhary (2001), Paliwal (2000) Peter *et al.* (2000), Dhanraj (2000), Pramanik and Chatterjee (2002) in cabbage as discussed earlier in this chapter, which lends support to the present findings.

5.3.3 Cabbage leaf webber : *Crociodolomia binotalis*

Data presented in tables 44 and 45, revealed significantly less mean larval density in M-III followed by M-II and M-IV. M-I recorded significantly higher larval density at all the intervals of observation (Fig. 11d). Different soil amendments like neem cake tried against *L.*

orbonalis gave significant reduction of larvae in brinjal (Mallikarjun Rao *et al.*, 1998). These reports corroborate the present findings. Further, the present findings are in conformity with report of Srinivasan and Krishnamurthy (1992a), Dhanraj (2000) who observed IPM plots with mustard trap recorded less larval load of the pest in cabbage. Similarly Peter *et al.* (2000) and Ghosh *et al.* (2001) reported spinosad and emamectin benzoate to give good control of the pest.

5.3.4 Yield

Among different IPM modules, significantly higher yield was recorded in module III compared to rest of the modules (Table 46). However, lower yield level was noticed in M-I (Fig. 12).

Cost effectiveness of each IPM module could be assessed based on net returns. Among the different IPM modules, M-III was found to be highly cost effective by recording highest net returns (Rs. 64,950), followed by M-II (Rs. 47,950) and M-IV (Rs. 37,225), M-I recorded lowest net returns (Rs. 20,625).

5.3.5 Larval parasitoid (*Cotesia plutellae*)

Data from Table 47 and 48 revealed least mean density of parasitoid cocoon in M-I. Higher activity of parasitoids in modules IV, and II indicates the safety of components used. However, module III gave moderate conservation of natural enemy (Fig 11b). Safety of soil amendments and other biorationals to natural enemies has been already discussed earlier in this chapter.

Thus taking into consideration the superiority in pest suppression along with, moderate conservation of larval parasitoid, increased yield and benefit cost ratio, the adoptable module comprising application of neem cake, mustard trap crop and sprays of spinosad, emamectin benzoate and Bt was the best when compared to rest of the modules.

FUTURE LINE OF WORK

1. Exploitation of predominant natural enemies like *Cotesia plutellae* and *Tetrastichus sokolowskii* in the pest management of *Plutella xylostella* through mass production and release.
2. Detail studies on integration of organic soils amendments (neem cake application) larval parasitoids, neem seed kernel extract and ecofriendly insecticides in the management of cabbage pests
3. Large scale evaluation of adoptable module developed for the management of diamondback moth

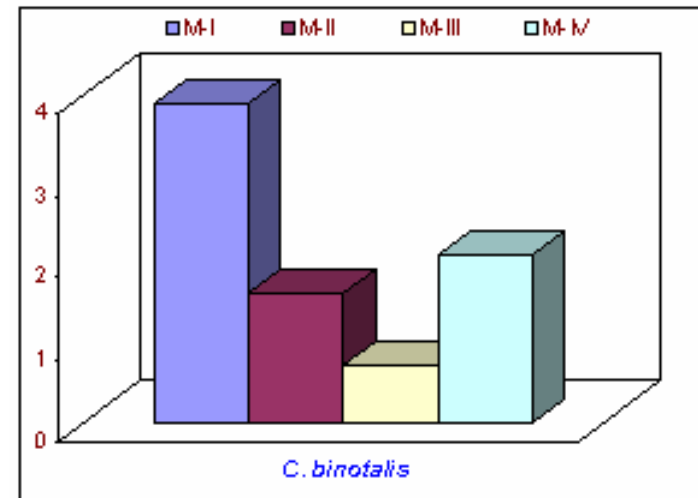
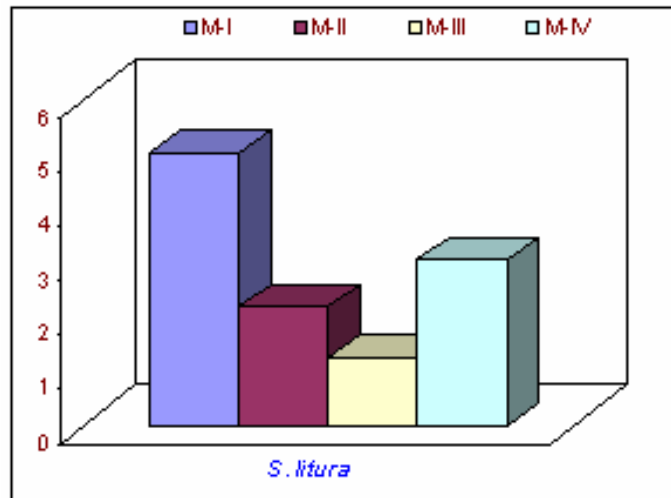
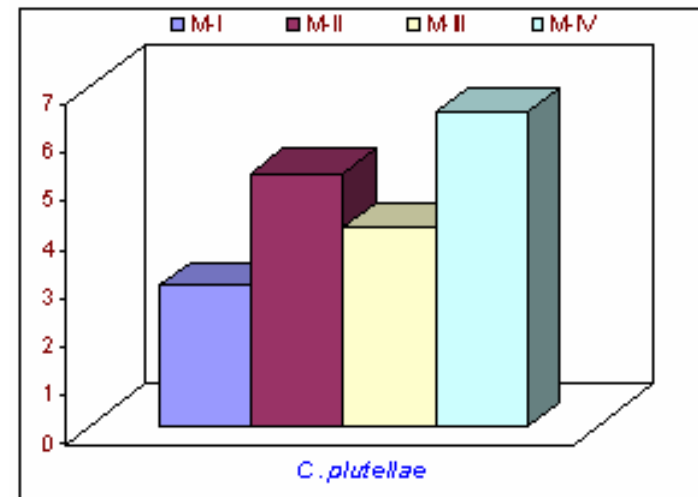
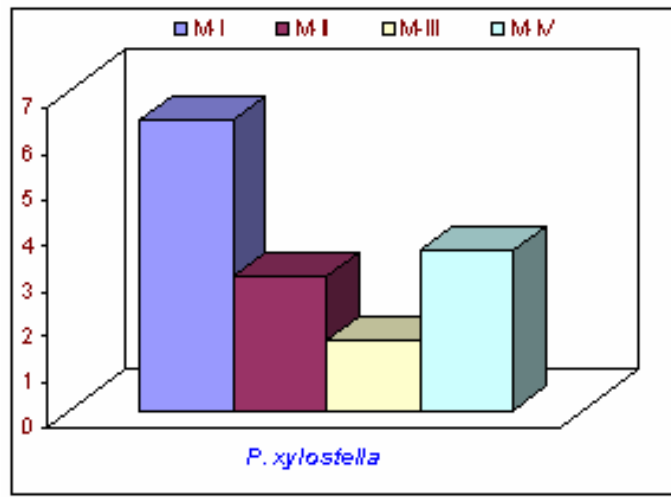


Fig. 11 : Effect of different modules on pest complex and natural enemy in cabbage (pooled data)

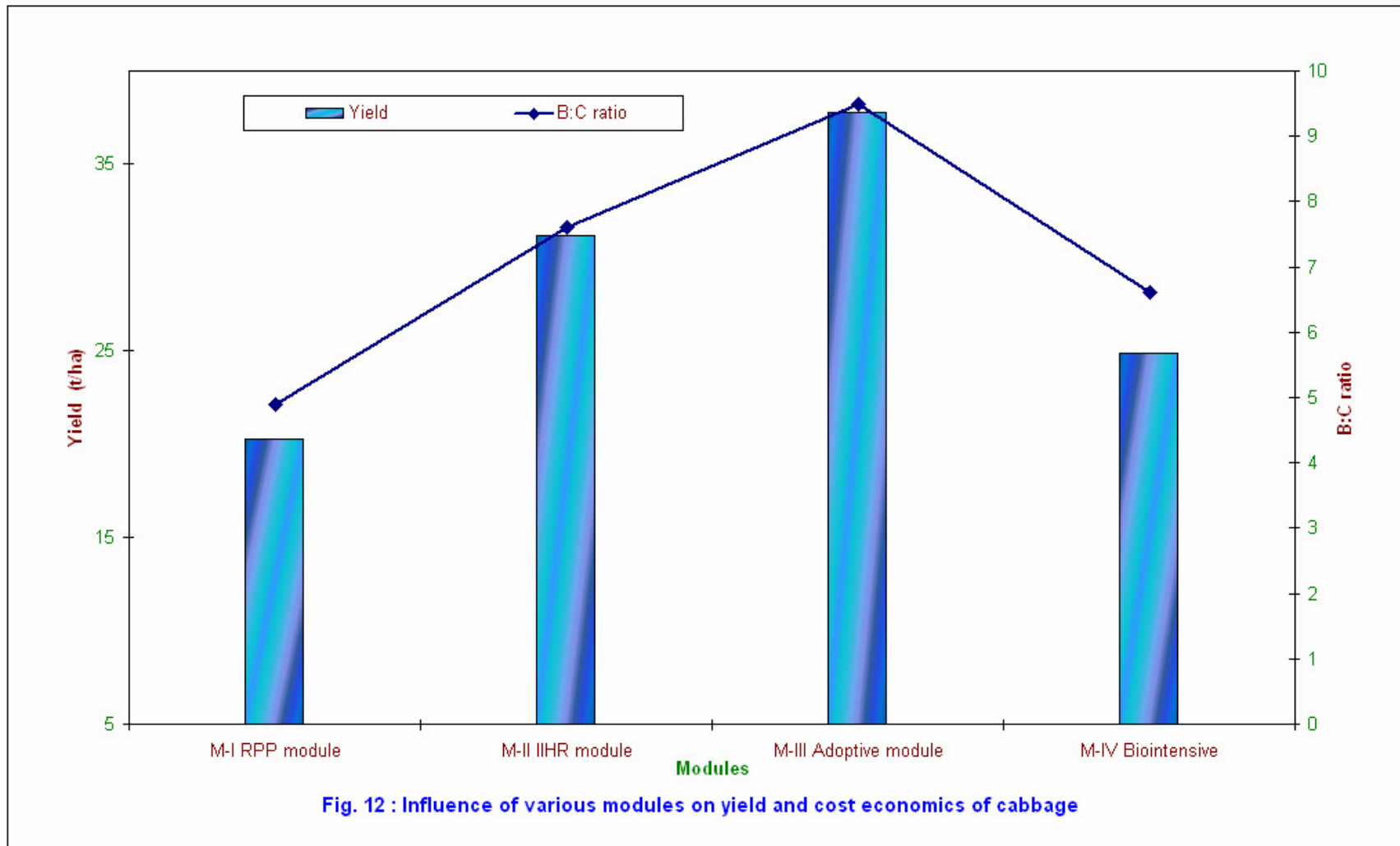


Fig. 12 : Influence of various modules on yield and cost economics of cabbage

VI. SUMMARY

The study on population dynamics of pests is an important field of research in entomology. The necessity of this branch of insect ecology in the adoption and practice of pest management principles is well established. Studies on diamondback moth were undertaken during 2005 to 2006 and 2006 to 2007 at Garag village and Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The focal objectives of the study included

1. Identification of key mortality factors contributing towards the control of diamondback moth and construction of life tables.
2. Management of diamondback moth through organic approach involving a) organic amendments, botanicals and vermiwash b) ecofriendly insecticides.
3. To develop and compare IPM modules against DBM

Adequate knowledge on the biology of the pest is an essential pre-requisite in the study of population dynamics. In the present study, it was found that the total life cycle of the pest and morphology of each stage was similar in both laboratory and field conditions. But the difference in the total life cycle was found in the three seasons. The incubation period of egg, total larval period and pupal period ranged between 3-4, 10-18 and 3-6 days, respectively for the three seasons. There were four larval instars. Longevity of mated male and female were 9-11 and 10-13 days correspondingly. First instar larvae were found to live in leaf mines and II instar fed with head and thorax buried in shallow feeding pith. Only mature IV instar larvae fed voraciously on leaves of cabbage. Average fecundity per female ranged between 108-269 eggs during three seasons.

Studies on the population dynamics of the pest were carried out by preparing life tables for 8 generations of *P. xylostella* for the first time in Dharwad region (four generations in rainy season and four in cold season). Only two important parasitoids were recorded on *P. xylostella* viz., the larval parasitoid, *Cotesia plutellae* and the larval-pupal parasitoid *Tetrastichus sokolowskii* which caused 18-44 per cent and 4-48 per cent parasitization of larval period 2 and pupae, respectively. The incidence of *C. plutellae* was more in rainy season while in winter season, *T. sokolowskii* was predominant. No egg parasitoid of *P. xylostella* was recorded.

The survivorship and death rate curves indicated, high mortality rate in larval period 2 and pupal stage. Generation survivability declined from first to last generation (0.2 to 0.015). The major mortality factor in pupal stage was parasitization by *T. sokolowskii* which was identified as the key mortality factor. Another key mortality factor recorded in life table studies was parasitization by *C. plutellae* in larval period 2.

Soil application of organic amendments viz., neem cake @ 500 kg/ha followed by sprays of vermiwash, garlic chilli kerosene extract + cow urine, NSKE 5 per cent and Neemazol at 10 days interval starting from 22 DAT recorded significantly lower population of *P. xylostella*, *S. litura*, *C. binotalis* and the treatment was comparable to the standard check, 100 per cent RDF + RPP. The treatment recorded 18.9 t/ha yield as compared to 19.41 t/ha in case of RPP. The same spray sequence with neem cake @ 250 kg/ha (instead of 500 kg/ha) was next best in terms of larval reduction and increase in yield. The activity of *C. plutellae* in plots with organic interventions was normal as compared to RPP, indicating its safety.

Among the different insecticides tested, spinosad (2.5 SC) @ 15 g a.i./ha, emamectin benzoate (5 SG) @ 7.5 g a.i./ha, indoxacarb (14.5 SC) @ 35 g a.i./ha, novaluron (10 EC) @ 50 g a.i./ha and dipel (8L) @ 60 g a.i./ha in that order proved significantly superior in reducing the larval population of *P. xylostella*, *S. litura* and *C. binotalis* through out the crop period. Spinosad proved to be highly cost effective by recording highest IBCR (13.71) followed by indoxacarb (10.34). However, emamectin benzoate (7.99) exhibited selective toxicity to the larval parasitoid *C. plutellae*. Among the tested chemicals dipel, novaluron, spinosad and emamectin benzoate in the mentioned order were found to be safe to the parasitoid.

Among different IPM modules evaluated, M-III (Adoptable module) comprising of mustard trap crop, application of neem cake @ 500 kg/ha + 50 per cent RDF super imposed with sprays of Bt, spinosad and emamectin benzoate was found to be the most effective module against *P. xylostella*, as well as against *S. litura* and *C. binotalis*. Higher yield

of 37.75 t/ha and net returns of Rs. 64,375/- was recorded in M-III followed by M-II (IHR module), M-IV (bio intensive module) and M-I (RPP). All IPM modules supported good activity of the parasitoid in the crop ecosystem compared to RPP.

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Appendix – II : Market rate for inputs and outputs

Sl. No.	Particulars	Quantity	Cost (Rs.)
Inputs			
1	Neem cake	1 quintal	400.0
2	Pongamia cake	1 quintal	800.0
3	Poultry manure	1 quintal	150.0
4	Vermicompost	1 quintal	100.0
5	Urea	Tonne	5000
6	DAP	Tonne	9900
7	MOP	Tonne	4600
8	Garlic	1 kg	25.00
9	Chilli	1 kg	6.00
10	Kerosene	1 lit	30.00
11	Neem seeds	1 kg	40.0
12	Neemazol	1 lit	300.0
13	Spinosad	1 lit	1300
14	Emamectin benzoate	1 kg	10500
15	Novaluron	1 lit	3000
16	Indoxacarb	1 lit	3000
17	Dipel	1 lit	860.0
18	<i>N.rileyi</i>	1 kg	200.0
19	<i>B. bassiana</i>	1 kg	250.0
20	Malathion	1 lit	300.0
21	Dichlorvos	1 lit	360.0
22	Halt	1 kg	1200
23	<i>Trichogramma bactrae</i>	1 card	70.00
Outputs			
1	Cabbage	1 quintal	250.00
Others (Labour services)			
1	NSKE preparation		50/-
2	Labour requirement	Per spray	3 No.
3	Labour charges	Per spray	Rs.50/labour
4	Spray volume	1 spray	500 l/ha

LIFE TABLE STUDIES AND MANAGEMENT OF DIAMONDBACK MOTH, *Plutella xylostella* L. THROUGH ORGANIC APPROACH IN CABBAGE

SHAILA H. M.

2007

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Major advisor

ABSTRACT

Investigations on the topic were undertaken during 2005 to 2007 at University of Agricultural Sciences, Dharwad and Garag village. Eight life tables of *Plutella xylostella* have been constructed for the first time in Dharwad region (four generations in rainy season and four in cold season). Only two important parasitoids were recorded on *P. xylostella* viz., the larval parasitoid, *Cotesia plutellae* and the larval-pupal parasitoid *Tetrastichus sokolowskii* which caused 18-44 per cent and 4-48 per cent parasitization of larval period 2 and pupae, respectively. These were the major key mortality factors. The incidence of *C. plutellae* was more in rainy season while, in winter season, *T. sokolowskii* was predominant.

Soil application of neem cake @ 500 kg/ha followed by sprays of vermiwash, garlic chilli kerosene extract + cow urine, NSKE 5 per cent and Neemazol at 10 days interval was comparable to the standard check, 100 per cent RDF+RPP in reducing the pest population and recording high yield.

Among different insecticides tested, spinosad (2.5 SC) @ 15 g a.i./ha, emamectin benzoate (5 SG) @ 7.5 g a.i./ha, indoxacarb (14.5 SC) @ 35 g a.i./ha proved significantly superior in reducing the larval population of *P. xylostella*, *Spodoptera litura* and *Crociodolomia binotalis* through out the crop period. Spinosad proved to be highly cost effective (IBCR 13.71). Among the tested chemicals dipel, novaluron, spinosad and emamectin benzoate in the mentioned order were found to be safe to the parasitoid.

Among IPM modules evaluated, Adoptable module comprising of mustard trap crop, application of neem cake @ 500 kg/ha + 50 per cent RDF super imposed with sprays of Bt, spinosad and emamectin benzoate offered good protection against the defoliators and proved cost effective. This was followed by IIHR module. All IPM modules supported good activity of the parasitoid in the crop ecosystem compared to RPP.