PESTS OF CABBAGE (*Brassica oleracea* L. var. *capitata*) AND CAULIFLOWER (*Brassica oleracea* L. var. *botrytis*) AND THEIR MANAGEMENT

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DECLARATION

I hereby declare that this thesis entitled **"Pests of cabbage (*Brassica oleracea* L. var. *capitata*) and cauliflower (*Brassica oleracea* L. var. *botrytis*) and their management"** is a bonafied record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Pests of cabbage (*Brassica oleracea* L. var. *capitata*) and cauliflower (*Brassica oleracea* L. var. *botrytis*) and their management** " is a record of bonafide research work done independently by Mr. G.B Ravi (2011-11-165) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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DEDICATED TO

MY GUIDE

MY BELOVED PARENTS
AND

MY BROTHER

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LIST OF ABBREVIATIONS

@	-	at the rate of
°C	-	Degree Celsius
%	-	Per cent
mg	-	Milligram
g	-	Gram
Kg	-	Kilogram
Kg^{-1}	-	Per Kilogram
CD	-	Critical difference
mm	-	millimetre
cm	-	Centimetre
m	-	Metre
µl	-	Micro litre
ml^{-1}	-	per millilitre
ml	-	Millilitre
h	-	Hour
sp.	-	Species
PI	-	Pest infestation Index

DAT	-	**Days After Treatment**
WAP	-	**Weeks After Planting**
PTC	-	**Pre treatment count**
CIB&RC	-	**Central Insecticide Board and Registration Committee**
SC	-	**Suspension concentrate**
EC	-	**Emulsifiable concentrate**
SG	-	**Soluble granules**
LT_{50}	-	**Lethal time taken for killing 50 per cent of tested caterpillars**
et al.	-	**And others**
Fig.	-	**Figure**
ha	-	**Hectare**
ha^{-1}	-	**Per hectare**
i.e.	-	**That is**
viz.	-	**Namely**
l	-	**Litre**
l^{-1}	-	**Per litre**
Sl No.	-	**Serial Number**

NS	**-**	**Not significant**
RH	**-**	**Relative humidity**
SD	**-**	**Standard deviation**
rpm	**-**	**Rotations per minute**
min^{-1}	**-**	**Per minute**

INTRODUCTION

1. INTRODUCTION

Cabbage *(Brassica oleracea* L. var. *capitata*) and Cauliflower (*Brassica oleracea* L. var. *botrytis*) are the two important cool season vegetables widely grown in all parts of India. According to the National horticultural database (2011), area under cultivation of cabbage is 0.369 million hectare with a total production of 7.949 million tonnes and average productivity of 21.5 tonnes. Cauliflower is cultivated in an area of 0.369 million ha with an annual production of 6.745 million tonnes and average productivity of 18.3 tonnes.

Being succulent, these crops are severely attacked by pests. Bonnemaison (1965) reviewed the distribution of pests attacking crucifers all over the world and reported nearly 51 insect species. In India, a total of 37 insect pests have been reported to feed on cabbage (Lal, 1975). The diamondback moth (DBM), *Plutella xylostella* (Linnaeus); cut worm, *Spodoptera litura* (Fabricius); cabbage butterfly *Pieris brassicae* L.; head borer, *Hellula undalis* Fabricius cause appreciable loss (Bhalani, 1984). Incidence of all these pests varies from season to season (Sachan and Gangwar, 1990) and region to region (Chaudhuri *et al.* 2001).

Cabbage and cauliflower being highly remunerative, commercial growers apply large quantities of insecticides which are often calendarbased rather than needbased. This practice not only accelerates the production cost but also worsens the ecosystem. As these vegetables are consumed raw or with little cooking, they must be free of pesticide residues. Integrated approaches for sustainable pest management are therefore highly warranted. Use of biopesticides, botanicals and new generation insecticides are some of the emerging alternatives to conventional insecticides.

In Kerala, cultivation of cabbage and cauliflower was earlier restricted to the cooler seasons in the hilly tracts. With the introduction of new tropical varieties it has become popular in the plains too. However, the pests attacking these crops in the new ecosystem has not been documented so far.

Considering the above factors, the present investigation entitled "Pests of cabbage and cauliflower (*Brassica oleracea* L. var. *capitata*) and cauliflower (*Brassica oleracea* L. var. *botrytis*) and their management" was undertaken to get detailed information on the following aspects.

1. Pests and natural enemies occurring in cabbage and cauliflower grown in Kerala.
2. Nature and extent of damage caused by the pests.
3. Biology of the major pest in the plains.
4. Abiotic factors affecting the population build up of the major pest.
5. Effect of entomopathogens, botanicals and new generation insecticides under laboratory conditions.
6. Field performance of the promising botanicals and insecticides
7. Residue levels of promising insecticides in plant and soil samples at the time of harvest.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In Kerala, the two major cruciferous vegetables, *viz.* cabbage (*Brassica olearaceae* var. L. *capitata*) and cauliflower (*Brassica olearaceae* L. var. *botrytis*) were cultivated only in the hilly tracts of Idukky and Wayanad during the cool seasons. With the development of tropical short duration varieties that can grow well under high temperatures, cultivation of these crops gained popularity in the plains of Kerala too (George, 2009). Though some information on pests of these crops in the hilly tracts is available, there is a dearth of knowledge about the pest complex and their management strategies in the new ecosystem. Considering the present scenario of cultivation of these crops in Kerala, detailed investigation on the pests and natural enemy complex occurring in these crops and management strategies of the major pests were undertaken.

2.1 Species diversity of pests of cabbage and cauliflower

A worldwide survey on cruciferous pests conducted by Bonnemaison (1965) revealed the presence of 51 insect pests which included four hemipterans, five lepidopterans, nine dipterans, three hymenopterans and the remaining 30, grouped as biting insects.

From India, as early as in 1914, Fletcher reported nine major pests from cruciferous vegetables. However, Patil and Pokharkar (1982) reported 21 insects from cabbage in Maharashtra, of which the major ones were cut worm, *Spodoptera litura* (Fab.), cabbage leaf webber, *Crocidolomia binotalis* Zell., head borer, *Hellula undalis* (Fab), cabbage butterfly *Pieris brassicae* (L.) and flea beetle, *Phyllotreta* spp. Srinivasan and Murthy (1991) and Chaudhuri *et al.*, (2001) reported Diamondback moth, *Plutella xylostella* (L.), head caterpillar, *C. binotalis*, webworm, *H. undalis*, cabbage butterfly, *Pieris brassicae* (Linn.) and *P. rapae* (L.), aphids, *Lipaphis erysimi* (Kalt.), *Brevicoryne brassicae* (L.) and flea beetle,

Phyllotreta cruciferae Goeze. as the important pests of crucifers. Devjani and Singh (2002) reported 24 insect pests attacking cauliflower in Imphal, of which twelve were from Lepidoptera, six from Hemiptera, three from Coleoptera, two from Orthoptera and one from Diptera.

2.1.1 Order : Lepidoptera

2.1.1.1 Diamondback moth *Plutella xylostella* (L.) (Plutellidae)

Severe infestation of Diamondback moth (DBM) *P. xylostella* was reported from Tamil Nadu (Abraham and Padmanabhan, *1968*) and Bangalore (Govindan, 1972). High infestation was reported by Khaire *et al.* (1987) from Maharashtra and Bhatia and Verma (1993) from Himachal Pradesh. Shankar *et al.* (1996) reported DBM as the most destructive pest of crucifers all over the world, while Zhang (1994) reported it all over Asia. The pest was recorded on cabbage, cauliflower, broccoli, brussel sprouts, collard, kale, kohlrabi, raddish, turnip, watercress and imported cabbage (Telekar and Shelton, 1993). Kfir (1998) reported six different species of genus *Plutella* on *Brassica,* with limited geographical distribution and *P. xylostella* as the cosmopolitan species. It was reported from temperate countries even before planting crucifers (Capinera, 2000). *P. xylostella* was recorded as one of the major pests of crucifers in Bangladesh (Ahmed *et al.*, 2002), cauliflower in Varanasi (Umashankar *et al.,* 2005), cabbage in Bhubaneswar (Mishra, 2009), cabbage during dry season (Dadang *et al.,* 2009) and cabbage in Rajasthan (Meena and Singh, 2010; Bana and Jat, 2012). It was enlisted as a key pest of cauliflower in Jaipur by Rao and Sharma (2012).

2.1.1.2 Cut worm *Spodoptera litura* (Fab.) (Noctuidae)

S. litura multiplied enormously in cabbage in Karnataka (Mallapur, 1988; Dhanaraj, 2000); in Andhra Pradesh (Murthy, 1994; Lavanya, 1995; Dey and Somchoudhury, 2001). In Bangladesh and Himachal Pradesh, it was found to attack both cabbage and cauliflower (Ahmed *et al.*, 2002). Patait *et al.* (2008) observed that *Spodoptera* population in cabbage was more during winter than in rainy season when cultivated in Latur district of Maharashtra. Mishra (2009) reported it as a major pest affecting heads of cabbage grown in Bhubaneswar, and it was reported to cause heavy infestation when grown in coastal plains of Orissa (Mandal *et al.*, 2009). Dhawan and Matharu (2011) reported *S. litura* as the major pest in tropics and subtropics of India on crucifer crops.

2.1.1.3 Leaf webbers *Crocidolomia* spp. (Pyralidae)

Devjani and Singh (2002) reported *C. binotalis* as sporadic pest of early, mid and late season crops of cauliflower in Manipur. Cabbage leaf webber, *C. pavonana* (Fabricius) (synonymous to *C. binotalis* Zeller) was reported as the major insect pest of cabbage and other cruciferous crops by Dadang *et al.* (2009). Mishra (2009) reported *C. binotalis* as a major head damaging pest on cabbage in Bhubaneswar. Venkateswarlu *et al.* (2011) reported that among the different pests, maximum damage was caused by cabbage leaf webber during curd formation stage of cabbage in New Delhi.

2.1.1.4 Cabbage butterfly *Pieris brassicae* (L.) (Pieridae)

Feltwell, (1978) reported cabbage butterfly, *P. brassicae* as a serious pest of cabbage, cauliflower and many other crucifers distributed along temperate, tropical and subtropical regions of the world. In India, it passes winter in plains and migrates to hilly regions during summer (Gupta, 1984). *P. brassicae* was reported as the most widely distributed and

destructive cosmopolitan pest of cruciferous crops in Himachal Pradesh by Bhatia and Verma (1993). It was reported as a serious pest of cole crops grown in winter as well as summer crop in Himachal Pradesh (Verma *et al.*, 1994). Sharma *et al.* (2002) reported that among the many insect pests, cabbage butterfly, *P. brassicae* was the major pest in mid hill region of Solan during winter season on cabbage. In India, *P. brassicae* was distributed along the plains of Himalayan region except the southern plain (Raquib, 2004). It was reported as a serious pest of cabbage, cauliflower, broccoli, brussels sprout, turnip, radish and toria in different parts of the world by Anurag *et al.* (2009). Dadang *et al.* (2009) reported it as the major insect pest on cabbage and other cruciferous crops. It was also considered as one of the most widely distributed of all the lepidopterans in cruciferous vegetables by Hasan and Ansari (2010). Venkateswarlu *et al.*, (2011) reported that maximum damage was caused by *P. brassicae* during curd formation stage of cabbage.

2.1.1.5 Cabbage head borer *Hellula undalis* (Fab.) (Pyralidae)

Among the different insect pests of cauliflower, *H. undalis* was reported as the major pest causing damage both in the seedling and vegetative stages of the crop (Sandhu and Bhalla, 1973). The cabbage head borer was reported as the most important Lepidopteran pest of cabbage in West Bengal by Dey and Somchoudhury (2001). Devjani and Singh (2002) observed *H. undalis* as a sporadic pest of early and late crops of cauliflower in Manipur. *H. undalis* was reported to cause maximum damage during vegetative stage of cabbage in New Delhi (Venkateswarlu *et al.*, 2011). Dhawan and Matharu (2011) reported *H. undalis* as a serious pest in cruciferous crops in tropics and subtropics.

2.1.1.6 Semiloopers (Noctuidae)

Among the semiloopers, *Trichoplusia ni* (Hubner) was reported as the major pest of cabbage in Dharwad and Belgaum districts of Karnataka (Mallapur, 1988). *Plusia* sp. occurred as a minor pest of cabbage in Central Kenya (Odour *et al.,* 1997). *Plusia signata* Fab. and *Thysanoplusia orichalcea* (Fab.) were observed as sporadic pests of early, mid and late season crop of cauliflower in Manipur (Devjani and Singh, 2002). *T orichalcea* was reported as the major pest of cabbage in mid hills of Himachal Pradesh (Puja and Vinay, 2009).

2.1.2 Order : Hemiptera

2.1.2.1 Aphids (Aphididae)

Myzus persicae (Sulz.) and *Brevicoryne brassicae* (Linn.) were reported as the major pests of cabbage in India (Mallapur, 1988; Chaudhuri *et al.,* 2001). *B. brassicae* as a key pest associated with winter cabbage crop in mid hills of Himachal Pradesh was reported by Bhatia and Verma (1994). *B. brassicae* was reported as a major pest of cabbage in Central Kenya also (Oduor, 1997). *M. persicae* and *Lipaphis erysimi* (Kalt.) were recorded as regular pests whereas *Aphis gossypii* Glover was recorded as sporadic and *B. brassicae* was seen as occasional pest of cauliflower in Manipur (Devjani and Singh, 2002). Badjena and Mandal (2005) reported *M. persicae* as the major one followed by *B. brassicae* and *L. erysimi* on cauliflower in Bhubaneswar. According to Mishra (2009) *B. brassicae* was the major head damaging pest of cabbage in Bhubaneswar. *L. erysimi* and *B. brassicae* were reported to cause maximum damage at vegetative stage of cabbage (Venkateswarlu *et al.*, 2011). Among the pests of cabbage, *L. erysimi* was observed as the major pest in semi-arid region of Rajasthan causing significant losses (Bana and Jat, 2012).

2.1.2.2 Painted bugs (Pentatomidae)

Bagarada cruciferarum Kirk was reported by Mallapur (1988) as a minor pest of cabbage in Dharwad and Belgum districts of Karnataka. Painted bug, *Eurydema pulchrum* (Westwood) was reported as sporadic pest of cauliflower in Manipur (Devjani and Singh, 2002).

2.1.3 Order: Coleoptera

2.1.3.1 Flea beetles (Chrysomelidae)

Flea beetle, *Phyllotreta cruciferae* was observed as a minor pest of cabbage in Dharwad and Belgum districts of Karnataka (Mallapur, 1988). Three species of the flea beetle, *Phyllotreta nemorum* (L.), *P. cruciferae* and *Monolepta signata* Olivier. were identified as pests of cruciferous crops in Nepal by Vaidya (1995). According to Indra and Kamini (2003) *P. nemorum* was the common and major pest of crucifer plants in Nepal. *P. brassicae* was the important pest found during both winter and spring seasons which had the ability to cause damage sporadically and occasionally on cabbage in terai region of West Bengal (Chaudhuri *et al.*, 2001). Devjani and Singh (2002) reported *P. nemorum* and *M. signata* for the first time as pests of cauliflower in Manipur. Grooves (2012) reported *P. cruciferae* as a sporadic pest of cabbage and cauliflower in Wisconsin.

2.1.4 Order: Orthoptera

2.1.4.1 Grasshoppers (Acridiidae)

Devjani and Singh (2002) reported short horned grasshopper, *Atractomorpha crenulata* Fabr. and rice grasshopper, *Oxya hyla hyla* Serv. as sporadic pests of early, mid and late season crop of cauliflower in Manipur.

2.1.5 Order: Diptera

2.1.5.1 Leaf miners (Agromyzidae)

Pea leaf miner, *Phytomyza horticola* Gour. was observed as regular pest of early, mid and late season crop of cauliflower in Manipur (Devjani and Singh, 2002).

2.2 Natural enemies associated with pests of cabbage and cauliflower

2.2.1 Parasitoids

2.2.1.1 Parasitoids of DBM

The braconid, *Cotesia plutellae* (Kurdj.) (*Apanteles plutellae* Kurdyumov) and the ichneumonid, *Diadegma insularis* (Cresson) were the predominant parasitoid species attacking *P. xylostella* on cabbage during 1984 in Hawaii and the total parasitism was upto 59 per cent (Johnson *et al.* 1988). Devi and Raj (1995) observed that the DBM larvae collected from cauliflower fields were parasitized by *Diadegma fenestralis* Halmgrew and the extent of parasitization varied from 77.33 to 86.67 per cent in Himachal Pradesh. Usha *et al.* (1997) reported nine hymenopteran parasitiods parasitizing *P. xylostella* of which *D. fenestralis*, *Diadromus collaris* Gravenhorst and *Cotesia* spp. were the predominant species. The population of DBM parasitoids encountered was mainly larval-pupal parasitoids including *Diadegma* sp. and *Oomyzus sokolowskii* (Kurdjumov) whose combined parasitism rarely exceeded 20% at any one time in Central Kenya (Oduor *et al.,* 1997). In India, Ushachauan *et al.* (1997) reported four larval parasitoids, four pupal parasitoids and one larval-pupal parasitoid against DBM on crucifers in mid hills region of Himachal Pradesh. *C. plutellae* and *Brachymeria* sp. were the most important natural larval and pupal parasitiods of DBM respectively (Dey and Somchoudhury, 2001). Abhishek and Ashok (2003) reported *C. plutellae* as a solitary and DBM specific larval parasitoid causing 47.2 and 47.3 per cent

parasitisation of *P. xylostella* in 2000-01 and 2001-02 respectively. The parasitoids of *P. xylostella* included a larval parasite *C. plutellae* and a larval - pupal parasite *O. sokolowskii.* The extent of larval and pupal parasitisation was 10.80 and 26.83 per cent, respectively in 2002-2003 while it was 11.33 and 28.38 per cent in 2003-04 in Marathawada region (Sable *et al.*, 2008). Devendra *et al.* (2012) reported *Diaeretiella rapae* (M'Intosh) as the important parasitoid of *L. erysimi* in Madhya Pradesh.

2.2.1.2 Parasitoids of *S. litura*

Kulkarni (1989) recorded larval parasitoids on *S. litur* in groundnut which included one braconid, *Bracon brevicornis* Wesmael, one ichneumonid, *Campoletis chlorideae* Uchidas and two tachinids, *Campsilure concinnata* Meigen, and *Peribaea orbatta* Wiedemann. The parasitiod complex of *S. litura* consisted of one egg parasitiod, *Trichogramma chilonis* Ishii (31.8%) and nine larval parasitiods of which *P. orbata* (14.3%) as the most abundant parasitiod of *S. litura* in cauliflower (Srivastava and Kushwaha, 1995). Sridhar and Prasad (1996) reported larval parasitoids of *S. litura viz. P. orbata* and *Apanteles ruficrus* (Haliday) which caused 13.7 and 8.2 per cent mortality of *S. litura* respectively in groundnut crop. Zhongshi *et al.* (2010) reported that *S. litura* larvae were parasitized by *Microplitis prodeniae* Rao and Chandry and *Campoletis chloridae* Uchida in toro plants. The egg-larval parasitoid, *Telenomus* sp. and larval parasitoid, *Cotesia glomeratus* (L.) were observed as parasitoids of larvae of *S. litura* on cauliflower (Ahuja *et al.,* 2012).

2.2.1.3 Parasitoids of Aphids

The important parasitoids recorded were *Aphidius* spp. from cabbage aphids with maximum parasitisation of 76.43 and 82.33 per cent in 2002-03 and 2003-04 respectively in Marathwada region (Sable *et al.*, 2008).

2.2.2 Predators

2.2.2.1 Predators of Aphids

Badjena and Mandal (2005) reported four species of lady bird beetle *viz. Coccinella repanda* Thunberg, *Cheilomenes sexmaculata* (Fabr.), *Micraspis discolor* (Fabricius) and *Coccinella septempunctata* (Fab.) and two speices of syrphid fly *viz. Ischiodon scutellaris* (Fabricius) and *Eumerus albifrons* Walker against aphids on cauliflower in Bhubaneswar. The aphidophagous lady bird beetles were one of the most important groups of predators and *C. septempunctata* was also one of them which fed on *L. erysimi* and the mean feeding potential of grub and adult were 50.38 and 83.54 aphids per individual respectively (Singh *et al.*, 2009).

2.2.2.2 Predators of *S. litura*

Chrysoperla carnea (Stephens) was recorded as a predator of neonate larvae of *S. litura* on cauliflower (Ahuja *et al.*, 2012)

2.3 Nature and extent of damage

2.3.1 *P. xylostella*

Prasad (1963) reported 42 to 97 per cent yield loss in cabbage due to cumulative infestation by the pest complex, whereas Krishna *et al.* (1983) reported 52 percent loss in marketable yield of cabbage due to DBM. In Ludhiana, 50-80 per cent yield loss was reported by Bindra *et al.* (1974) and Satpathy *et al.* (2005). In the case of severe infestation of DBM, growing hearts were affected and the productions of marketable curds were reduced (Kumar *et al.*, 2011).

2.3.2 *S. litura*

S. litura caused economic loss of crops from 25.8-100 per cent, based on crop stage and its infestation level in the field (Dhir *et al.*, 1992). *S. litura* was recorded as an economically

important polyphagous pest causing damage to more than 50 crops including tobacco, cole crops, castor, cotton, sunflower and chilli (Shankaramurthy *et al.*, 2006).

2.3.3 *P. brassicae*

The caterpillars of *P. brassicae* damaging plants by feeding the foliage and contaminating heads with faecal matter caused marketable yield loss. On seed crop of cabbage, it fed on the inflorescences and reduced the seed yield considerably in Himachal Pradesh (Anonymous, 1989). A single larva of *P. brassicae* consumed 74-80 sq.cm. leaf area and it fed all parts of plant like leaves, branches and the seeds of cabbage and cauliflower (Siraj, 1999). Youns *et al.* (2004) and Ali and Rizvi, (2007) reported that *P. brassicae* caused extensive damage at all growing stages such as seedling, vegetative and flowering stage.

2.3.4 *H. undalis*

H. undalis was active on cauliflower crop from April-October. The first and second instar larvae mined the leaves whereas third and fourth instar bored into stem after feeding growing points and killed young plants that caused 21.42 to 88.52 per cent loss in nursery and 61 to 80 per cent loss on transplanted crop in Ludhiana (Labh and Harjapinder, 1993). In Rajasthan Sachan and Srivastava (1973) reported yield loss varying from 2 to 60 per cent in cabbage. Where as Sandhu and Bhalla (1973) reported 58 per cent yield loss of cauliflower in Punjab. Mewis *et al.* (2001) reported that *H. undalis* caused yield losses upto 100% within three weeks in the Philippines during dry seasons. Dhawan and Matharu (2011) observed that *H. undalis* larva fed on young leaves and bored inside the growing tips, which resulted in the termination of plant development and formation of multiple shoots.

2.3.5 Flea beetles

P. nemorum adults fed on the cotyledons and leaves of young plants which resulted in shot holes. Occasionally seedling were completely destroyed by the larvae that lived in soil which fed on roots (Indra and kamini, 2003).

2.4 Biology of *S. litura*

Biology of *S.litura* varied with crop as well as environmental conditions as reported by various workers. Balasubramanian *et al.* (1984) worked out the biology of *S. litura* on different crops *viz.* castor (*Ricinus communis* L.), tomato (*Lycopersicon esculentum* Mill.), sweet potato (*Ipomoea batatas* L.), okra (*Abelmoschus esculentus* L.), cotton (*Gossypium sp.*), sunflower (*Helianthus annuus* L.), Lucerne (*Medicago sativa* L.) and egg plant (*Solanum melongena* L.). They observed that the incubation period was shortest on castor (3.5 days) and longest on okra (5.0 day). The duration of larval, pre-pupal and pupal periods were less and the larval length, pupal weight and length, percentage of pupation and adult emergence were higher on castor. Moths reared on castor had shorter developmental period, high growth index, low pre-oviposition period, extended oviposition period and high fecundity. Kulkarni (1989) also reported castor as the most suitable host as it favored optimum growth and development of the insect. The larval period was 16.5 days on castor as against 20.0 days on cultivated groundnut. The larvae passed through six instars on all the hosts except the wild peanut genotypes. *S. litura* reared on the castor had shorter life cycle (30.8 days), while groundnut had longer life cycle (37.8 days). The fecundity was maximum on castor (635), minimum on mulberry (450) and intermediate on groundnut (585).

Kumar *et al.* (1992) observed that average duration of the egg stage of *S. litura* on sunflower ranged from 3 days in May-June to 5.4 days in October. The average duration of the

larval stage was 15.09 days in June and 16.67 days in October. Larval survival varied from 72 to 92 per cent in May-October. The average duration of the pupal stage was 7.49 days in September and 12.26 days in October. The adult lifespan recorded was 4.1-6.2 days in males and 5.1-7.8 in females. Studies at constant temperatures of 20, 25 and 30°C showed that the egg stage lasted 5, 4 and 3 days at the three temperatures, respectively. Corresponding values for the larval stage were 34.4, 15.5 and 14.5, and for the pupal stage 23.7, 10.7 and 7.9 days, respectively.

Cardona *et al.* (2007) reported that *S. litura* underwent holometabolous type development, the duration of eggs were 5±0 days; larva 23.9±0.71 days; pupa 17.80±2.33 days; adult female 12.10±2.65 days and male 7.45±1.31 days on castor plant.

Maghodia and Koshiya (2008) studied the life history of *S. litura* at 27°C in the laboratory on five different crops presumably observed as host plants of *S. litura*. The highest intrinsic rate of increase (r), the finite rate of increase and the net reproduction rate (Ro) of *S. litura viz.*, 0.174, 1.192 females per day, 1370.74 offspring per individual, respectively were observed on castor, while the highest mean generation time (T) of 45.48 days was observed on cotton. The life expectancy of newly deposited eggs was 17.34, 17.44, 16.39, 17.45 and 17.98 on castor, tobacco, groundnut, cotton and cabbage, respectively. Studies on age-specific distribution of the pest on different hosts revealed that the eggs and larvae contributed highly to the population.

The biology of *S. litura* was determined in laboratory by Shukla and Patel (2011) who indicated that on an average female moth laid 241.60 ± 41.25 eggs in her life span. The duration of egg, larval and pupal stages lasted for an average of 4.21 ± 0.99, 16.02 ± 1.09 and 10.42 ± 0.85 days, respectively. The adult male and female survived for a period of 8.66 ± 0.60

and 6.89 ± 0.19 days, respectively with the sex ratio of 1: 1.77. The total life cycle from egg laying to adult emergence was completed in 39.80 ± 1.88 days.

Effects of four host plants, tobacco, Chinese cabbage, cowpea and sweet potato, on larval and pupal development and survival, and longevity and fecundity of adults of *S. litura* were studied under laboratory conditions (26° C, 60-80% RH), *S. litura* females oviposited most on chinese cabbage, least on tobacco, and intermediate on cowpea and sweet potato. Larvae survived best on cowpea (81.6%), followed by chinese cabbage (75.5%), sweet potato (66.1%), and worst on tobacco (49.2%). Pupal survival rates were relatively high (91.4 - 95.9%) in all four host plant treatments. Pupal weights on tobacco and sweet potato were similar, but both were lower than those on chinese cabbage and cowpea. Numbers of eggs oviposited by female *S. litura* were highest on sweet potato, followed by those on cowpea, Chinese cabbage, and lowest on tobacco. Relative food consumption rate was highest on sweet potato and it was followed by that on cowpea, Chinese cabbage, and lowest on tobacco (Xue *et al.*, 2009).

2.5 Pest population in association with weather parameters

2.5.1 *P. xylostella*

According to Odour *et al.* (1997) DBM population was inversely related to rainfall. The larval population of *P. xylostella* showed positive correlation with average temperature, relative humidity and total rainfall and negative correlation with average sunshine hours in terai region of West Bengal as observed by Chaudhuri *et al.* (2001). Peak incidence of DBM on cabbage (10.33 larvae/plant) was noticed in December in Bihar (Ojha *et al.*, 2004). *P. xylostella* population was 8.2 larvae/plant on cabbage, during last week of January, in Meerut, (Kumar *et al.*, 2007). Shaila (2007) reported 12.17 larvae/plant on cabbage during

kharif season and 12.53 larvae/plant during rabi season. Gill *et al.* (2008) observed that DBM was active on cabbage and cauliflower from February to April and September to December under Punjab conditions. Studies conducted by Meena *et al.* (2012) showed that *P. xylostella* incidence occurred after 35 days of transplanting and attained its peak level in the last week of January in arid region of Rajasthan and the population fluctuated from 2.0 to 11.0 larvae per plant. The maximum temperature, maximum and minimum relative humidity, wind speed and rainfall had positive non-significant correlation while minimum temperature showed positive significant correlation with the larval population

2.5.2 *S. litura*

Population of *S. litura* occurred on cabbage crop during the warmer months between September to December with a peak in November-December during 1982-1984 in southern Taiwan (Lee, 1986). Murthy (1994) was also of the opinion that November and December months were favorable for multiplication of *S. litura* on cauliflower in Andhra Pradesh. Lavanya (1995) reported that high population of *S. litura* on cabbage occurred during January, but slowly declined and reached to a minimum by second week of March and thereafter there was a slight increase during third and last week of March. In a study conducted by Dhanaraj (2000) in Dharwad districts during summer, *S. litura* incidence was found throughout the season and the intial population recorded was 4.42 larvae per plant. The population was 6.89 larvae per plant on 40 days old crop during March. The incidence of *S. litura* on cauliflower was observed from fourth week of November to third week of February and peak population (21.3 larvae per plant) was observed during second week of January in Bhubaneswar (Badjena and Mandal, 2005). Rao *et al.* (2006) reported that *S. litura* population had no significant relationship with temperature, relative humidity and wind speed, whereas, Kumar *et al.* (2007)

reported that its population had a significant positive correlation with mean temperature and non-significant negative correlation with relative humidity in Meerut.

Patait *et al.* (2008) reported that *S. litura* population on cabbage ranged from 0.6 to 3.2 larvae per quadrat and that it was positively correlated with minimum temperature and negatively correlated with forenoon RH. The study on the seasonal incidence of *S. litura* during 2007-08 and 2008-09 on Grand Naine variety of banana revealed that the larval population initiated during the month of June- July and reached its maximum during August-September (Shukla and Patel, 2011). They also observed that the population declined by the end of September and disappeared in the month of October during both the years of investigation. During 2007-08, a non-significant positive correlation with mean temperature and mean relative humidity was recorded, whereas in year 2008-09 it showed a non-significant negative correlation with mean temperature and mean relative humidity.

2.5.3 *C. binotalis*

The highest population of *C. binotalis* was observed by Lavanya (1995) in the second week of January that declined to a minimum by last week of March. December and January months were favorable for multiplication of cabbage leaf webber and peak incidence was observed in the month of January in Andhra Pradesh (Sujatha *et al.*, 1997). During spring season, the larval population of *C. binotalis* showed positive correlation with average temperature, relative humidity and total rainfall and negative correlation with average sunshine hours on cabbage in terai region of West Bengal (Chaudhuri et al., 2001). *C. binotalis* was seen from third week of November to third week of February and peak incidence of 25.6 larvae per plant was observed during third week of January on cauliflower (Badjena and Mandal, 2005). During rainy season

population of *C. binotalis* was maximum and was positively correlated by forenoon RH and negatively correlated with minimum temperature. (Patait *et al.*, 2008).

2.5.4 *H. undalis*

The population of *H. undalis* on cabbage varied from 1.0 to 6.2 larvae/quadrat and the population was positively correlated with minimum temperature and negatively correlated with forenoon RH (Patait *et al.*, 2008).

2.5.5 *Trichoplusia ni*

The population of *T. ni* first appeared on the first week of February and it was reported to reach its peak level of 2.8 larvae per plant on fourth week of March. The population was positively correlated with mean temperature and negatively correlated with relative humidity, in Meerut (Kumar *et al.*, 2007). During rainy season population of *T. ni*, was maximum and was positively correlated with forenoon RH and negatively correlated with minimum temperature (Patait *et al.*, 2008).

2.5.6 Aphids

The population dynamics of *B. brassicae* was studied during 1997-98 by Parbhani. (Mulik *et al.*, 2000). They found that its population had a significant negative correlation with maximum and minimum temperature and positive correlation with morning humidity. Correlation of *L. erysimi* with weather parameters in terai region of West Bengal was worked out by (Chaudhuri *et al.*, 2001). They observed that its population was negatively correlated with temperature, sunshine hours and total rainfall and it was positively correlated with average relative humidity during winter and during spring, it was positively correlated with average relative humidity and total rainfall. Badjena and Mandal (2005) reported that in cauliflower grown in Bhubaneswar, aphids first appeared during the second week of November

and it gradually increased in number and reached peak the level of 213.3 aphids per three leaves in the fourth week of January and later declined. In Meerut, population of *L. erysimi* appeared in the second week of January and increased to the maximum level of 95.4 aphids per plant during second week of February. The population decreased very fast during March-April. The population had non-significant negative correlation with mean temperature while relative humidity showed non significant positive correlation (Kumar *et al.*, 2007). Among the abiotic factors minimum temperature, sunshine hours and relative humidity seemed to influence the population of aphids *L. erysimi* to a higher extent (Venkateswarlu *et al.*,2011).

2.5.7 Flea beetle

Chaudhuri *et al.* (2001) observed that during winter season flea beetle population was positively correlated with average temperature and sunshine hour but was negatively correlated with average relative humidity and total rainfall during spring season in West Bengal.

2.6 Management of pest complex in cabbage and cauliflower

2.6.1 *P. xylostella*

2.6.1.1 Entomopathogenic fungi

The commercial formulation of *Beauveria bassiana,* Bio-power gave significantly higher per cent mortality of DBM ranging between 6.7 to 86.7 per cent (Sood *et al.*, 2001). *B. bassiana* based formulations *viz.* Biobit and Biolep were effective against DBM on cabbage (Ram *et al.*, 2001). Ramarethinam *et al.*, 2002 recorded 47.6 to 83.2 per cent mortality of DBM with *B. bassiana* formulation.

2.6.1.2 Botanicals

Fagoone (1987) opined that NSKE was found as effective as deltamethrin against DBM on cabbage and cauliflower in Mauritius. Patel *et al.* (1993) reported that NSKE 5% was

effective against DBM while neem leaf extract 5% suspension was least effective. The weekly application of neem kernel powder @ 25-50 gl^{-1} of water achieved good control of DBM on cabbage (Dreyer, 1987). Dhanraj (2000), Sanjeev *et al.* (2001) and Mishra, (2009) reported the efficacy of different commercial formulations of neem, viz., neemazal, azadirachtin and neemarin in suppressing DBM. Neemarin @ 1500 ppm and 10,000 ppm gave significant suppression of DBM population.

2.6.1.3 Synthetic insecticides

The field experiment counducted in Dharwad by Dhanaraj (2000) recorded maximum larval mortality of 95.0 per cent with new chemical spinosad 48 EC @ 0.048 per cent and it was followed by novaluron 10 EC @ 0.01per cent with 92.30 per cent mortality. Johnpeter *et al.* (2000) found that spinosad 2.5 SC gave significantly better control of *P. xylostella* when applied @ 15 and 25 g a.i. ha^{-1} by recording least number of 2.10 and 2.18 larvae per 10 plants respectively of cabbage at Secunderabad. The field evaluation of spinosad 48 SC against DBM revealed that it was effective in controlling of DBM @15 to 25 g a.i. ha^{-1} and the population reduction ranged from 83.03 to 98.99 per cent on six days after treatment. The efficacy of spinosad 48 EC in controlling DBM was reported to persist for seven days in cabbage (Dey and Somchoudhury, 2001). Gill *et al.* (2008) reported that spinosad 48 SC @ 600 ml ha^{-1}, proclaim 5 SG @ 170 g ha^{1} and indoxacarb 14.5 SC @ 333 ml ha^{-1} significantly reduced the DBM larval population. Spinosad 45 SC @ 75g a.i.ha^{-1} was found effective against DBM larvae (Kumar *et al.*, 2011).

Babu *et al.* (2002) reported that indoxacarb 14.5 EC was effective against *P. xylostella* compared to abamectin 1.9 EC under laboratory conditions. Liu *et al.* (2003) reported that indoxacarb @ 0.05 to 0.07 kg a.i ha^{-1} was effective against DBM, by suppressing the larvae

below economic threshold level. In addition, indoxacarb was found to be as effective as spinosad and significantly more effective than emamectin benzoate.

Field trials conducted on cabbage by Suganyakanna *et al.* (2005) to evaluate the efficacy of insecticides against DBM revealed that emamectin benzoate 5 SG @ 10 g a.i.ha^{-1} and 8.75 g a.i.ha^{-1} were more effective against the pest when compared to profenophos 50 EC @ 750 g a.i.ha^{-1} and lambda cyhalothrin 5 EC @ 30 g a.i.ha^{-1}, recording the highest yield of 36 and 37.7 tha^{-1}, respectively. Kumar and Devappa (2006) evaluated the bioefficacy of emamectin benzoate (5% SG) against diamondback moth and reported that the chemical @ 150 g and 200 g ha^{-1} were effective in reducing the larvae and increasing the yield of cabbage. The population reduction ranged from 84.54 to 93.58 per cent on cauliflower and 89.24 to 91.49 per cent on cabbage crop compared to 43.14 to 58.60 per cent reduction in standard controls on cauliflower and 68.61 to 77.45 per cent reduction on cabbage crop respectively.

2.6.2 *S. litura*

2.6.2.1 Entomopathogenic fungi

The entomopathogenic fungi *B. bassiana* @ 1 x 10^7 spores ml^{-1} was not found to be effective against *S. litura* on ground nut in glass house condition (Jayanthi and Padmavathamma, 2001). In-vitro bioassay conducted by Sahayaraj and Borgio (2010) to evaluate the bioefficacy of *Metarhizium anisopliae* (Metsch.) Sorokin against seven insect pests revealed that the fungus was more pathogenic to *Helicoverpa* than *Spodoptera* and remaining insects. Rajinikanth, *et al.* (2010) conducted investigations to evaluate pathogenicity of three isolates of *B. bassiana viz.,* Bb-13, Bb-11 and Bb-5A from PDBC, Bangalore and one commercial isolate coded as Bb-N and two local isolate, Bb-L-1 and Bb-L-2 against third

instar larvae of *S. litura*. The results showed that strain Bb-5A was superior with significantly higher spore viability and pathogenicity.

2.6.2.2 Botanicals

Rajashri *et al.* (1991) tested four neem formulations *viz.*, neem oil, neem guard, repelin and biozol and some synthetic insecticides against *S. litura*. These neem products were reported to give 48.5 to 64.35 per cent reduction in fruit damage over control. Joshi *et al.* (1993) reported that *S. litura* was effectively managed with neem extract in South India. Rao *et al.* (1998) reported the effectiveness of garlic extract in combination with other extracts like neem, chilli, ginger, tobacco and cow urine against *S. litura* upto 13 days of spraying. Patil *et al.* (2009) found NSKE @ 5 per cent gave higher larval reduction of *S. litura* (62.97, 84.81per cent), respectively after first and second spray, on soyabean. The aqueous extract of *Azadirachta indica* A. Juss. and *Melia* sp. were found to give statistically higher larvicidal effect (20.9 and 19.2 per cent mortality, respectively) against *S. litura*. Ethonal extract of *A. indica* and *M. azadirachta* A. Juss. also were highly effective against *Spodoptera* larvae (Anurag *et al.*, 2009). Singh, *et al.* (2012) conducted experiment in Andhra Pradesh with rhizome extracts of different plants *viz.*, *Curcuma caesia* Roxb., *C. aromatic* Salisb., *C. longa* L., *Zingiber officinale* Roscoe cv. Nadia, *Z. officinale* cv. Adi Local, *Z. officinale* cv. Kekir and *Acorus calamus* L.. Hexane and chloroform extracts of *A. calamus* were found highly effective with mortality ranging from 84 to 100 per cent. *Curcuma* spp. gave better performance than the *Zingiber* spp. in similar solvent extracts.

2.6.2.3 Synthetic insecticides

Ovicidal toxicity of conventional and new insecticides against eggs of *S. litura* were evaluated under laboratory condition by Khalid *et al.* (2001). It was found that thiodicarb 75

WP @ 0.075% was the most effective with a mortality of 95.55 per cent and it was followed by indoxacarb 15 EC @ 0.024%, chlorpyriphos 20 EC @ 0.05%, spinosad 48 SC @ 0.015%, quinalphos 25 EC @ 0.05% and beta-cyfluthrin 2.5 SC @ 0.007% with 86.66, 75.55, 73.33, 71.11 and 66.66 per cent mortality respectively. Dey and Somchoudhury (2001) reported spinosad 48 SC @ 15-25 g a.i ha^{-1} gave effective control of *S. litura.*

Mallareddy *et al.* (2004) reported that spinosad 48 SC @ 0.015% recorded 62.20 per cent reduction in *S. litura* larval population on cabbage crop. Likewise, Soujanya *et al.* (2004) reported that spinosad 45 SC @ 0.015% reduced the larval population of *S. litura* by 59.00 per cent in cabbage crop.

Jat and Bhardwaj (2005) found that malathion 50 EC (700 ml ha^{-1}) was effective against third and fifth instar larvae of *S. litura*. Indoxacarb 14.5 SC @ 0.0145% and thiodicarb 75 WP @ 0.075% were found to be effective in reducing larval population of *S. litura* (Rao *et al.*, 2006).

High toxicity of emamectin benzoate 5 SG with LC_{50} value 0.0015% against *S.litura* was reported by Stanley *et al.* (2006). Toxicity of emamectin benzoate 5 SG and indoxacarb 15.8 EC to *S. litura* was reported by Dhawan *et al.* (2007). Prasad *et al.* (2007) conducted a comparative study of insecticides on relative toxicity and found that emamectin benzoate 5 SG was the superior chemical followed by novaluron 10 EC and indoxacarb 14.5 EC. The bioassay of new generation insecticides based on LC_{50} values indicated that emamectin benzoate 5 WSG and indoxacarb 14.5 SC were highly toxic and abamectin 1.9 EC was least toxic to four, seven and ten days old larvae of *S. litura* (Suby *et al.*, 2008). The field experiment conducted by Khalid and Prasad (2009) on chilli in Guntur, showed that emamectin benzoate 5 SG @10 g a.i

ha^{-1} was effective against *S. litura*. Yogesh and Srivastava (2009) reported the superiority of cypermethrin 25 EC, among the synthetic pyrethroids tested based on toxicity to *S. litura* larva.

2.6.3 *Crocidolomyia* spp.

2.6.3.1 Entomopathogenic fungi

Efficacy of *B. bassiana* isolated from *Hypothenemus hampei* (Ferrari) in controlling *C. pavonana* was reported by Trizelia (2000). Trizelia and Firdos (2010) reported *B. bassiana* isolate HhTK9 @ 10^8 conidia ml^{-1} caused 82.50 per cent mortality to second instar larvae of *C. pavonana* with LT_{50} of 3.39 days.

2.6.3.2 Botanicals

Mishra (2009) reported the efficacy of commercial formulation of neem, neemarin @1500 ppm and 10,000 ppm in suppression of *C. binotalis* population.

2.6.3.3 Synthetic insecticides

Field trail carried out by Harikrishna (1996) showed that methomyl and triazophos were very effective against *C. binotalis* on cabbage. Cartap hydrochloride also exerted significant suppression of *C. binotalis* population (Mishra, 2009).

2.6.4 *H. undalis*

2.6.4.1 Synthetic insecticides

Kumaraswamy and Azam (1987) found that deltamethrin (0.00375%) was effective against *H. undalis* throughout the crop period and that it resulted in higher yield. Similarly, Ganapathi (1989) also observed the superiority of deltamethrin 0.03%, cypermethrin 0.02% and fenvalerate each at 0.01% in controlling *H. undalis*, with 85.38 per cent population reduction. Sumalatha *et al.* (1992) observed complete mortality of second instar larvae of *H. undalis* when treated with 0.1 per cent diflubenzuron in laboratory condition. Dey and

Somchoudhury (2001) reported spinosad 48 SC @ 15-25 g a.i ha^{-1} was effective in controlling *H. undalis* on cabbage.

2.6.5 *P. brassicae*

2.6.5.1 Entomopathogenic fungi

The field trial conducted by by Cipriano *et al.* (2010) to assess the efficacy of one native strain of *B. basssiana* (BbPM) and two commercial products of *B. bassiana* (Bea-Sin™) and *M. anisopliae* (Meta-Sin™) against *P. brassicae* on cabbage with three concentrations @ 1.2×10^{12}, 1.2×10^{9} and 1.2×10^{6} conidia ha^{-1} respectively showed that the native strain recorded highest mortality (92.7 per cent) and it was followed by Bea-Sin™ (91.8 per cent).

2.6.5.2 Botanicals

Atwal and Pajani (1964) reported 33.3 and 40 per cent mortality of *P. brassicae* with alcohol extract of *M. azadirachta* 5 and 10%, respectively. The aqueous extract of *A. indica and M. azadirachta* showed statistically higher larvicidal effect (18.5 and 19.6 per cent) against larvae of *P. brassicae* (Anurag *et al.*, 2009).

2.6.5.3 Synthetic insecticides

The evaluation of three insecticides under field condition on cabbage in Himachal Pradesh by Sanjeev *et al.* (2001) indicated that treatment cartap hydrochloride 50 WP @ 0.075% was the most effective against *P. brassicae.* In the field experiment conducted by Puja and Vinay (2009) in mid hills of Himachal Pradesh, spinosad 45 SC @ 0.015% recorded 68-78 per cent population reduction of *P. brassicae.* Chlorantraniliprole 18.5% SC @ 10 g a.i ha^{-1} showed highest population reduction of 84.42 and 84.54 per cent over control during 2009-10 and 2010-11 respectively (Vekateswarlu *et al.*, 2011).

2.6.6 *T. orichalcea*

2.6.6.1 Synthetic insecticides

Puja and Vinay (2009) conducted a field experiment in mid hills of Himachal Pradesh and found that spinosad 45 SC @ 0.015% was effective with 52-69 per cent reduction in population of *T. orichalcea*.

2.6.7 Aphids

2.6.7.1 Entomopathogenic fungi

Verticillium lecanii (Zimm.) has been used successfully as biological control agent against various species of aphids for number of years (Hall, 1982). Pathogencity of various strains/isolates of *V. lecanii* has been well established against various aphid species *viz.*, *Aphis fabae*, *Myzus persicae* (Fegan *et al.*, 1992). Loureiro and Moino (2006) recorded 100 per cent mortality of *M. persicae* with *B. bassiana* and *M. anisopliae* applied at 10^6 and 10^7 spores ml^{-1}, respectively.

2.6.7.2 Botanicals

Mishra (2009) reported neemarin @ 10000 ppm could significantly control *B. brassicae* with 98.41 per cent reduction in population over control. Field experiment on bio efficacy of botanicals against *L. erysimi* conducted by Devendra *et al.* (2012) revealed that decoction of tobacco 5% was the most effective in reducing the population and it was followed by tobacco decoction 2%, neem 5%, neem 2%, tulsi 5% and tulsi 2%. The population reduction obtained was 62.73, 57.68, 55.32, 51.34, 46.8 and 45.31per cent respectively. Decoction of lantana, garlic and ipomoea were safe for parasitiods in comparision to decoction of tobacco, neem and tulsi.

2.6.7.3 Synthetic insecticides

Among the new insecticides tested, the lowest incidence and highest population reduction of *L. erysimi* population was obtained with imidacloprid 200 SL @ 30 g a.i ha^{-1} and it was followed by the treatment @ 20 g a.i ha^{-1} and 10 g a.i ha^{-1} after one, seven, fifteen days after spraying (Anjumoni *et al.*, 2011).

2.7 Effect of plant protection on yield of cabbage and cauliflower

The IPM module (Spinosad + Azadirachtin + B.t.K) was effective against DBM and it gave maximum yield, 199.02 and 198.45 q ha^{-1} cabbage during 2000-01 and 2001-02 respectively in Rajasthan (Abhishek and Ashok, 2003). *Gill et al.* (2008) reported that marketable yield was significantly higher in spinosad 48 SC @ 0015% treatment for DBM, with 193.03 q ha^{-1} of cauliflower and 320.26 q ha^{-1} of cabbage.

Venkateswarlu *et al.* (2011) reported that two sprays of acetamiprid 20 SP @ 20 g a.i ha^{-1} followed by chlorantraniliprole 18.5 SC @ 10 g a.i ha^{-1} and emamectin benzoate 5 SG @ 10 g a.i ha^{-1} treatment against the major pests of cabbage gave good marketable yield of 30.6 and 32.17 t ha^{-1} during 2009-10 and 2010-11, respectively. Bana and Jat (2011) found highest yield of 189.12 q ha^{-1} with endosulfan and it was on par with malathion (186.77 q ha^{-1}) and significantly superior to other treatments in managing the pest complex in cabbage. The next effective treatments were spinosad (173.17q ha^{-1}), imidacloprid (171.40q ha^{-1}), indoxacarb (168.65 q ha^{-1}) and lufenuron (166.32 q ha^{-1}). Yield was low in NSKE (143.67q ha-1) and azadirachtin (147.37 q ha^{-1}). Bana and Jat (2012) found that three applications of endosulfan, gave highest yield of cabbage (192.56 q ha^{-1}) and it was followed by the treatment spinoad + Btk + endosulfan (190.73 q ha^{-1}) in Jaipur. Ratnasri (2012) found that the highest yield of

58.31 t ha^{-1} was obtained from indoxacarb 15.8 % SC treated plots, when sprayed against defoliator pests of cabbage in Dharwad.

2.8 Pesticide residues in cabbage heads

Zhi-yong *et al.* (2007) observed when cabbage was treated four times at the maximal dosage with a five-day's interval, the half-lives of chlorpyrifos, cypermethrin and chlorothalonil in the cabbage were 2.9, 2.6 and 4.1 days, respectively, and the final residual amount of chlorothalonil exceeded its MRL on cabbage, but the final residual amounts of cypermethrin and chlorpyrifos were below its MRLs on the cabbage. Furthermore, in both one-time and four-time spraying treatments, the final degradation rates of pesticides residues were above 80%.

Fujita *et al.* (2012) observed distribution of cypermethrin residue levels in cabbage was slightly skewed at higher residue levels as compared to that of acetamiprid.

Frederick (2011) reported that 21 pesticides residues were detected in cabbage samples of which nine (allethrin, bifenthrin, lambdacyhalothrin, fenvalerate 2, cyfluthrin 3, cypermethrin, cypermethrin 2, permethrin and deltamethrin) were pyrethroids and 12 (diazinon, fenitrothion, ethoprophos, chlorpyriphos, phorate, fonofos, pirimidophos-m, profenophos, malathion, dimethote, chlorfenvip and parathion-et) were organophosphates.

Urvashi *et al.* (2012) conducted laboratory analysis of indoxacarb residues by employing standardized QuEChERS technique in cabbage, following three applications of Avaunt 14.8 EC @ 52.2 and 104.4 g a.i. ha^{-1}. The average recoveries of indoxacarb on cabbage for fortification levels of 0.01, 0.05 and 0.1 mg $^{kg-1}$ were observed as 83.93, 89.86 and 95.40%, respectively, with relative standard deviation of 1.21, 1.53 and 2.23. The average initial deposits of indoxacarb on cabbage were observed as 0.18 and 0.39 mg kg^{-1} at single and

double the application rate, respectively. These indoxacarb residues dissipated below its LOQ of 0.01 mg/kg after 7 and 10 days respectively at single and double dosages. Half-life of indoxacarb was observed as 2.88 and 1.92 days, respectively at the recommended and double the recommended dosages.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Investigations on the pests and natural enemies associated with cabbage and cauliflower and their management were undertaken during 2011-13 at College of Agriculture, Vellayani.

3.1 Pests and natural enemies

3.1.1 Pests

3.1.1.1 Identification of pests, symptoms of attack and nature of damage

Occurrence of pests in cabbage and cauliflower grown in the plains and hilly tracts of Kerala was monitored during 2011-13. The pests and symptoms of attack were recorded from four districts *viz.* Thiruvananthapuram, Kollam and Thrissur, representing the plains and from Idukki district representing hilly tracts. From each district, five plots having two cents or more were selected for the survey. The period of observation was from November to February that coincided with the peak cultivation season of these crops in Kerala. Adult and immature stages of the pests were collected from field and brought to the laboratory for further studies and identification. The unknown species of Pierid butterfy was sent to Dr. Kumar Ghorpade, Emeritus Scientist, UAS Dharwad and Dr. Krushnamegh Kunte, National Center for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru. The aphid species were sent to Dr. Sunil Joshi, Entomologist, National Bureau of Agriculturally Important Insects, Bengaluru. Other doubtful specimens were identified with the help of Dr. Prathapan, K.D, Assistant Professor and Taxonomist, Department of Entomology, College of Agriculture, Vellayani. All the specimens were collected and preserved to serve as repository of pests of cruciferous vegetables.

Observations on the morphological features of the pests encountered, symptoms manifested by them and the nature of damage caused were recorded.

3.1.1.2 Pests affecting different growth stages

Pests attacking the specific growth stages of the crop were recorded separately from the plots cited in para 3.1.1.1

Crop specific growth stages

Cabbage		Cauliflower	
WAP	**Specific stage***	**WAP**	**Specific stage***
1 – 4	Seedling stage	1 – 4	Seedling stage
5- 7	True Leaf stage	5- 7	True Leaf stage
8	Pre cupping stage	8- 10	Curd initiation stage
9 – 10	Cupping stage	11 - 13	Curd development stage
11- 12	Early head formation stage	14 - 15	Curd maturity stage
13-14	Head fill stage	-	-
15	Head maturity stage	-	-

WAP- Weeks after planting *Andaloro *et al.* (1983)

3.1.2 Natural enemies

Predators and parasitoids were collected from the plots selected as mentioned in para 3.1.1.1

3.1.2.1 Predators

Predators collected from the field were identified and preserved as dry specimens.

3.1.2.2 Parasitoids

Parasitised insects collected from field were brought to the laboratory and maintained for adult emergence. Adults preserved in 70 percent alcohol were sent to Dr. T.C. Narendran, Taxonomist (Retd.), Calicut University for identification.

3.2 Extent of infestation and damage caused by pests

From the selected district five plots, each having 2 cents or more were selected for observation.

3.2.1 Extent of infestation

Extent of infestation of pests was recorded from 30 plants selected at random and Pest Infestation Index (PI) was calculated using the formula

$$PI = \frac{\text{Number of plants infested}}{\text{Total number of plants observed}} \times 100$$

3.2.2 Extent of damage caused by major pests

Extent of damage caused by the major pests during the vegetative stage was worked out by counting the total number of leaves an

d the number of leaves damaged per plant. During the reproductive phase it was calculated by counting the number of heads or curds damaged out of the thirty observational plants. Mean number of leaves and heads or curds damaged was worked out using standard deviation.

3.3 Biology of *S. litura* on cabbage

3.3.1 Rearing of *S. litura*

Biology of *S. litura* was studied at room temperature using the laboratory culture. The nucleus culture was obtained by collecting larvae from the infested leaves of cabbage and cauliflower. Larvae were reared in the laboratory in plastic troughs (20×10 cm). Fresh leaves were provided to the larvae until pupation. One

freshly emerged female and two males were released together for mating and oviposition on fresh leaves of cabbage and cauliflower kept in the rearing jars (30 × 15 cm) and closed with muslin cloth. Cotton swabs soaked in five per cent honey were kept on the walls of the jar as artificial diet. Fresh leaves were supplied daily until oviposition. The egg masses laid were kept undisturbed for hatching in petriplates (9 cm diameter) with a piece of moist blotting paper at its bottom.

3.3.2 Duration of each stage

Time taken for hatching of eggs was noted. To study the duration of each instar, ten first instar caterpillars were confined singly in petriplates provided with leaf disc (2.5 cm) as food. Caterpillars were observed daily for the presence of moult. The bottom of petriplate was lined with colour paper for easy detection of exuvia. Time taken for each moulting was recorded.

When the last instar stopped feeding they were transferred to glass troughs (30×15) provided with soil for pupation. The number of days taken for adult emergence and number of pupae that emerged into adults were recorded. The mean duration of each stage was worked out along with standard deviation.

3.3.3 Survival percentage

Egg masses were kept for hatching and observed for percentage emergence. On hatching, the first instar caterpillars were grouped into three batches of twenty each and transferred to small petriplates without lid and covered with chimney. The mouth of chimney was covered with muslin cloth. They were provided with fresh leaves daily and excreta were cleaned off. The larvae were observed for moulting if any, on each day using a 4x hand lens. Dead ones were removed as and when observed. Observations were continued till all the caterpillars moulted. The moulted caterpillars were further transferred to rearing troughs and observations on number of caterpillars moulted and dead were

recorded separately for each stage. Survival percentage of each stage was calculated using the formula

$$\text{Survival percentage} = \frac{\text{Number of caterpillar moulted}}{\text{Number of caterpillar observed}} \times 100$$

3.4 Population build up of *S. litura* on cabbage and cauliflower

S. litura was found to be the dominating pest species in the plains of Kerala and hence further studies were concentrated on this species. Population build up of *S. litura* in cabbage and cauliflower was studied during two consecutive seasons, November – February of 2011 – 12 and 2012- 13 in one of the farmer's field at Kalliyoor panchayat of Trivandrum district where no pesticides were applied. Area of observation for each crop comprised 50 cents. Mean population of caterpillars per plant per week was observed from thirty randomly selected plants.

The data collected were analysed and compared with the specific growth stages, to draw conclusions on the susceptibility of each stage to the pests.

3.4.1 Correlation with weather parameters

Weekly mean population recorded as above, was correlated with the corresponding weather parameters *viz.* maximum and minimum temperature, morning and evening relative humidity, rainfall and sunshine hours, from the observatory of the Department of Meteorology, College of Agriculture, Vellayani, during the period of study. The correlation coefficients were worked out.

3.5 Laboratory evaluation of entomopathogenic fungi, botanicals and new generation insecticides for the management of *S. litura*

3.5.1 Pot culture of cabbage and cauliflower

Seeds of cabbage and cauliflower were sown in protray filled with peat moss and coir pith. Thirty days old seedlings were transplanted into poly grow bags filled with potting mixture having 1:1:1 ratio of soil : sand : cowdung. The plants were maintained for rearing *S. litura*.

3.5.2 Test insect

Third instar caterpillars of *S.litura* were used for the experiment. The insects were reared in the laboratory as described as para 3.3.1

3.5.3 Treatments

Two entomopathogenic fungi, five botanicals and eight insecticides were tested for their efficacy against *S. litura* in laboratory.

Entomopathogens

Beauveria bassiana (Isolate no. 5) @ 10^3 spores ml^{-1}, 10^6 spores ml^{-1}, 10^9 spores ml^{-1}

Metarhizium anisopliae (Isolate no. 4) @ 10^4 spores ml^{-1}, 10^7 spores ml^{-1}, 10^{10} spores ml^{-1}

Botanicals

Neem seed kernel extract (NSKE) 2 % and 5%, Anona seed extract (ASE) 2 % and 10%, Garlic extract (GE) 2 % and 4%, Sweet flag extract (SFE) 2 % and 10%, Bird chilli extract (BE) 2 % and 4%.

Insecticides

The insecticides recommended for pest management in cabbage and cauliflower by the Central Insecticide Board and Registration Committee (CIB&RC) were selected for the experiment. The details are given in table below.

Sl. No	Chemical name	Trade name	Concentration	Dosage
1	Spinosad	Tracer 45 SC	0.06%	1.4 ml l^{-1}
2	Chlorantraniliprole	Coragen 18.5 SC	0.002%	0.1 ml l^{-1}
3	Indoxacarb	Avaunt 15.8 EC	0.008%	0.5 ml l^{-1}
4	Fipronil	Regent 5 SC	0.008%	1.6 iml l^{-1}
5	Emamectin benzoate	Benzate 5 SG	0.002%	0.4 g l^{-1}
6	Chlorfenapyr	Interpid 10 SC	0.02%	1.5 ml l^{-1}
7	Cypermethrin	Lacer 10 EC	0.03%	3.25 ml l^{-1}
8	Malathion	Hilmala 50 EC	0.15%	3 ml l^{-1}

3.5.3.1 Spore suspension of entomopathogenic fungi

M. anisopliae and *B. bassiana* maintained in the Biocontrol laboratory of the Department of Entomology were tested for its efficacy against *S. litura*. Fifteen day old culture filtrates of the fungi were used. The spore suspensions prepared at required concentrations were sprayed on the third instar larvae using an atomiser and sterile water spray served as check. Each treatment was replicated thrice and in each replication there were five caterpillars. Observations were recorded on the symptoms of infection, till each caterpillar completed its life cycle.

3.5.3.2 Preparation of botanical extracts

3.5.3.2.1 Neem seed kernel extract

Neem seed kernel was ground to a coarse powder using a mortar and pestle. From this, 20 g was taken in a small muslin cloth bag. This was soaked overnight in 500 ml of water. The cloth bag was squeezed well until the extracts turned light brown. The extract was then made upto one litre to get two per cent NSKE. Similarly from 50 g, five per cent extract was prepared.

3.5.3.2.2 Anona seed extract

Seeds of *A. squamosa* were ground to a coarse powder. From this, 20 g was taken in a small muslin cloth bag. This was soaked overnight in 500 ml of water. The cloth bag was squeezed well until the extracts turned light brown. The extract was then made upto one litre to get two per cent aqueous extract. Similarly from 100 g, 10 per cent extract was prepared.

3.5.3.2.3 Sweet flag extract

Dried stem of *Accorus calamus* was ground to a coarse powder. From this, 20 g was taken in a small muslin cloth bag. This was soaked overnight in 500 ml of water. The cloth bag was squeezed well until the extracts turned light brown. The extract was then made upto one litre to get two per cent aqueous extract. Similarly from 100 g, 10 per cent extract was prepared.

3.5.3.2.4 Garlic extract

Garlic, 20g and 40g was ground separately in a mortar and pestle and mixed with 500 ml of water and filtered through a muslin cloth. These were made upto one litre to get two and four per cent extracts respectively.

3.5.3.2.5 Bird chilli extract

Aqueous extracts of ripe fruits of *Capsicum frutescens* were prepared at two and four per cent strength by mixing 20 g and 40 g of crushed fruits in one litre water separately.

3.5.3.3 Insecticidal solutions

Required quantities of insecticides (para 3.5.3) in liquid formulation were measured out using a micropipette and dry formulations were weighed using an electronic balance and dissolved in water to get their respective strengths.

3.5.4 Testing of efficacy

3.5.4.1 Entomopathogenic fungi

Third instar larvae of *S. litura* obtained from laboratory culture was used as the test insect. Fungal spore suspension at concentrations detailed in para 3.5.3 were applied topically using an atomiser. Larvae treated with sterile water served as control. Treated larvae were air dried for the spray fluid to evaporate. Caterpillars were then carefully transferred to cabbage and cauliflower leaves kept in glass troughs. Three replications were maintained for each treatment. The treated caterpillars were observed for symptom development and mortality at 24 hours interval.

3.5.4.2 Botanicals

3.5.4.2.1 On mortality

The treatments were applied topically on the third instar larvae of *S. litura* using an atomiser. Larvae treated with water served as control. The caterpillars were air dried and transferred to treated cabbage leaves kept in glass troughs. At the end of 24 hours they were fed with fresh leaves. Three replications were maintained for each treatment. Mortality of the caterpillars was recorded every 12 hours after treatment.

3.5.4.2.2. On antifeedant activity

To evaluate the effect of botanical insecticides, third instar larvae were allowed to feed on poisoned cabbage leaf discs of uniform diameter. Leaf discs were smeared with botanical insecticides mentioned in para 3.5.3.2 and were shade dried before releasing the caterpillars. Five caterpillars obtained from laboratory culture were released in each petriplate provided with poisoned leaf disc. Each treatment was replicated thrice. Observations were recorded on the feeding activity of caterpillars at 24 hours interval.

3.5.4.3 Insecticides

Treatments (para 3.5.3) were applied topically using an atomiser. Three replications were maintained for each treatment. Treated larvae were air dried for the spray fluid to evaporate. Caterpillars were then transferred to fresh cabbage leaves kept in glass troughs. Larvae sprayed with water served as control. Mortality of the caterpillars was recorded at every two hours after treatment till 12 hours.

3.6 Field evaluation of different botanicals and new generation insecticides for the management of *S. litura* on cabbage and cauliflower

A field trial was conducted to evaluate the effectiveness of three botanicals and three new generation insecticides that were found to be effective against *S. litura* in the preliminary trial conducted in the laboratory. The experiment was conducted in Randomised Block Design with seven treatments and three replications.

Cabbage variety NS-183 and cauliflower variety NS-60 were raised separately in the Instructional farm, College of Agriculture, Vellayani during November 2012 to February 2013. Seedlings used for the experiment were obtained from the Department of Olericulture, College of Agriculture, Vellayani. Cabbage was raised at a spacing of 45 x 45 cm and a spacing of 60 x 45 cm was followed for cauliflower. The crop was raised and maintained as per the package of practices recommendation of KAU (2011).

Treatments

T_1- Indoxacarb 0.008%

T_2- Cypermethrin 0.03%

T_3- GE 2 %

T_4 - NSKE 5%

T_5- SFE 10%

T_6- Malathion 0.15% (treated check)

T_7- Untreated check

3.6.1 Sprayings

Spray solutions of the botanicals and new generation insecticides were prepared as described in para 3.5.3.1 and 3.5.3.3. Treatments were given in the true leaf stage, at fortnightly interval commencing from seven weeks after planting (WAP), when five per cent plants were found infested.

3.6.2 Assessment of field population of *S. litura*

Field count of *S. litura* was recorded separately from cabbage and cauliflower. Three plants were selected at random from each replication for recording observations. Field population was assessed by taking direct count of the caterpillars present in the observational plants on one day before, one and three days after each treatment.

Further, the reduction in *S. litura* population due to different treatments was calculated using the formula developed by Henderson and Tilton (1955).

Per cent reduction = $[1 - (T_a / T_b \times C_b / C_a)] \times 100$

T_a = post count in treatment plots.

T_b = precount in treatment plots.

C_a = post count in untreated plots.

C_b = precount in untreated plots.

The data were converted to $\sqrt{x+1}$ before statistical analysis. The data were subjected to statistical analysis using Duncan's multiple range test (DMRT).

3.6.3 Assessment of yield

Harvesting of heads and curds was done according to the maturity indices. Gross weight of heads and curds were recorded from 15 plants under each treatment. In cabbage, net weight (marketable yield) of the produce was recorded, after removing the infested outer parts. In cauliflower, the percentage of marketable curds was worked by counting the number of marketable curds out of total number of harvested curds. To find out the effect of different treatments on yield, the per cent marketable yield was calculated by using the formula

Per cent marketable yield (heads) =

$$\frac{\text{Gross head weight (g)} - \text{Weight of removed parts (g)}}{\text{Gross head weight}} \times 100$$

Per cent marketable yield (curds) =

$$\frac{\text{Total number of curds harvested} - \text{Number of curds damaged}}{\text{Total number of curds}} \times 100$$

3.7 Estimation of pesticide residue in plant and soil samples

Two insecticides which were found to be the best under field trial were subjected for residue analysis. Plant as well as soil samples from treated plots were analysed.

3.7.1 Plant samples

Samples for analysis were collected in labelled polythene covers at the time of harvest. Three cabbage heads were collected from each plot treated with indoxacarb and cypermethrin. They were analysed at the Pesticide Residue Research and Analytical Laboratory (ISO 17025:2005 accredited), College of

Agriculture, Vellayani. The analysis of pesticide residues in cabbage was done by following the AOAC 18th edition 2007:2007.17 and European Union reference laboratory multi residue method using QuEChERs method.

3.7.1.1 Extraction and clean up of plant samples.

A sub sample of 500 g cabbage was taken from two treatment plots by quartering and commuting method. Twenty five gram of the blended sample was taken from each replicate and extracted using 50 ml acetonitrile. It was homogenised at 14,000 rpm for two minutes. Vigorous shaking for one minute was followed by the addition of 10g sodium chloride. The sample was centrifuged at 2500 rpm for five minutes. From the supernatant, 16 ml was transferred in to 50ml centrifuge tube containing six gram anhydrous Na_2SO_4. It was mixed well using high speed vortex shaker for two minutes. Twelve ml extract was transferred to 15 ml centrifuge tube containing 0.2 g primary secondary amine (PSA) sorbent and 1.2 g anhydrous $MgSO_4$ and sample was centrifuged for about three minutes at 2500 rpm. The extract (4 ml) was evaporated in a turbovap at 50°C.

3.7.1.2 Estimation of cypermethrin

The dry extract prepared as in para 3.7.1.1 was redissolved in one millilitre of n- hexane and was subjected to GC- MS estimation.

3.7.1.3 Estimation of indoxacarb

The dry extract prepared on para 3.7.1.1 was redissolved in five millilitre methanol and was subjected to LC- MS/MS estimation.

3.7.2 Soil samples

A representative sample of 500 g was collected from the treated plots at the time of harvest following the quartering method.

3.7.2.1 Extraction and clean up

Samples were processed by the method suggested by Asensio- Ramos *et al.* (2010). Samples were air dried and sieved through two mm sieve. Soil sample (10 g) was transferred to a 50 ml polypropylene centrifuge tube and 20 ml acetonitrile was added to it. The sample was shaken vigorously for one minute. To the sample, four gram of magnesium sulphate and one gram of sodium chloride were added. It was centrifuged at 3300 rpm. Ten millilitre of the supernatant was transferred to a 15 ml polypropylene centrifuge tube containing 1.5 g of magnesium sulphate and 0.25 g of primary secondary amine (PSA). The contents were shaken for few seconds, sonicated for one minute and centrifuged for 10 minutes at 4400 rpm. The aliquot (4 ml) was evaporated to dryness using turbovap at 40°C.

3.7.2.2 Estimation of cypermethrin

The dry sample extracted as described in para 3.7.2.1 was redissolved in one millilitre n- hexane was subjected to GC-MS estimation.

3.7.2.3 Estimation of indoxacarb

The dry sample extracted as described in para 3.7.2.1 was redissolved in two millilitre of methonal was subjected to LC-MS/MS estimation.

Estimation of residues was done using GC equipped with ECD operating under the following conditions. Temperature : Column (DB5)-170-250^0 C, Injector -250^0 C, Detector-300^0 C; Carrier gas-nitrogen, flow rate - 0.79 ml/minute. For LC-MS/MS triple quadrupole MS/MS with electro spray ionization (ESI) in the positive mode. All LC separations were carried out using a reversed phase column, Atlantis d C_{18} (2.1X100 mm) with 5µm spherical porous particles. The elution was performed using gradient between methanol and water. Mobile phase A contained 5 milli molar Ammonium acetate in water and B contained five milli molar Ammonium acetate in methanol. Total run time was 10 min. Flow rate 0.80 ml min^{-1}, column temperature 40°C, sample temperature 5°C, and the injection volume 10 µl were used in all the estimation.

4. RESULTS

Results of the studies conducted on the occurrence and extent of damage of the pests of cabbage and cauliflower, factors affecting the population build up of the major pest and efficacy of entomopathogens, botanicals and chemicals in managing the major pest are presented below.

4.1 Pests and natural enemies in cabbage and cauliflower

4.1.1 Pests

The details of the pests encountered on cabbage and cauliflower grown in four districts of Kerala *viz.* Thiruvananthapuram, Kollam, Thrissur and Idukky are presented in Table 1. Eleven insect pests from the order Lepidoptera, two each from Hemiptera and Orthoptera and one each from Diptera and Coleoptera were observed. An unidentified species of slug was also recorded.

4.1.1.1 Description of pests, nature of damage and symptoms

The pests listed in Table 1, except the bell moth and slug were found to feed both on cabbage and cauliflower.

4.1.1.1.1 Order: Lepidoptera

4.1.1.1.1.1 *Spodoptera litura* (Fabricius)

Adult was a medium sized noctuid moth, fore wings brown with black lines and criss-cross markings, Hind wings were silvery white with a brown patch along the margin and it has a wingspan of about 40 mm (Plate 1a). Eggs were laid in groups, creamy white in colour and covered with brown hairs (Plate 1b). They were laid on the stem and leaves of host plants. Both adults and larvae were nocturnal in habit. The early instar larvae were green, slender with blackish head, seen in clusters on the under surface of leaves (Plate 1c). Later instar larvae were stout, cylindrical and dark brown in colour with black shiny markings on lateral sides of the body wall (Plate 1d). Pupa is elongated oval, brownish red in colour (Plate 1e). Pupation was in the soil.

Table 1. Details of the pests infesting cabbage and cauliflower.

Sl no.	Pests observed		Family	Destructive stage	Susceptible stage of host plant	Plant parts affected
	Common name	Scientific name				
	Order: Lepidoptera					
1	Cut worm	*Spodoptera litura* (Fabricius)	Noctuidae	Caterpillar	All stages except seedling stage	Leaves, Head, Curd
2	Diamondback moth	*Plutella xylostella* (Linnaeus)	Plutellidae	Caterpillar	All stages	Leaves, Head, Curd
3	Semilooper	*Plusia signata* Fab.	Noctuidae	Caterpillar	True leaf stage, Pre cupping and cupping / curd initiation stages	Leaves
4	Semilooper	*Plusia orichalcea* Fab.	Noctuidae	Caterpillar	True leaf stage, Pre cupping and cupping/ curd initiation stages	Leaves
5	Hairy caterpillar	*Dasychira mendosa* Hb.	Lymantriidae	Caterpillar	True leaf stage	Leaves
6	Hairy caterpillar	*Spilosoma obliqua* Walker	Arctiidae	Caterpillar	True leaf stage	Leaves
7	Hairy caterpillar	*Pericallia ricini* F.	Arctiidae	Caterpillar	True leaf stage	Leaves
8	Beet army worm	*Spodoptera exigua* Hb.	Noctuidae	Caterpillar	True leaf stage	Leaves
9	Pierid butterfly	*Appias lyncida* (Cramer)	Pieridae	Caterpillar	True leaf stage	Leaves
10	Bag worm	Unidentified	Psychidae	Caterpillar	Seedling stage	Leaves
11	Bell moth*	Unidentified	Tortricidae	Caterpillar	Early head formation stage	Growth primordia

	Order: Hemiptera					
12	Mustard aphid	*Lipaphis erysimi* (Kaltenbach)	Aphididae	Nymph, Adult	True leaf stage, Pre cupping, Cupping/ curd initiation and Early head formation stage	Leaves, Head
13	Cabbage aphid	*Brevicornye brassicae* (Linnaeus)	Aphididae	Nymph, Adult	True leaf stage, Pre cupping, cupping/ curd initiation and Early head formation stage	Leaves, Head
	Order: Diptera					
14	Leaf miner	*Liriomyza trifolii* (Burgen)	Agromyzidae	Caterpillar	Seedling, True leaf stage	Leaves
	Order: Coleoptera					
15	Flea beetle	*Phyllotreta chotanica* Duv.	Alticidae	Adult	Seedling, True leaf stage	Leaves, Roots
	Order: Orthoptera					
16	Short horn grasshopper	*Atractomorpha crenulata* (Fabricius)	Pyrgomorphidae	Nymph, Adult	Seedling, True leaf stage	Leaves
17	Long horn grasshopper	Unidentified		Nymph, Adult	Seedling, True leaf stage	Leaves
	Phylum: Mollusca					
18	Slugs*	Unidentified			Early head formation and head fill stage	Head

*Pest of cabbage only

Plate 1a. Adult

Plate 1b. Egg mass

Plate 1c. Early instar

Plate 1d. Late instar

Plate 1e. Pupa of *S. litura*

Plate 1. Life stages of *Spodoptera litura*

Plate 2a. Netted appearance on leaves

Plate 2b. Damaged wrapper leaves

Plate 2c. Larva inside head

Plate 2d. Larva inside curds

Plate 2. Symptom and damage caused by *Spodoptera litura* in cabbage and cauliflower

The early instar larvae fed gregariously from the ventral surface of leaves, leaving a netted appearance (Plate 2a). Late instars were voracious feeders feeding the leaves, leaving large regular holes on them. The damage caused by the last instar caterpillars was extensive. They were found feed on the wrapper leaves and bore into the heads as well as curds (Plates 2b, c, d). Damage caused to the curds was more intensive than those caused to the heads. Presence of excreta inside the heads and curds made the product unfit for marketing. Inside the curds webbings were also seen.

4.1.1.1.1.2 *Plutella xylostella* (Linnaeus)

The adult was a minute, greyish-brown moth with a wing span of 12 to 15 mm. Proximal portion of the forewing had diamond shaped markings (Plate 3a). The wing tips were fringed with long hairs. The eggs were yellowish, tiny, flat to oval shaped and found singly as well as in groups on both surfaces of leaves. The larvae were cigar shaped, pale yellowish-green coloured, and covered with fine, tiny scattered, erected hairs (Plate 3b). Pupae were covered with thin loose silken cocoon (Plate 3c). Pupation took place in the plant debris itself.

The early instars were found to bore into the leaf tissues, leaving the upper surface intact (Plate 4a). The later instars were found to feed on all parts of the crop, including heads and curds (Plate 4b, c, d) on grown up plants.

4.1.1.1.1.3 *Plusia signata* Fab.

The adult was a medium sized brown noctuid moth with silvery markings on the centre of the fore wings (Plate 5a). The wing span was about 20-30 mm. Eggs were white and round, laid singly on the under surface of the leaves. Larvae were green, elongated with white stripes on the dorsal and lateral sides of the body. Erected hairs were seen on the body. Each body segment had a single black spot on the lateral sides (Plate 5b). Pupal cocoons were roughly spun with silken threads (Plate 5c). Pupation was on the underside of the older leaves.

Plate 3a.Adult

Plate 3b. Larva

Plate 3c. Pupa

Plate 3. Life stages of *Plutella xylostella*

Plate 4a. Damage by early instar

Plate 4b. Damaged wrapper leaves

Plate 4c. Damage on head

Plate 4d. Damage on curd

Plate 4. Symptom and damage caused by *Plutella xylostella* in cabbage and cauliflower

Plate 5a. Adult

Plate 5b. Larva

Plate 5c. Pupa

Plate 5d. Feeding symptom

Plate 5. Life stages and feeding symptom of *Plusia signata*

Early instars remained on the under surface of leaves, along the mid rib, eating through the upper epidermis. Later instars fed on the mature leaves leaving larger holes on leaf surface and caused extensive damage to leaves (Plate 5d).

4.1.1.1.1.4 *Plusia orichalcea* Fab.

The adult was a light brown medium sized moth with a wedge shaped golden marking on the fore wings (Plate 6a). Hind wings were brown in colour. The wing span was 36 to 42 mm. Eggs were white and round, laid singly on the under surface of leaves. Larvae that were green with white longitudinal markings on dorsal and lateral sides of the body (Plate 6b), have small hairs too on their body surface. The difference observed in this species from that of *P. signata* was the absence of black spots on the body segments. Pupae were roughly spun with silken cocoon (Plate 6c). Pupation was on the underside of older leaves.

Damage and symptoms observed were as same as that of *P. signata*

4.1.1.1.1.5 *Spilosoma obliqua* Walker

The arctid moth was medium sized with a wing span of 40 to 45 mm. Wings were pinkish-buff coloured and spattered with black spots (Plate 7a). The head, thorax and ventral sides of body were dull yellow in colour. The eggs were laid in group in large conspicuous masses (Plate 7b). The larvae were stout and had an orange coloured broad band on the dorsal side. The body was covered with tuft of hairs (Plate 7c). Pupae were brown in colour. Pupation occurred beneath the soil surface or plant debris.

The young caterpillars were found feeding on the leaves gregariously, leaving the epidermis intact (Plate 7d). Late instars were found to feed the entire leaf.

Plate 6a. Adult

Plate 6b. Larva

Plate 6c. Pupa

Plate 6. Life stages of *Plusia orichalcea*

Plate 7a. Adult

Plate 7b. Egg mass

Plate 7c. Larvae

Plate 7c. Feeding symptom

Plate 7. Life stages and feeding symptom of *Spilosoma obliqua*

Plate 8a. Adult

Plate 8b. Larva

Plate 8c. Pupa

Plate 8. Life stages and feeding symptom of *Dasychira mendosa*

4.1.1.1.1.6 *Dasychira mendosa* Hb.

The adult was a medium sized smoky brown, lymantrid moth, with hind wings pale grey in colour (Plate 8a). The fore wings were uniformly brown with black specks and pale patch outside the sub-basal line. The wing span was 46 to 54 mm. The hairy larvae had pronounced prothoracic and pre anal tuft of hairs. Red spots and white warts were seen on the body surface (Plate 8b). Pupae were creamy white, seen inside rough silken cocoon (Plate 8c). Pupation took place on plant debris.

The caterpillars were found to feed voraciously on leaves, leaving the midrib intact.

4.1.1.1.1.7 *Pericallia ricini* F.

The adult was a medium sized arctid moth, with brown fore wings and crimson coloured hind wings. Brown patches were seen all over the wings. Abdomen was crimson coloured (Plate 9a). Wing span was 46 mm. Larvae were black with brown head and had long brownish hairs all over the body (Plate 9b). Pupation took place on the underside of older leaves.

Caterpillars fed on older leaves leaving irregular holes on them.

4.1.1.1.1.8 *Spodoptera exigua* Hb.

The adult was a medium sized moth, with wing span of 25-30 mm. The fore wings were grey brown in colour with irregular banding pattern (Plate 10). The hind wings were white in colour, and trimmed with a dark margin. The eggs were cylindrical, greenish white in colour, laid in groups and covered with a layer of whitish scales. They were laid on the under surface of leaves. The larvae were pale green or yellow in colour during the early instars and acquired pale stripes

Plate 9a.Adult **Plate 9b. Larva**

Plate 9. ***Pericallia ricini***

Plate 10. ***Spodoptera exigua***

dorsally, during the later instars. The pupa is light brown in colour. Pupation was in the soil.

Young larvae, found in clusters, fed gregariously on leaves leading to skeletonization. Mature ones got dispersed and made large irregular holes on foliage. They were found to burrow into the crown or centre of the head.

4.1.1.1.1.9 *Appias lyncida* Cramer

The adult was a medium sized pierid butterfly with a wing span of 55-70mm. Wings were white with grey - black wing margins. Hind wings were white with brown border (Plate 11a). The ventral of the hind wing was dirty white in colour, with yellow and grey-black pigmentation (Plate 11b). The veins were faint on the upper side but prominent on the underside. The eggs were orange in colour, spindle shaped and laid in groups of 5-10 on the upper surface of tender leaves. Caterpillars were slender, green in colour found on the lower surface of leaves (Plate 11c). Pupae were light green with one or two triangular projections on the upper surface (Plate 11d). Pupae were seen on the upper surface of leaves. Caterpillars were found feeding on the leaves by remaining on the under surface.

It was for the first time this pest was observed to be feeding on Brassicaceae plants, in contradiction to its host plants belonging to the family Capparidaceae.

4.1.1.1.1.10 Bell moth (unidentified)

The adult was a small sized bell shaped moth. Both the wings were pale brown in colour (Plate 12a). Wing span was 20 mm. The larvae were green with black head (Plate 12b). Small white coloured hairs were present on the lateral sides of the body. Pupation was inside the inner whorls of tender heads. Pupa was brown in colour.

The caterpillar was found to bore into the growth primordia during the head initiation stage in cabbage (Plate 12c). Only a single caterpillar entered

Plate 11a. Dorsal view

Plate 11b. Ventral view

Plate 11c. Larva

Plate 11d. Pupa

Plate 11. Life stages of *Appias lyncida*

Plate 12a. Adult

Plate 12b. Larva

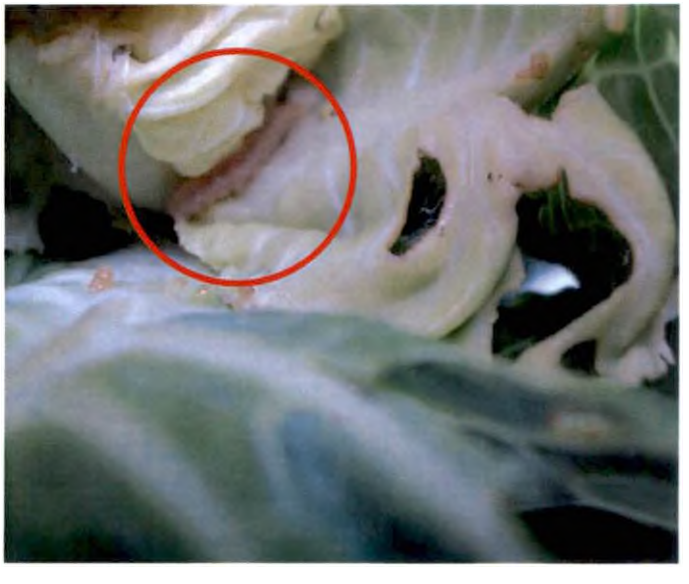


Plate 12c. Feeding symptom

Plate 12. Life stages and feeding symptom of bell moth

the feeding site. The internal tissues were damaged and the leaves subsequently dried up making the heads unfit for consumption.

4.1.1.1.1.11 Bagworm (unidentified)

The bagworm cases constructed using plant materials ranged in size from less than 10 mm to 15 mm. These cases were found attached to the plants in the seedling stage.

They were found to feed on the leaves and to leave holes on the lamina.

4.1.1.1.2 Order : Hemiptera

4.1.1.1.2.1 *Lipaphis erysimi* (Kaltenbach)

Adults were yellowish pear shaped aphids (Plate 13). Nymphs were pale yellow in colour. They were observed to congregate in large numbers and feed from the under surface of leaves. They also de sapped the immature heads. The infested parts lost their turgidity and the plant growth was stunted.

4.1.1.1.2.2 *Brevicornye brassicae* (Linnaeus)

The nymphs and adults were pale green in colour. Body was covered by white waxy powder like coating (Plate 14). Aphids congregated in large clusters in the centre of the heads. The infested parts lost their turgidity.

4.1.1.1.3 Order : Coleoptera

4.1.1.1.3.1 *Phyllotreta chotanica* Duv.

The adult was a small, metallic blue chrysomellid beetle, about 3 mm in length (Plate 15a). The adults were found to damage young seedlings and exhibited shot-hole symptoms on leaves of seedlings (Plate 15b). Grubs were suspected to feed on roots.

Plate 13. *Lipaphis erysimi*

Plate 14. *Brevicornye brassicae*

Plate 15a. *Phyllotreta chotanica*

Plate 15b. Symptom of attack

4.1.1.1.4 Order : Diptera

4.1.1.1.4.1 *Liriomyza trifolii* (Burgen)

Small black flies, about 2mm in length. Yellowish markings were there in the head region. Wings were hyaline. Maggots were cream in colour, minute, seen inside the mines. Severely mined leaves turned yellow, disfigured and were finally dropped (Plate 16).

4.1.1.1.5 Order : Orthoptera

4.1.1.1.5 .1 *Atractomorpha crenulata* (Fabricius)

A medium sized green coloured adult was found feeding voraciously on cabbage and cauliflower leaves (Plate 17). Irregularly cut marginal areas appeared on leaf margins.

4.1.1.1.5.2 Long horned grasshopper (Unidentified)

A medium sized green coloured grasshopper with long threadlike antennae was found feeding cabbage and cauliflower leaves (Plate 18).

4.1.1.1.6 Slug (unidentified)

A greyish brown slug, that measured 40 mm in length (Plate 19). It produced thin and slimy trail while moving.

The slugs caused damage to cabbage during early head formation stage. They were found attacking the wrapper leaves of head. They grated away the surface of wrapper leaves. Presence of a glistening slime trail, helped to distinguish the injury. Their excreta made the heads unfit for consumption.

Of the pests identified as above, bell moth and slug was found to feed on cabbage only.

Plate 16. *Liriomyza trifolii* – **symptom**

Plate 17. *Atractomorpha crenulata*

Plate 18. Long horned grasshopper

Plate 19. Slug

4.1.1.2 Pests affecting different growth stages

Accurate growth stage descriptions of the crop and susceptibility of different stages of the crop to the pest complex in the ecosystem could particularly be useful from the management point of view. Susceptibility of plant to pests, varied with crop stages. Hence the pests affecting the crop at specific stages are detailed below.

4.1.1.2.1 Seedling stage

Diamond Back Moth (DBM), *P. xylostella*, flea beetle, *P.chotanica*, leaf miner *L. trifolii*, short horned grass hopper, *A. crenulata* and long grass hopper (unidentified) and bag worm (unidentified) were the pests that damaged seedlings.

4.1.1.2.2 True leaf stage

True leaf stage was found to be the most susceptible stage of cabbage and cauliflower. Fourteen insect species were recorded as defoliators during this stage. Data collected showed that the cutworm, *S. litura* was the predominant pest in plains where as in the hilly tracts of Idukki district, DBM was the predominant one. There was no incidence of DBM in the plains and so also no incidence of *S. litura* was noticed in the hilly tracts. Other lepidopteran pests that attacked the crop were beet army worm, *S. exigua,* semilooper caterpillars, *P. signata* and *P. orichalcea*, hairy caterpillars, *P. ricini*, *D. mendosa.*, *S. obliqua*, and pierid butterfly, *A. lyncida*. The aphid species observed were *L. erysimi* and *B. brassicae*. *L. erysimi* was found to attack the crop in plains also, whereas *B. brassicae* was observed only in the hilly areas. The flea beetle, *P. chotanica* was another pest that dominated in the true leaf stage. *L. trifolii* and short horned grasshopper, *A. crenulata* and long horned grasshopper (unidentified) were also found to feed on leaves to a lesser extent.

4.1.1.2.3 Pre cupping and Cupping stages / Curd initiation stage

The pests observed during this stage were cut worm, DBM, aphids and semiloopers.

4.1.1.2.4 Early head formation stage / Curd development stage

This stage was observed to be the most critical stage of the crop. Apart from cut worm, DBM and aphids, bell moth and slugs were found to feed on the developing heads. The most injurious pest observed was the bell moth since it fed on the growth primordia of cabbage.

4.1.1.2.5 Head fill stage

When the heads were formed, cut worm was the only pest seen in plains while DBM and slug were the pests observed in the hilly tracts.

4.1.1.2.6 Head/ Curd maturity stage

The population of cut worm and DBM was found to decline during this stage. In the hilly tracts slugs were found to dominate in this stage.

4.1.2 Natural enemies

Details of natural enemies recorded from cabbage and cauliflower fields are given below.

4.1.2.1 Predators

Natural enemies were observed only in fields where there was aphid infestation. The natural enemies recorded from the colonies of *L. erysimi* were the coccinellid beetles, *Chilomenes sexmaculata* Fabr. and *Coccinella transversallis* Fabricius (Plate 20a, b, c). The syrphid predator collected was identified as *Ischiodon scutellaris* (Fabricius)(Plate 20d, e).

Plate 20a. *Chilomenes sexmaculata*

Plate 20b. *Chilomenes sexmaculata*

Plate 20c. *Coccinella transversallis*

Plate 20d. *Ischiodon scutellaris*

Plate 20e. Larvae of *Ischiodon scutellaris*

Plate 20. Predators of Cabbage aphids

Plate 21a. ***Plusia signata*** **parasitized by** ***Protapanteles*** **sp.**

Plate 21b. Emergence of ***Protapanteles*** **sp.**

Plate 21. Larval parasitoid of ***Plusia signata***

4.1.2.2 Parasitioids

Larvae of *P. signata* were found to be parasitised by the braconid endo-parasitiod, *Protapanteles* sp. (Plate 21a). White coloured silken cocoons were found to emerge from the last instar larvae of the host insect. A single parasitized larva was found to harbour 32 cocoons. Pupal period of the parasitoid was four days. The adults were black, minute and with hyaline wings having black pterostigma (Plate 21b).

The host insect was not dead even at the time of formation of cocoons of the parasitoid, but was found paralysed and it stopped feeding. Eventually, on emergence of the adults, death of the host occurred.

4.2 Extent of infestation and damage caused by pests

4.2.1 Extent of infestation

The extent of infestation caused by different pests in different districts was worked out based on the Pest infestation Index (PI).

In Thiruvananthapuram, Kollam and Thrissur districts, representing the plains of Kerala, the major infestation was that of *S. litura*, the PI were 71.99, 71.33, and 69.99 respectively (Table 2). Infestation of other pests in these districts was very low. The minor pests, mustard aphid, *L. erysimi,* semi loopers, *P .signata, P. orichalcea*, hairy caterpillars, *P. ricini, D. mendosa, S. obliqua* and leaf miner, *L. trifolii* were also prevalent in all the above districts. Their pest infestation index ranged from 8.66 to 12.66, 6.66 to 11.99, 1.33 to 2, 2.66 to 3.99, 2 to 5.33, 2.66 to 4.66 and 7.33 to 15.33 respectively. The incidence of flea beetle, *P. chotanica* was observed only in Thiruvanathapuram (PI 14.66) and Kollam districts (PI 7.33). It was not observed in Thrissur district. The pierid butterfly *A. lyncida* was observed only from one location at Thiruvanathapuram district. Other pests with lesser indices were, *S. exigua, A, crenulata and* unidentified species of bell moth, bag worm and long horned grass hoppers.

Table 2. Extent of infestation caused by pests of cabbage and cauliflower in the different districts of Kerala.

Sl. No.	Pests	Mean pest infestation index			
		Plains			Hilly tract
		Thiruvananthapuram	Kollam	Thrissur	Idukki
1	*Spodoptera litura*	71.99	71.33	69.99	--
2	*Pultella xylostella*	--	--	--	73.99
3	*Plusia signata*	6.66	11.99	10.66	--
4	*Plusia orichalcea*	2	1.33	1.33	--
5	*Spilosoma obliqua*	3.33	4.66	2.66	1.33
6	*Dasychira mendosa*	2	5.33	3.99	2.66
7	*Pericallia ricini*	3.33	3.99	2.66	3.33
8	*Spodoptera exigua*	1.33	--	1.33	--
9	*Appias lyncida*	1.33	--	--	--
10	*Lipaphis erysimi*	9.99	8.66	12.66	--
11	*Brevicornye brassicae*	--	--	--	19.33
12	*Phyllotreta chotanica*	14.66	7.33	--	--
13	*Liriomyza trifolii*	7.33	15.33	8.66	11.99
14	Grass hoppers	7.99	8.66	9.99	7.33
15	Bell moth	4.66	7.33	10.66	--
16	Bag worm	2.66	3.99	1.33	--
17	Slug	4.66	--	--	11.33

Mean of five locations per district

The PI of DBM was high (73.99) in the major cool season vegetable growing areas *viz.* Devikulam, Vattavada and Kanthalloor comprising the hilly tracts of Idukky district. In these areas, infestation index of *S. litura* was zero. The cabbage aphid, *B. brassicae* was observed in the hilly tracts only with a PI of 19.33. Other pests observed with less infestation indices were *D. mendosa, S. oblique, P. ricini, L. trifolii* and grasshoppers.

The pests that were found to occur in both the hilly tracts and plains were *L. trifolii, D. mendosa, P. ricini, S. obliqua* and short horned grass hoppers.

4.2.2 Extent of damage caused by major pests

4.2.2.1 *S. litura*

In cabbage, observations recorded from five different locations (Table 3) revealed that the mean number of leaves damaged per plant ranged from 1.4 ± 1.77 to 2.90 ± 1.79. Percentage of leaves damaged during vegetative phase was estimated as 15.32 only but in the bearing stage it was 30.00 per cent.

In cauliflower (Table 4) the mean number of leaves damaged per plant, ranged from 3.2 ± 1.81to 3.7 ± 1.63 and the per cent damage caused to leaves was 20.80 only but in the bearing stage it was 30 per cent.

4.2.2.2 *P. xylostella*

Observations recorded from cabbage plots (Table 5) revealed that mean number of leaves damaged per plant ranged from 2.1 ± 1.52 to 2.9 ± 1.52. Percentage of leaves damaged during vegetative phase was estimated as 17.58 only but in the bearing stage it was 38 per cent.

In cauliflower (Table 6), the mean number of leaves damaged ranged from 2.4 ± 1.71 to 3.3 ± 1.88. Percentage of leaves damaged during vegetative phase was estimated as 17.63 only but in the bearing stage it was 26 per cent.

Table 3. Extent of damage caused by *Spodoptera litura* during vegetative and reproductive stages of cabbage

Location	Mean number of leaves/plant	Mean number of leaves damaged/plant	Extent of leaves damaged (%)	Number of heads damaged	Extent of heads damaged (%)
1	11.2	1.6 ± 1.26	14.28	3 ± 0.48	30
2	12.5	2 ± 1.76	16	2 ± 0.42	20
3	13.9	1.4 ± 1.77	10.07	3 ± 0.48	30
4	14.6	2.9 ± 1.79	19.86	3 ± 0.48	30
5	13.4	2.2 ± 1.47	16.41	4 ± 0.51	40
Mean	---	--	15.324	---	30

Mean of 10 plants

Table 4. Extent of damage caused by *Spodoptera litura* during vegetative and reproductive stages of cauliflower

Location	Mean number of leaves/plant	Mean number of leaves damaged/plant	Extent of leaves damaged (%)	Number of curds damaged	Extent of curds damaged (%)
1	17.3	3.6 ± 2.06	20.80	3 ± 0.48	30
2	15.9	3.2 ± 1.81	20.12	2 ± 0.42	20
3	16	3.3 ± 1.88	20.62	3 ± 0.48	30
4	16.9	3.7 ± 1.63	21.89	3 ± 0.48	30
5	17	3.5 ± 2.01	20.58	4 ± 0.51	40
Mean	---	----	20.80	---	30

Mean of 10 plants

Table 5. Extent of damage caused by *Plutella xylostella* during vegetative and reproductive stages of cabbage

Location	Mean number of leaves/plant	Mean number of leaves damaged/plant	Extent of leaves damaged (%)	Number of heads damaged	Extent of heads damaged (%)
1	13.3	2.1 ± 1.72	15.78	3 ± 0.48	30
2	13.6	2.7 ± 1.70	19.85	5 ± 0.52	50
3	15.1	2.9 ± 1.52	19.20	5 ± 0.52	50
4	14.9	2.9 ± 1.44	19.46	3 ± 0.48	30
5	15.4	2.1 ± 1.52	13.63	3 ± 0.48	30
Mean	---	---	17.58	---	38

Mean of 10 plants

Table 6. Extent of damage caused by *Plutella xylostella* during vegetative and reproductive stages of cauliflower

Location	Mean number of leaves/plant	Mean number of leaves damaged/plant	Extent of leaves damaged (%)	Number of curds damaged	Extent of curds damaged (%)
1	16.2	3.3 ± 1.88	20.37	3 ± 0.48	30
2	15	2.6 ± 1.83	17.33	2 ± 0.42	20
3	15.6	3.1 ± 2.46	19.87	4 ± 0.51	40
4	15.8	2.4 ± 1.71	15.18	3 ± 0.48	30
5	14.9	2.3 ± 1.25	15.43	1 ± 0.31	10
Mean	---	---	17.63	---	26

Mean of 10 plants

4.3 Biology of *S. litura* on Cabbage

The duration of different stages of the insect, as well as its survival, worked out under laboratory conditions are given in Table 7.

4.3.1 Duration and survival of each stage

Egg - The eggs were round and dirty white, covered with buff coloured hairs. The incubation period was 2.8 ± 0.42 days. 83.33 per cent of eggs kept for hatching emerged into first instar larvae.

First instar larva - The newly emerged larva was yellow green in colour and measured 1.92 mm in length. Head was brownish black and broader than body. They remained in clusters on the under surface of the leaves scrapping on the green matter. Duration of the first instar was for 3 ± 0 days. Eighty eight per cent of the first instar larvae moulted to the second stage.

Second instar larva - The second instar larvae were 4.51 mm in length. The caterpillars turned more greenish and the heads became more prominent and brownish in colour. They still remained in clusters actively feeding the lower epidermis. It took 3.4 ± 0.51 days to complete this stage. Survival percentage recorded was 90.90.

Third instar larva – The caterpillars were 11.71 mm in length, greenish brown in colour with black conspicuous head. They were active feeders, leaving small holes on the leaves. During this stage they scattered at different parts of the leaves, mostly hiding behind the leaves. It took 4.3 ± 0.48 days to complete this stage and the survival percentage recorded was 80.

Fourth instar larva - The caterpillars were brown with three thin yellow lines down the back, one in the middle and one on each side. A row of black glazy markings were there on the lateral walls. Body became cylindrical and measured 25.66 mm in length. They were found to disperse all over the rearing tray. When disturbed, they coiled up. They were voracious feeders leaving large holes on

Table 7. Biology of *Spodoptera litura* on cabbage

Stage of insect	Number observed	Mean ± SD duration (days)	Survival (%)
Egg	6 egg masses	2.8 ± 0.42	83.33
Larval stages			
1st instar	25	3 ± 0	88.23
2nd instar	22	3.4 ± 0.51	90.90
3rd instar	20	4.3 ± 0.48	80
4th instar	16	2.2 ± 0.42	100
5th instar	16	3.5 ± 0.52	87.5
Total larval period		16.4 ± 0.23	---
Pupa	14	9.6 ± 0.51	100
Adult longevity	--	7.7 ± 0.48	---

*Mean of ten observations

SD- Standard deviation

leaves. It took 2.2 ± 0.42 days to complete this stage. The survival percentage recorded was 100

Fifth instar larva - They measured about 45.91 mm in length and were dark brown in colour with black shiny patches on lateral walls of the body. They fed voraciously on leaves leaving the midrib intact. After two to three days the feeding rate was reduced. Fifth instar duration lasted for 3.5 ± 0.52 days. Survival percentage was 87.5. By the fourth day they stopped feeding and went beneath the soil for pupation. The total larval period lasted for 16.4 ± 0.23 days.

Cannibalism was not observed during any of the stages.

Pupa – Elongated, oval shaped and shiny brown in colour, the average weight being 0.312 g. The pupal period was 9.6 ± 0.51 days and there was no pupal mortality.

Adult – Adult longevity was 7.7 ± 0.48 days.

Total life cycle ranged from 36.5 ± 0.19 days.

4.4 Population build up of *S. litura* in cabbage and cauliflower

The mean population of *S. litura* per plant was recorded during November-February of the two consecutive years 2011-12 and 2012-13.

4.4.1 Population of *S. litura* during different growth stages of the crop

The population data was analysed separately for cabbage and cauliflower to find out the susceptibility of different growth stages of the crop to the pest.

4.4.1.1 Cabbage

Analysis of the data on population build up revealed that during 2011-12, there was no *S. litura* infestation in the cotyledons and seedlings (Table 8). The pest build up commenced from the early true leaf stage i.e. five weeks after planting (WAP). The mean number of caterpillars per plant was 2.63. At the pre cupping stage (8 WAP), the population increased significantly, reaching the level

of 9.90 caterpillars per plant. At the cupping (10 WAP) and early head formation (12 WAP) stages also the larval count was found to increase steadily (13.57 and 20.47 caterpillars per plant respectively) reaching the peak at 13 WAP, the head fill stage (24.10 caterpillars per plant). Thereafter, the pest population showed a slow decline (23.37 caterpillars per plant) when the heads attained maturity (15 WAP).

During 2012 -13 also, incidence of *S. litura* was observed only from the fifth week onwards. The population build up started with a mean number of 4.37 caterpillars per plant and gradually increased during the true leaf stage and reached a significantly higher population at the pre cupping stage (12.30 caterpillars per plant). The population observed at the cupping and early head formation stages (21.03 and 26.50 caterpillars per plant respectively) showed a steady increase in population, but they were on par with that observed at the pre cupping stage. Thereafter, at the head fill and maturity stages, a slow decline was noted (26.73 and 26.76 caterpillars per plant respectively).

4.4.1.1 Cauliflower

In the year 2011 -12, infestation commenced from the early true leaf stage (5 WAP) and the number of caterpillars per plant during this stage was 22.90 (Table 9). The population seemed to increase slowly and steadily reaching the peak level (36 caterpillars per plant), at the curd development stage (12 WAP). Thereafter, the pest population showed a gradual decline when curds have fully developed. The population level went down reaching the minimum level at 15 WAP (15.66 caterpillars per plant), when the curds attained maturity.

A similar trend was observed during 2012- 13 also. Starting from a minimum level of 31.43 caterpillars per plant at 5 WAP, the population growth was slow and steady, till it increased significantly at curd development stage (49.33caterpillars per plant) and then decreased gradually reaching a minimum of 23.27caterpillars per plant at curd maturity stage.

Table 8. Population build up of *Spodoptera litura* during different growth stages of cabbage

WAP	Growth stages	Mean number of caterpillars / plant*	
		2011-12	2012-13
1-4	Seedling stage	Nil	Nil
5	True leaf stage	2.63	4.37
6	True leaf stage	3.80	6.87
7	True leaf stage	7.03	9.13
8	Pre cupping stage	9.90	12.30
9	Cupping stage	11.63	17.87
10	Cupping stage	13.57	21.03
11	Early head formation	16.73	23.57
12	Early head formation	20.47	26.50
13	Head fill stage	24.10	28.73
14	Head fill stage	23.93	26.73
15	Mature stage	23.37	26.76
CD (0.05)		4.769	5.520

*Mean of 30 observational plants

WAP – Weeks after planting

Table 9. Population build up of *Spodoptera litura* during different growth stages of cauliflower

WAP	Growth stages	Mean number of caterpillars / plant*	
		2011-12	2012-13
1-4	Seedling stage	Nil	Nil
5	True leaf stage	22.90	31.43
6	True leaf stage	23.90	33.00
7	True leaf stage	30.43	34.07
8	Curd initiation	31.53	38.47
9	Curd initiation	36.00	41.57
10	Curd initiation	37.30	44.97
11	Curd development	41.30	45.87
12	Curd development	42.30	49.43
13	Curd development	30.70	38.77
14	Curd maturity	21.97	27.67
15	Curd maturity	15.67	23.27
CD (0.05)		13.612	17.486

*Mean of 30 observational plants

WAP – Weeks after planting

4.4.2 Correlation of population of *S. litura* in cabbage and cauliflower with weather parameters.

Population of *S. litura* observed during the two consecutive seasons 2011-12 and 2012-13, their association with weather parameters and the correlation coefficients are presented in Tables 10 and 11.

4.4.2.1 Cabbage

4.4.2.1.1 2011-12 (November-February)

Analysis of data during 2011-12 revealed that there was no incidence of the pest during the first four weeks after planting. The mean population observed at 5 WAP was 2.63 caterpillars per plant. The larval population observed at weekly intervals thereafter, showed a general increasing trend, reaching the peak population of 24.10 at 13 WAP. The population observed during 12 to 15 WAP were significantly higher than the lower population levels observed during 5 to 10 WAP.

Correlation coefficients between *S. litura* population and weather parameters (Table 10), revealed that the population was significantly and positively correlated with the total sunshine hours (0.5222). The maximum sunshine recorded during the experimental period was 9.4 h, during which the population recorded was also maximum 24.10 caterpillars per plant. During the period when total sunshine hours were minimum (7.2 h) the population was also its minimum level (2.63 caterpillars per plant).

However, the minimum temperature and evening relative humidity showed a significant negative correlation (- 0.5613 and 0.5244, respectively) with the population of caterpillars. At minimum temperature (19.9°C) and minimum evening RH (55.3%), the caterpillar population reached its peak (24.1 caterpillars per plant). The minimum population of 2.63 caterpillars per plant was recorded when the minimum temperature (23.6°C) and maximum evening RH (79.3) was highest. Though the maximum temperature and morning humidity showed a

Table 10. Correlation between *Spodoptera litura* population and weather parameters during 2011-12 and 2012-13 on cabbage (Crop period - November to February)

Parameters	Correlation coefficients		
	2011-12 (n=12)	2012-13 (n=12)	Pooled values (n=24)
Maximum temperature (°C)	0.2593	-0.1511	0.1392
Minimum temperature (°C)	-0.5613*	-0.4787	-0.4550
Morning Relative humidity (%)	0.3836	-0.5414*	-0.2443
Evening Relative humidity (%)	-0.5244*	0.6316*	0.0993
Sunshine (hours)	0.5222*	0.3466	0.4173
Rainfall (mm)	-0.3055	0.2479	-0.0789

* Significant at 10% level

Table 11. Correlation between *Spodoptera litura* population and weather parameters during 2011-12 to 2012-13 on cauliflower. (Crop period- November to February)

Parameters	Correlation coefficients		
	2011-12 (n=12)	2012-13 (n=12)	Pooled values (n=24)
Maximum temperature	-0.1747	-0.3139	-0.1449
Minimum temperature	-0.5053*	-0.1943	-0.3153
Morning Relative humidity	0.5238*	-0.1575	0.0322
Evening Relative humidity	-0.3824	-0.0084	-0.0667
Sunshine (hours)	0.4849	-0.0849	0.2124
Rainfall (mm)	0.1173	0.3811	0.1927

* Significant at 10% level

positive association with population growth, the correlation coefficients were not statistically significant. Similarly, negative association was observed with total rainfall and population of caterpillars but the effect was not enough to get statistical significance.

4.4.2.1.2 2012-13 (November to February)

The data presented in Table 10, represent the population fluctuation of *S. litura* in cabbage during 2012-13. Population build up started from 5 WAP, with a minimum population of 4.37 caterpillars per plant. As observed in the previous year, the population grew up gradually to the peak level (28.73 caterpillars per plant) at 13 WAP with a gradual decline thereafter.

As against that observed during 2011-12, here the correlation coefficients expressed a significant positive association of the population with evening RH and a strong negative association with morning RH.

Pooled analysis of both the years (November to February of 2011-12 and 2012-13), revealed that maximum temperature, morning humidity and sunshine hours are positively correlated with *S. litura* population in cabbage, whereas minimum temperature, evening humidity and rainfall are the factors that can bring down the pest population. However the pooled data did not show correlations with weather parameters.

4.4.2.2 Cauliflower

4.4.2.2.1 2011-12 (Crop period- November-February)

Analysis of data on population, revealed that the pests appeared in the field only at 5 WAP, with a mean number of 22.90 caterpillars per plant. The population was observed to increase gradually reaching the highest levels at 12 WAP (42.3 caterpillars per plant).

The population had a positive correlation with morning RH and total sunshine hours, though the latter was not statistically significant. When the

morning RH increased by four per cent *i.e.* from 94.7 to 98.7, the population of caterpillars per plant was increased by two fold (from 22.9 to 42.3). Like wise, when the total sunshine hours increased from 7.2 to 9.3, the population increased from 22.9 to 42.3 caterpillars per plant. A negative correlation was observed with the maximum and minimum temperature. However the association with maximum temperature was not enough to get statistical significance.

4.4.2.2.2 2012-13 (Crop period- November- February)

During 2012-13 also, population build up started from 5 WAP with a mean number of 31.43 caterpillars per plant. The field counts recorded at weekly intervals showed an increase in population when compared to the previous season. The population reached its highest level at 12 WAP (49. 43 caterpillars per plant) after which it was observed to decline gradually reaching to a count of 23.27 caterpillars per plant at the maturity phase.

Population build up was found to be negatively correlated with decrease in maximum and minimum temperature, morning and evening humidity as well as the total sunshine hours. The correlation coefficients were -0.3139, -0.1943, -0.1575, -0.0084 and -0.0849 respectively. Rainfall was found to be positively correlated with the population of caterpillar per plant, but did not vary statistically.

Pooled analysis of both the seasons revealed that maximum temperature, minimum temperature and evening RH had a negative correlation, while the morning RH, sunshine hours and rainfall are positively correlated with the population growth of *S. litura.*

4.5. Evaluation of botanical insecticides, entomopathogens and new generation insecticides on *S. litura* under laboratory conditions

4.5.1 Effect of entomopathogenic fungi

The third instar caterpillars of *S. litura* treated with spore suspensions of *Metarhizium anisopliae* (Isolate no. 4) at three different concentrations viz. 10^4,

10^7 and 10^{10} spores ml^{-1} and *Beauveria bassiana* (Isolate no. 5) 10^3, 10^6 and 10^9 spores ml^{-1} were observed at 24 h intervals for symptom development or mortality till adult emergence. There was neither symptoms of infestation nor mortality.

4.5.2 Effect of botanicals

4.5.2.1 On mortality

Data on mean per cent mortality of third instar larvae of *S. litura* recorded at 12 h interval are given in Table 12.

Neem Seed Kernel Extracts (NSKE) 2 and 5%, Anona Seed Extracts (ASE) 2 and 10%, Sweet Flag Extracts (SFE) 2 and 10%, Garlic Extracts (GE) 2 and 4%, Bird chilli Extracts (BE) 2 and 4% were the botanical insecticides evaluated against the third instar larvae. Observations were recorded at 12 h interval till the end of 84^{th} hour.

None of the aqueous extracts caused mortality of larvae till the end of 12 h of treatment. Larval mortality recorded after 24 h of treatment revealed that except with NSKE 5%, SFE 10% and GE 2 and 4%, none of the treatments were effective. The mortality rates observed with the above treatments too were very low (3.01 to 11.69).

At 36 h after treatment, NSKE 2 and 5% and SFE 10% were found to be equally effective, their mortality rates being 32.89 per cent. GE 2 and 4% recorded 25 per cent mortality which was on par with that caused by ASE 10% (11.69). The mortality by BE 2 and 4% were very low (3.01). SFE and ASE at lower concentrations were not at all effective at this exposure period.

At 48 h, NSKE 5% recorded 50 per cent mortality followed by GE 2 and 4% (41.31 and 50 per cent respectively). SFE 10% was equally effective as GE 2% but with NSKE 2% the mortality recorded was low (32.89). Mortality of BE 4% was significantly lower (25). However, the higher concentration of ASE as

Table 12. Effect of botanical insecticides on the mortality of *Spodoptera litura* under laboratory conditions.

Treatments	Percentage mortality of *S. litura* at different intervals after treatment (mean of three replication)						
	Hours after treatment						
	24	36	48	60	72	84	LT 50(hours)
NSKE 2%	0(0)	32.89(34.98)	32.89(34.98)	41.31(39.98)	58.68(49.97)	82.15(64.98)	64.67(8.04)
NSKE 5%	11.69(19.99)	32.89(34.98)	50(44.98)	82.15(64.98)	96.99(79.99)	100(90)	46.52 (6.82)
Anona 2%	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Anona 10%	0(0)	11.69(19.99)	11.69(19.99)	11.69(19.99)	25(29.98)	32.89(34.98)	496.20 (22.27)
Sweet flag 2%	0(0)	0(0)	11.69(19.99)	32.89(34.98)	41.31(39.98)	58.68(49.97)	92.26(9.60)
Sweet flag 10%	3.01(9.99)	32.89(34.98)	41.31(39.98)	58.68(49.97)	88.31(69.98)	100(90)	56.45(7.51)
Garlic 2%	3.01(9.99)	25(29.98)	41.31(39.98)	58.68(49.97)	100(90)	100(90)	56.81(7.53)
Garlic 4%	11.69(19.99)	25(29.98)	50(44.98)	82.15(64.98)	100(90)	100(90)	48.07(6.93)
Bird chilli 2%	0(0)	3.01(9.99)	11.69(19.99)	11.69(19.99)	11.69(19.99)	25(29.98)	935.29(30.58)
Bird chilli 4%	0(0)	3.01(9.99)	25(29.98)	25(29.98)	25(29.98)	32.89(34.98)	294.66(17.16)
Untreated check	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	---
CD (0.05)	NS	(17.118)	(17.119)	(22.548)	(16.549)	(13.986)	(24.094)

Figures in parentheses are values after Arc sin transformation

NS – Non significant

well as the lower concentrations of SFE, ASE and BE were significantly inferior to other treatments.

At 60 h of treatment, a similar trend was seen, but the mortality rates were higher ranging from 58.68 to 82.15 per cent with higher concentrations of NSKE (5%), GE (2%) and SFE (10%) and also with lower concentration of GE (2%).

At 72h after treatment both the concentrations of GE recorded cent per cent mortality, however there was no significant difference between NSKE 5% (96.99), SFE 10% (88.31). Mortality observed with NSKE 2% was 58.68. All other treatments were found to be inferior in terms of mortality rate as they did not even cause 50 per cent mortality. The mortality rates observed with these were only 11.69 to 41.31 per cent.

At the end of the experiment (84 h), NSKE 5%, SFE 10% and GE 2 and 4% were found to be equally effective causing 100 per cent mortality of *S. litura.* NSKE 2% resulted in 82.15 per cent mortality of the larvae. ASE 2% did not cause any mortality and was on par with plain water treatment.

Overall observations on the effect of aqueous extracts of botanicals on the third instar larvae of *S. litura* indicated that, all the botanicals needed two to three days to give a substantial mortality rate. It took 60h for the higher concentrations of NSKE and GE to cause 50 per cent mortality.

Analysis of LT_{50} values (Table 12) also revealed the superiority of NSKE 5%, LT_{50} being the lowest (46.52). This was followed by GE 4% (LT_{50} - 48.07) and SFE 10% (LT_{50}- 56.45). LT_{50} values of NSKE 2% and GE 2% were 64.673 and 56.813 respectively.

GE at lower and higher concentrations resulted in higher mortality rates. Moreover their LT_{50} values did not vary significantly.

4.5.2.2 On antifeedant activity

Third instar caterpillars of *S. litura* fed with leaf discs poisoned with botanical insecticides were observed for three days. The results are presented in Fig. 1. After two days, only 25 percentage of the leaf area was found to be fed when treated with NSKE 5%.With 2% NSKE, the area fed was 38 per cent. The leaf area fed with 2 and 4% GE was 26 and 20 percent respectively. The antifeedant effect of 2 and 10% SFE was found to be less, the leaf area fed being 57 and 30 per cent respectively. The leaf area fed with higher concentrations of ASE (10%) and BE (4%) was 90 and 82 per cent respectively. The effect of lower concentrations of ASE (2%) and BE (2%) was negligible. Eventually on the third day, all the caterpillars that were fed with higher concentrations of GE, NSKE and SFE stopped feeding and were found to be dead. At lower concentrations, only GE and NSKE were observed to have antifeedant action.

Based on the observations recorded in Table 12, NSKE 5%, GE 2%and SFE 10% were carried over for the field trial.

4.5.3 Effect of new generation insecticides

The third instar caterpillars of *S. litura* treated with different insecticide solutions were observed for mortality at two hour interval for the first twelve hours after treatment (Table 13).

Mortality of larvae recorded after two hours of treatment showed the superiority of the synthetic pyrethroid, cypermethrin 0.03% with a highest mortality of 96.99 per cent. The mortality with malathion 0.15% was 88.31 and was on par with that of cypermethrin 0.03%. A similar trend was observed at the end of fourth hour also.

At the end of six hours, the new generation insecticide indoxacarb 0.008% also recorded 96.99 per cent mortality and was on par with the cypermethrin 0.03% and malathion 0.15% recorded in cent per cent mortality. Spinosad 0.06% and chlorfenapyr 0.02% recorded 67.10 and 50 per cent mortality and they were

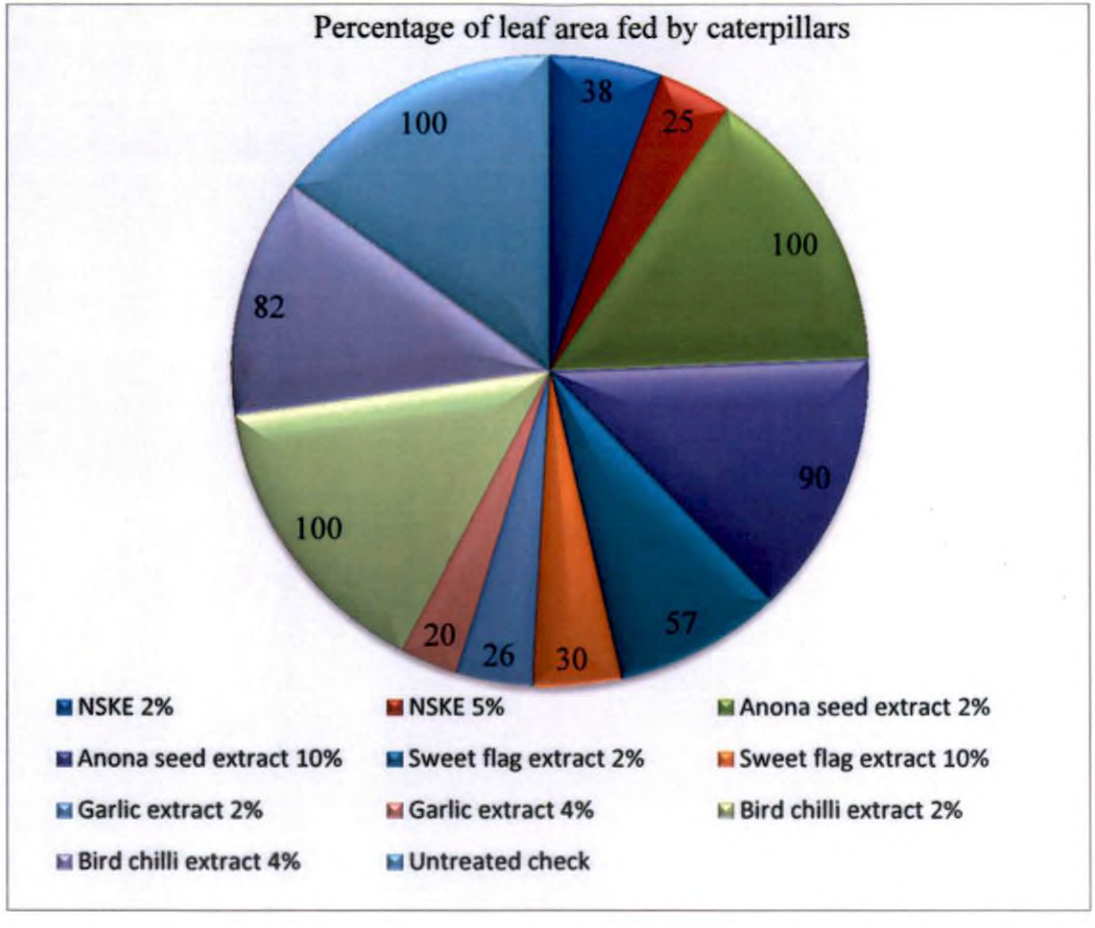


Fig. 1. Antifeedant effect of botanicals on *Spodoptera litura* at 48 hours after treatment

Table 13. Effect of new generation insecticides on the mortality of *Spodoptera litura* under laboratory conditions.

Treatments	Mean percentage mortality of *S. litura* at different interval after treatment (mean of three replication)					
	Hours after treatment					
	2	4	6	8	10	12
Spinosad 0.06%	58.68(49.97)	58.68(49.97)	67.10(54.97)	67.10(54.97)	88.31(69.98)	100(90)
Chlorantraniliprole 0.002%	0(0)	0(0)	0(0)	0(0)	0(0)	50(44.98)
Indoxacarb 0.008%	50(44.98)	82.15(64.98)	96.99(79.99)	96.99(79.99)	100(90)	100(90)
Fipronil 0.008%	25(29.98)	32.89(34.98)	41.31(39.98)	82(64.98)	93.32(74.99)	96.99(79.99)
Emamectin benzoate 0.002%	0(0)	0(0)	32.89(34.98)	88.31(69.98)	96.99(90)	100(90)
Chlorfenapyr 0.02%	25(29.98)	25(29.98)	50(44.98)	75.01(59.98)	96.99(79.99)	100(90)
Cypermethrin 0.03%	96.99(79.99)	96.99(79.99)	100(90)	100(90)	100(90)	100(90)
Malathion 0.15% (treated check)	88.31(69.98)	100(90)	100(90)	100(90)	100(90)	100(90)
Untreated check	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
CD (0.05)	(18.367)	(19.118)	(19.109)	(26.514)	(24.303)	(10.608)

Figures in parentheses are values after Arc sin transformation

on par. This was followed by fipronil 0.008% (41.31 per cent mortality) and emamectin benzoate 0.002% (32.89 per cent mortality) which were not statistically different.

After eight hours, the mortality observed with emamectin benzoate 0.002%, fipronil 0.008% and chlorfenapyr 0.02% too increased to 88.31, 82 and 75.01 per cent respectively and were on par. The significantly lower treatments were chlorfenapyr 0.02% and spinosad 0.06% (75.01 and 67.10 respectively).

After 10 hours, the mortality observed with emamectin benzoate 0.002% and chlorofenapyr 0.02% increased to 96.99 per cent. This was followed by fipronil 0.008% and spinosad 0.06% which were on par, mortality being 93.32 and 88.31 per cent respectively.

At the end of 12 hours, all the insecticides were found to be equally effective with their mortality ranging from 96.99 to 100 per cent but, chlorantraniliprole 0.002% treatment caused only 50 per cent mortality.

The above observations based on mortality revealed that, under laboratory conditions, it took 12 hours for all the chemicals to yield a positive response, except with chlorantraniliprole 0.002%.

Based on the above observations under laboratory conditions, where there is cent per cent exposure of the test insect with the chemicals, all the insecticides were equally effective after 12 hours of treatment, even though significant variations were noticed during the early hours of treatment. Therefore, the superiority of insecticides was tested based on the time taken to cause 50 per cent mortality (LT_{50}). LT_{50} values of the above mentioned chemicals are presented in Table 14.

Analysis of LT_{50} values showed that, the time taken for 50% mortality was least in the case of malathion 0.15% (0.13 h), the check treatment, cypermethrin 0.03% (0.65 h) and the new generation insecticide, indoxacarb 0.008% (1.06 h) which were on par. The time taken for mortality was significantly higher in the

Table 14. Efficacy of new generation insecticides against *Spodoptera litura* based on LT50 values.

Treatments	Concentration	LT50 (hours)
Spinosad 0.06%	1.4ml/ l	3.30(1.81)
Chlorantraniliprole 0.002%	0.1ml/ l	91.28(9.55)
Indoxacarb 0.008%	0.5ml/l	1.06(1.03)
Fipronil 0.008%	1.6ml/l	6.84(2.61)
Emamectin benzoate 0.002%	0.4g/l	8.62(2.93)
Chlorfenapyr 0.02%	1.5ml/l	6.81(2.61)
Cypermethrin 0.03%	3.25ml/l	0.65(0.81)
Malathion 0.15% (treated check)	3ml/l	0.13(0.36)
Untreated check	Water	---
CD (0.05)		(0.683)

Figures in parentheses are values after Arc sin transformation

case of microbial metabolite based insecticide spinosad 0.06% (3.30 h). This was followed by fipronil 0.008%, chlorfenapyr 0.02% and emamectin benzoate 0.002% (6.85, 6.81 and 8.62 h respectively). Chlorantraniliprole 0.002% recorded the highest LT_{50} value of 91.28 h. Hence cypermethrin 0.03% and indoxacarb 0.008% were selected for field evaluation. Although spinosad 0.06% and emamectin benzoate 0.002% had LT_{50} values less than 10 h, considering the cost and availability, they were not included in the field trial.

4.6. Field evaluation of botanicals and new generation insecticides against *S. litura* on cabbage and cauliflower

Based on laboratory studies the following treatments were included for field study. They were the botanicals *viz.*, GE 2%, NSKE 5% and SFE 10% and the insecticides indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15% (treated check). Untreated plot served as control. A total of three sprays were given for cabbage starting from seven weeks after planting when five percent of the plants were found infested. The results are presented in tables 15 to 18.

4.6.1 Cabbage

4.6.1.1 First spraying (True leaf stage)

First spraying was given when five per cent of plants were found infested with *S. litura*. The pre treatment count at the true leaf stage, ranged from 2.86 to 19.66 caterpillars per plant.

First day after treatment, there was no infestation in the plots treated with indoxacarb 0.008% .The population level in cypermethrin 0.03% and malathion 0.15% treated plots were very much reduced (0.33 and 0.44 caterpillars per plant), and was on par with that of indoxacarb 0.008%. Among the botanicals NSKE 5% and GE 2% recorded a minimum population (2 and 4.88) which was significantly lower than indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15%. The population levels in SFE 10% and untreated control plots were significantly higher than all other treatments.

More or less a similar trend was observed on the third day in all the treated plots, except that the population levels were slightly higher. It was 0.11, 0.67 and 0.44 caterpillars per plant in indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15% treated plots and 3 and 8.66 caterpillars per plant in NSKE 5% and GE 2% treated plots. The population level in SFE 10% (8.66 caterpillars per plant) was on par with that of GE 2%.

4.6.1.2 Second spraying (Cupping stage)

Before the spraying given at cupping stage, the population level ranged from 1.11 to 4.22 caterpillars per plant.

First day after treatment, caterpillar population was nil in indoxacarb 0.008% and cypermethrin 0.03% treated plots. The population levels in malathion 0.15%, GE 2%, and NSKE 5 % were on par (0.22, 0.55 and 0.67 caterpillars per plant) with those of indoxacarb 0.008% and cypermethrin 0.03% treated plots. Population levels in untreated control was significantly higher (4.55 caterpillars per plant) than other treatments.

Third day after treatment, there was no reinfestation in indoxacarb 0.008% treated plots, whereas in all other plots there was slight reinfestation. However, the trend observed was exactly the same as that observed after first day, the population levels being 0.44 and 0.78 in malathion 0.15% and cypermethrin 0.03% treated plots and 1 and 1.11 in GE 2% and NSKE 5% treated plots.

4.6.1.3 Third spraying (Early head formation stage)

No spraying was given in indoxacarb 0.008% treated plots as there was no reinfestation.

First day after treatment, there was no infestation in cypermethrin 0.03% and malathion 0.15% treated plots. The population levels observed in NSKE 5% (0.44 caterpillars per plant), SFE 10% (0.55 caterpillars per plant) and GE 2% (1.11 caterpillars per plant) plots were on par, but significantly higher than the

Table 15. Effect of botanicals and new generation insecticides on *Spodoptera litura* population on cabbage

Treatments	Mean number of larvae per plant								
	First spray (True leaf stage/ Seven weeks after transplanting)			Second spray (Cupping stage/ Nine weeks after transplanting)			Third spray (Early head formation stage/ Eleven weeks after transplanting)		
	PTC	1 DAT	3 DAT	PTC	1DAT	3 DAT	PTC	1 DAT	3 DAT
Indoxacarb 0.008%	7.11 (2.66)	0.00 $(0.71)^{c}$	0.11 $(0.78)^{c}$	1.11 (1.26)	0.00 $(0.71)^{c}$	0.00 $(0.71)^{c}$	0.00 (0.71)	0.00 $(0.71)^{c}$	0.00 $(0.71)^{c}$
Cypermethrin 0.03%	12.33 (3.27)	0.33 $(0.90)^{c}$	0.67 $(1.05)^{c}$	2.66 (1.75)	0.00 $(0.71)^{c}$	0.78 $(1.12)^{bc}$	2.77 (1.81)	0.00 $(0.71)^{c}$	0.55 $(1.00)^{bc}$
Garlic extract 2%	19.66 (4.47)	4.88 $(2.25)^{ab}$	8.66 $(2.99)^{a}$	2.00 (1.46)	0.55 $(0.96)^{bc}$	1.00 $(1.18)^{bc}$	3.94 (1.90)	1.11 $(1.25)^{b}$	1.33 $(1.34)^{b}$
Sweet flag extract 10%	13.66 (3.53)	7.11 $(2.66)^{a}$	8.66 $(2.99)^{a}$	2.33 (1.57)	1.33 $(1.34)^{b}$	1.78 $(1.51)^{b}$	1.00 (1.19)	0.55 $(0.96)^{bc}$	0.67 $(1.05)^{bc}$
NSKE 5%	6.11 (2.02)	2.00 $(1.46)^{bc}$	3.00 $(1.87)^{b}$	2.00 (1.40)	0.67 $(1.05)^{bc}$	1.11 $(1.20)^{bc}$	1.22 (1.25)	0.44 $(0.92)^{bc}$	0.77 $(1.08)^{bc}$
Malathion 0.15%(treated check)	2.86 (1.80)	0.44 $(0.95)^{c}$	0.44 $(0.95)^{c}$	4.22 (2.05)	0.22 $(0.83)^{bc}$	0.44 $(0.92)^{bc}$	1.33 (1.18)	0.00 $(0.71)^{c}$	0.33 $(0.90)^{c}$
Untreated check	4.88 (2.25)	5.11 $(2.33)^{a}$	5.44 $(2.42)^{ab}$	4.22 (2.05)	4.55 $(2.21)^{a}$	4.66 $(2.24)^{a}$	4.55 (2.22)	4.89 $(2.30)^{a}$	5.33 $(2.41)^{a}$
CD (0.05)	NS	(0.846)	(0.694)	NS	(0.559)	(0.619)	NS	(0.473)	(0.387)

PTC – Pre treatment count; DAT-Days after treatment; NS – Non significant

Figures in parentheses are values after $\sqrt{x+1}$ transformation;

Means followed by same alphabet do not differ significantly.

population levels observed after spraying cypermethrin 0.03% and malathion 0.15%.

Third day after treatment, there was no infestation in indoxacarb 0.008% treated plots, whereas with cypermethrin 0.03% and malathion 0.15% the population levels were 0.33 and 0.55 caterpillars per plant respectively. The population levels observed in NSKE 5% and GE 2% (0.77 and 1.33 caterpillars per plant) were on par and significantly higher than those observed with cypermethrin 0.03% and malathion 0.15%. However the population in these plots was significantly lower than that in the untreated plots.

Overall observation recorded from cabbage revealed that, the synthetic insecticides indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15% were significantly superior to the botanicals NSKE 5%, GE 2% and SFE 10% based on population levels recorded after treatment and among the botanicals GE 2% and NSKE 5% were more effective than SFE 10%. However all the treatments were found to be superior to untreated check.

Fig. 2a shows the overall reduction in population obtained after spraying during the true leaf, cupping and early head formation stages. The highest population reduction was obtained with indoxacarb 0.008% (99.65 per cent) followed by cypermethrin 0.03% (91.51 per cent) and malathion 0.15% (89.33 per cent). Among the botanicals GE 2% was most effective (68.47 per cent) followed by NSKE 5% (59.24 per cent). SFE 10% was least effective (43.82 per cent). In control plot there was a population build up to an extent of 8.84 per cent, with respect to pre treatment count.

4.6.2 Cauliflower

4.6.2 .1 First spraying (True leaf stage)

During this stage the Pre treatment count (PTC), ranged from 2.33 to 19.22 caterpillars per plant.

No infestation was observed with indoxacarb 0.008% treated plots. The population level recorded was least in cypermethrin 0.03% (0.22). This was followed by malathion 0.15% (0.33), GE 2% (0.66) and NSKE 5% (0.67) which was on par with indoxacarb 0.008%. The population levels were higher in SFE 10% and untreated control plots (3.33 and 5.11 respectively).

After third day also, the trend in population level was observed to be similar.

4.6.2.2 Second spraying (Curd initiation stage)

The mean population per plant was ranged from 1.11 to 3.55 caterpillars per plant. As there were no infestation in plots treated with indoxacarb 0.008% and cypermethrin 0.03% no spraying was given in these plots.

First day after treatment least population was recorded in malathion 0.15% treated plot (0.11 caterpillars per plant). The population level in GE 2% (0.22 caterpillars per plant) was on par with malathion 0.15%. NSKE 5% and SFE 10% recorded the population levels of 0.96 and 1.33 caterpillars per plant respectively which was significantly higher than malathion 0.15% and GE 2%.

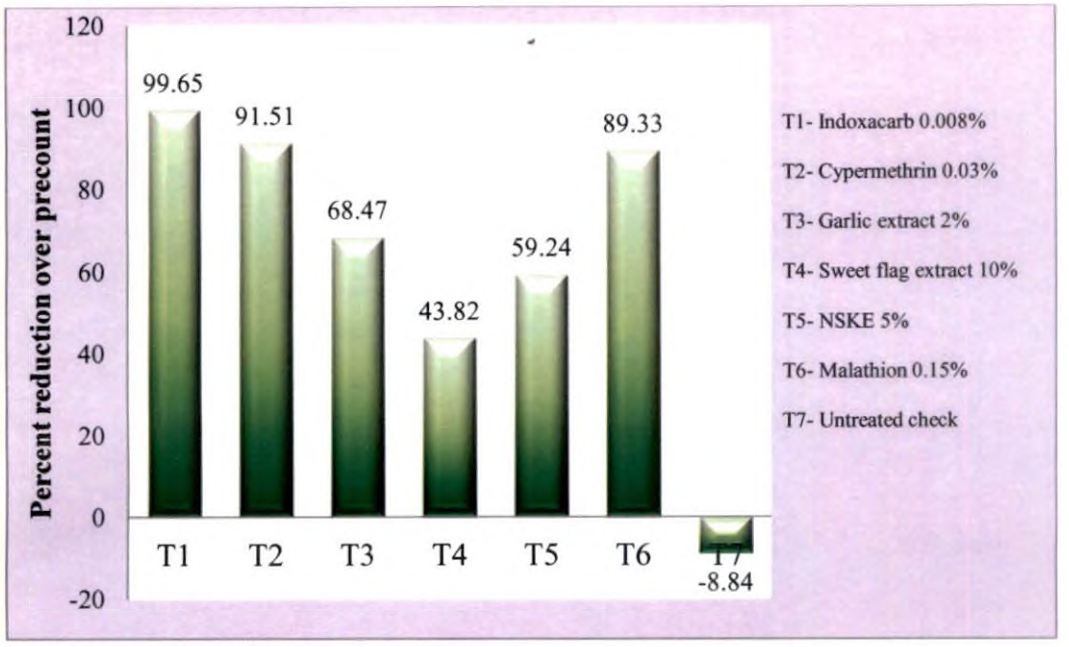
After the third day there was no infestation in indoxacarb 0.008% and cypermethrin 0.03%. The population levels in malathion 0.15% and GE 2% were 0.44 caterpillars per plant. which was significantly lower than that observed in NSKE 5% (1.14 caterpillars per plant) and SFE 10% (1.88 caterpillars per plant).

4.6.2.3 Third spraying (Curd development stage)

Spraying was avoided in indoxacarb 0.008% treated plots as there was no reinfestation.

After one day, there was no infestation in cypermethrin 0.03% and malathion 0.15% treated plots. The corresponding population level in GE 2%, NSKE 5% and SFE 10% were 1, 1.22 and 1.11 caterpillars per plant respectively. The population levels recorded from plots treated with synthetic insecticides were

A. Cabbage



B. Cauliflower

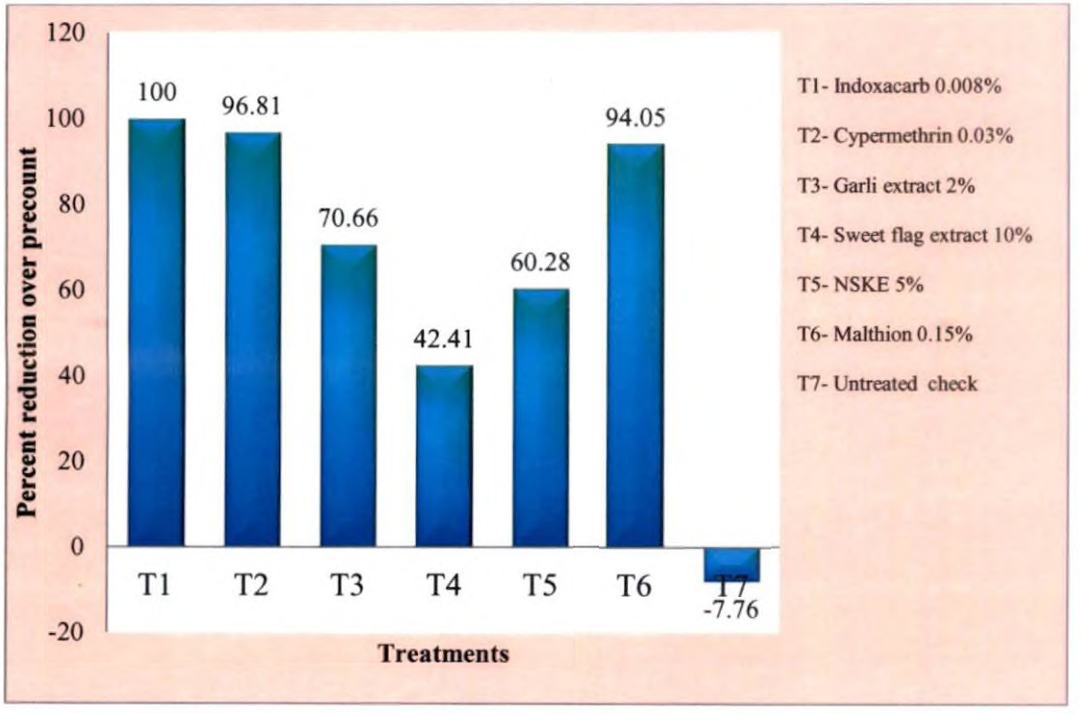


Fig. 2. Percentage reduction in population of *Spodoptera litura* after spraying

Table 16. Effect of botanicals and new generation insecticides on *Spodoptera litura* population on cauliflower.

Treatments	Mean number of larvae per plant								
	First spray (True leaf stage/ Seven weeks after transplanting)			Second spray (Curd initiation stage/Nine weeks transplanting)			Third spray (Curd development stage/ Eleven weeks transplanting)		
	PTC	1 DAT	3 DAT	PTC	1DAT	3 DAT	PTC	1 DAT	3 DAT
Indoxacarb 0.008%	19.22 (4.13)	0.00 $(0.71)^{b}$	0.00 $(0.71)^{b}$	0.00 (0.71)	0.00 $(0.71)^{d}$	0.00 $(0.71)^{c}$	0.00 (0.71)	0.00 $(0.71)^{c}$	0.00 $(0.71)^{c}$
Cypermethrin 0.3%	7.77 (2.48)	0.22 $(0.84)^{b}$	0.78 $(1.09)^{b}$	0.00 (0.71)	0.00 $(0.71)^{d}$	0.00 $(0.71)^{c}$	1.33 (1.34)	0.00 $(0.71)^{c}$	0.00 $(0.71)^{c}$
Garlic extract 2%	3.05 (1.70)	0.66 $(1.05)^{b}$	1.00 $(1.22)^{b}$	1.11 (1.26)	0.22 $(0.83)^{cd}$	0.44 $(0.95)^{c}$	2.70 (1.67)	1.00 $(1.17)^{b}$	1.23 $(1.25)^{b}$
Sweet flag extract 10%	6.00 (2.26)	3.33 $(1.95)^{a}$	3.78 $(2.03)^{a}$	2.44 (1.71)	1.33 $(1.34)^{b}$	1.88 $(1.54)^{b}$	2.11 (1.60)	1.11 $(1.26)^{b}$	1.55 $(1.41)^{b}$
NSKE 5%	2.33 (1.38)	0.67 $(1.00)^{b}$	1.00 $(1.17)^{b}$	2.55 (1.67)	0.96 $(1.19)^{bc}$	1.14 $(1.27)^{b}$	2.55 (1.73)	1.22 $(1.30)^{b}$	1.33 $(1.35)^{b}$
Malathion 0.15% (treated check)	5.44 (2.40)	0.33 $(0.90)^{b}$	0.55 $(1.00)^{b}$	3.55 (2.00)	0.11 $(0.78)^{d}$	0.44 $(0.95)^{c}$	1.22 (1.31)	0.00 $(0.71)^{c}$	0.11 $(0.78)^{c}$
Untreated check	5.11 (2.36)	5.11 $(2.36)^{a}$	5.67 $(2.48)^{a}$	3.22 (1.90)	3.32 $(1.91)^{a}$	3.89 $(2.09)^{a}$	4.55 (2.22)	4.66 $(2.25)^{a}$	5.00 $(2.34)^{a}$
CD (0.05)	NS	(0.440)	(0.569)	NS	(0.398)	(0.304)	NS	(0.459)	(0.452)

PTC – Pre treatment count; DAT-Days after treatment; NS – Non significant

Figures in parentheses are values after $\sqrt{x+1}$ transformation;

Means followed by same alphabet do not differ significantly.

significantly lower than those recorded from botanicals. However all the treatments were effective with respect to control were the number of caterpillars per plant was 4.66.

On the third day, infestation was not noticed in indoxacarb 0.008% and cypermethrin 0.03% treated plots, whereas in malathion 0.15% treated plots, population level was 0.11 caterpillars per plant and was on par with indoxacarb 0.008% and cypermethrin 0.03%. The trend followed by botanicals were similar to those observation recorded on the first day after treatment.

Fig. 2b shows the overall reduction in population obtained after treatment during the true leaf, curd initiation and curd development stages. The highest population reduction was obtained with indoxacarb 0.008% (cent per cent) followed by cypermethrin 0.03% (96.81 per cent) and malathion 0.15% (94.05 per cent). Among the botanicals GE 2% was most effective (70.66 per cent) followed by NSKE 5% (60.28 per cent). SFE 10% was least effective (42.41 per cent). In control plot there was a population build up to an extent of 7.76 per cent with respect to precount.

Overall observation from cabbage and cauliflower revealed the superiority of indoxacarb 0.008 %, cypermethrin 0.03% and malathion 0.15% over botanicals in terms reduction in *S. litura* population. However GE 2% and NSKE 5% were significantly superior to untreated control.

4.6.3 Effect of different treatments on yield

The yield data recorded at the time of harvest are given in Tables 17 and 18.

4.6.3.1 Cabbage

Maximum mean gross weight per head was recorded from indoxacarb 0.008% treated plots (498 g) followed by cypermethrin 0.03%, GE 2%, malathion 0.15% and NSKE 5% (457.66, 422.66, 417.33 and 396.66 g respectively) which did not vary statistically. Yield obtained from SFE 10% treatment (310 g) was

Table 17. Effect of different treatments on yield of cabbage

Treatments	Mean weight of head per plant*		
	Gross weight of head per plant (g)	Net weight of head per plant (g)	Marketable yield (%)
Indoxacarb 0.008%	498	456	91.56
Cypermethrin 0.03%	457.66	394.66	86.23
Garlic extract 2%	422.66	355.33	84.06
Sweet flag extract 10%	310	228.00	73.54
NSKE 5%	396.66	336.66	84.87
Malathion 0.15% (treated check)	417.33	376.66	90.25
Untreated check	88.66	57.33	64.66
CD (0.05)	122.27	60.41	---

*Mean weight of 15 observational plants

Table 18. Effect of different treatments on yield of cauliflower

Treatments	Mean number of curds per treatments*		
	Number of curds harvested	Number of marketable curds	Percentage of Marketable curds
Indoxacarb 0.008%	5.00	5.00	100
Cypermethrin 0.03%	5.00	4.67	93.40
Garlic extract 2%	4.67	4.00	85.65
Sweet flag extract 10%	4.00	2.33	58.25
NSKE 5%	4.67	4.00	85.65
Malathion 0.15% (treated check)	5.00	4.33	86.60
Untreated check	3.33	1.33	39.93
CD (0.05)	NS	1.503	---

*Mean number of 15 observational plants

significantly lower than indoxacarb 0.008% and cypermethrin 0.03%, but was on par with malathion 0.15%, garlic 2% and NSKE 5% treatments. Least gross weight was recorded from untreated plot (88.66 g).

Analysis of mean net weight per head revealed that yield obtained was highest in indoxacarb 0.008% (456 g). This was followed by the yield in cypermethrin 0.03% (394.66 g), malathion 0.15% (376.66 g), GE 2% (355.33 g), and NSKE 2% (336.66 g) which were on par. The least net weight was recorded from SFE 10% treated plots (228 g) which was significantly higher than that in untreated plot (60.41 g).

The percentage of marketable yield calculated was highest in indoxacarb 0.008 % (91.66), followed by malathion 0.15% (90.25) and cypermethrin 0.03% (86.23). Among the botanicals highest marketable yield was obtained from plots treated with NSKE 5% and GE 2% (84.87 and 84.06 per cent respectively). SFE 10% recorded the lowest marketable yield (73.5 per cent). In untreated plot the percentage of marketable yield was 64.66.

4.6.3.1 Cauliflower

The yield data recorded revealed that the mean number of curds harvested from different treatments did not vary significantly.

Maximum mean number of marketable curds was recorded from indoxacarb 0.008% treated plots (5.00), followed by cypermethrin 0.03% (4.67), malathion 0.15% (4.33), GE 2% and NSKE 5% (4.00 each) which do not vary statistically. The least marketed curd was recorded from SFE 10% treated plots (2.33) which was significantly higher than that in untreated plot (1.33).

The percentage of marketable yield calculated was highest in plots treated with indoxcarb 0.008% (cent per cent), followed by cypermethrin 0.03 % (93.40 per cent) and malathion 0.15% (86.60 per cent). Among the botanicals, highest percentage of marketable curds was obtained from 2%GE and 5%NSKE treated plots (85.65 per cent each). In SFE 10% treated plot the percentage of marketable

yield calculated was lowest (58.25 per cent) and in the untreated plot it was 39.93 per cent.

4.7 Estimation of pesticide residue in plant and soil samples

4.7.1 Plant samples

The results of the analysis of pesticide residue in cabbage at harvest time revealed that the mean residues of indoxacarb and cypermethrin were below detectable limit. The limit of quantitation for indoxacarb in LC MS/MS and cypermethrin in GC MS was 0.05 mg kg^{-1}.

4.7.2 Soil samples

The results of the analysis of pesticide residue in soil at harvest time of cabbage revealed that the mean residues of indoxacarb and cypermethrin were below detectable limit. The limit of quantitation for indoxacarb in LC MS/MS and cypermethrin in GC MS was 0.1 mg kg^{-1}.

DISCUSSION

5. DISCUSSION

Cultivation of the cool season vegetables, cabbage and cauliflower in Kerala is no more restricted to the high ranges. The introduction of new tropical varieties of these crops has made possible the cultivation in the plains as well. It is probable that the pests occurring in the crops and the damage caused by them in these two different ecosystems vary and hence it is highly essential to gain in depth knowledge of the pests affecting the crops in the new ecosystem, to standardize their production procedures. Nature and symptoms of damage caused by each pest, the level of injury caused by them and the factors favouring the population build up are to be elucidated before evolving sound pest management strategies.

The present study on "Pests of cabbage (*Brassica oleracea* L. var. *capitata*) and cauliflower (*Brassica oleracea* L. var. *botrytis*) and their management" carried out at College of Agriculture, Vellayani during 2011-13, is the first of its kind in Kerala. The period of observation was from November to February that coincided with the peak cultivation season of these crops in Kerala.

Analysis of pest fauna from four districts *viz.* Thiruvananthapuram, Kollam, Thrissur and Idukki districts, revealed that the crops were attacked by eighteen pest species. Of these, eleven were from the order Lepidoptera, two from Hemiptera and Orthoptera and one each from Diptera, and Coleoptera. An unidentified species of slug was also recorded.

The occurrence of the pierid butterfly, *Appias lyncida* Cramer on cabbage is reported for the first time. Earlier this species was not reported from Brassicaceae. The pest was collected from Thiruvananthapuram district, where it was found to defoliate cabbage. Later it was observed to feed on cauliflower too when reared in laboratory. Originally the species was reported to feed on plants belonging to the family Capparidaceae only.

The extent of infestation worked out for each pest revealed that in the three districts coming under the plains, *Spodoptera litura* Fabricius was the major

pest whereas in Idukki district, which is at a higher altitude and having a different climatic regime, it was the diamondback moth (DBM), *Plutella xylostella* (Linnaeus) that dominated.

The observation on the dominance of *S. litura* in plains during the study period of November to February is in agreement with the findings of Lee (1986) and Murthy (1994), who reported that November to March was the ideal season of multiplication of *S. litura* in warmer climates where cabbage was grown. There are few reports which stated that *S. litura* is the important pest in cabbage and cauliflower. It was reported as a pest that caused extensive damage to cabbage and cauliflower in Bihar (Chand and Triparthi, 2008), in Dapoli (Ambekar *et al.*, 2009), in Odisha (Mishra, 2009). *S.litura* was identified as a limiting factor for the successful cultivation of crucifers in India by Singh *et al.* (2012) also. The report of Ratnasri (2012) that the *S.litura* population was very high in cabbage grown in Karnataka also supports the above findings.

Although *S. litura* is considered as a sporadic pest, in the present study it was observed as a persistent pest of from the true leaf stage till harvest. This observation is in agreement with that of Dhanaraj (2000) who found it as a serious problem through out the crop period in cabbage and cauliflower.

P. xylostella reported here as the key pest in Vattavada, Kaanthallur and Devikulam of Idukki district which is at a higher altitude of 1980 M above mean sea level, is in agreement with the earlier observations made by Saucke *et al.* (2000), who surveyed the cabbage fields situated at three different climatic regimes existing in the low, mid and high elevations. They found that *P. xylostella* as the only core pest in the Papua, New Guinea highlands which is at 2000 M above mean sea level. There are numerous reports that reveal *P. xylostella* as the key pest of cabbage and cauliflower in various parts of the country. Verma *et al.* (1994) reported DBM as the key pest in different agroclimatic situations of Himachal Pradesh. Chaudhuri *et al.* (2001) observed that incidence *P. xylostella* varied with seasons in different regions of North Bengal. Mishra in 2009 opined that DBM is one of the major pest that attacked heads in Odisha. Kumar *et al.*

(2011) reported the attack of DBM as one of the major constraints in the profitable cultivation of cole crops in Uttar Pradesh. Most of the above studies were confined to the cooler seasons of the year, which coincided with the major growing season of cabbage and cauliflower.

Among the minor pests, the infestation index was higher (14.66 per cent) for the flea beetle *Phyllotreta chotanica* Duv., but during the study it was under control with the use of any of the botanical or synthetic insecticides. Its incidence was more in non weeded plots. Though it is reported from India for the first time, earlier reports are there on its incidence in kale, *Brassica oleracea* L. from South East Asia (Kianmeesuk *et al.*, 1999; Kianmatee and Ranamukhaarachchi, 2007). It was also reported from Taiwan on brassica plants by Chi-fenglee *et al.* (2011).

The other pests observed during this study with lesser infestations were, the hairy caterpillars, *Pericalia ricini* F., *Spilosoma obliqua* Walker, *Dasychira mendosa* Hb, beet army worm, *Spodptera exigua* Hb., and semi looper caterpillars, *Plusia signata* Fab. and *P. orechalcea* Fab. were earlier reported in India, by various workers, as cited in the check list of vegetable pests of India prepared by Sharma (2011).

The aphid species observed in the plains differed from that seen in hilly areas. *Brevicoryne brassicae* Linnaeus was the species seen in hilly tracts whereas it was *Lipaphis erysimii* Kaltenbach in the other three districts. However, these pests were earlier seen reported from cabbage and cauliflower by various workers (Mulik *et al.*, 2000; Ghosh *et al.*, 2001; Chaudhuri *et al.*, 2001; Mishra, 2009 and Bana and Jat, 2011).

Perusal of literature did not reveal any incidence of leaf miner *Liriomyza trifolii* (Burgen), and bell moth in these crops and the present reports are new.

Lesser number of pest species were observed in Idukki when compared to the other three districts, this may be due to the fact that, in the locations selected for observation, farmers used different combinations of insecticides at weekly intervals for combating the pests.

All the pests encountered were found to attack both cabbage and cauliflower, except the unidentified species of bell moth and slug which fed exclusively on cabbage. The bell moth may be considered as the most injurious pest, because the presence of even one caterpillar in the early head formation stage can prevent the head formation.

During the course of this investigation, predators were observed only from those fields where aphid infestation was there. The coccinellids obtained from *L. erysimi* colonies were *Chilomenes sexmaculata* Fabr. and *Coccinella transversalis*. Fabricius. The earlier reports by Singh *et al.* (2009) and Anjumoni (2011), shows that the predominant coccinellid species in *L. erysimi* colonies is *C. septumpuncata*. Though none of the natural enemies were encountered in Idukki district where DBM dominated, numerous reports exists which reveal the presence of more than 90 species of parasitoids in DBM (Ullyett, 1947; Harcourt, 1963; Goddwin, 1979; Lim, 1986; Ooi, 1992; Kok, 2004 and Rowell *et al.*, 2005). Reena (2000) reported that, coccinellids and spiders were predators of DBM. Reena (2000) and Shaila (2007) also reported two parasitoids *viz., C. plutellae* and *T. sokolowskii* on DBM larvae from Dharwad region of Karnataka district. Although several workers (Tontadarya and Nangia, 1983; Kulkarni, 1989; Srivastava and Kushwaha, 1995; Sridhar and Prasad, 1996 and Ahuja *et al.*, 2012) have reported natural enemies of *S. litura*, *viz. Trichogramma chilonis*, *Bracon brevicornis*, and *Brachymeria* sp. *Campoletis chloridae* Uchidas, *Apanteles ruficrus* (Halliday) and *Telenomus* sp., from the present survey.

Accurate growth stage descriptions of the crop and susceptibility of different stages of the crop to the pest complex in the ecosystem could particularly be useful from the management point of view.

Seedling stage was badly affected by DBM, *P. chotanica*, *L. trifolii*, *Atractomorpha crenulata* (Fabricius) and bag worm. The observation that *S. litura* did not damage the seedlings was in agreement with that of Ahuja *et al.* (2012), who found that *S. litura* incidence was noticed after the seedling stage of the crop only. It was the true leaf stage that was found more susceptible to pests. All the

defoliators recorded in Table 1 were observed during the true leaf stage. The flea beetle, *P. chotanica,* was the pest that dominated in this stage.

The most critical stage of the crop was the early head formation stage of cabbage (11to 12 weeks after planting, WAP) and curd initiation stage of cauliflower (8 to 10 WAP). Apart from cut worm, DBM and aphids, bell moth and slugs were found to feed on the developing heads. The most injurious pest observed was the bell moth since it fed on the growth primordia of cabbage. No reports on the occurrence of pests affecting different growth stages of cabbage and cauliflower were been made earlier elsewhere.

The extent of damage caused by *S. litura* to the heads and curds was 30 per cent in both cabbage and cauliflower, but the population levels recorded during the two consecutive seasons indicated the crop preference of *S. litura* to cauliflower. However the damage caused by *P. xylostella* varied in these two crops. It was higher in cabbage (38 per cent) when compared to cauliflower (26 per cent). Such studies on comparative susceptibility of these two crops to two different major pests observed at two different altitudes were not seen carried out earlier.

Detailed studies on the biology of *S. litura* on various crop plants are abundant as they are highly polyphagous in nature, but that on cabbage is scanty. Instar wise data on survival percentage, duration as well as adult longevity were gathered. Detailed data on biology of a key pest like *S. litura* are essential for preparing proper models for pest forecasting and adopting integrated control of the pest. Data revealed that high fecundity and survival percentage of the pest, ranging from 80 to 100 might result in rapid build up of the population. Cent per cent survival of the fourth instar larvae denotes an increased damage to the crops as the last instar, are voracious feeders. Similar observations on high fecundity and survival percentage of *S. liutra* on weed plants of Jabalpur were earlier reported by Sushilkumar and Pujaray (2007) and on banana by Shukla and Patel (2011). Studies on age-specific distribution of the pest conducted by Maghodia

and Koshiya (2008) on different hosts revealed that the eggs and larvae contributed highly to the population.

The total life cycle calculated in this study was 36.50 days indicating that the pest can undergo two to three generations within a single crop period which explains the reason for its persistent nature during the crop period (100-120days). The larval period observed during this study was 16.40 days which was in accordance with the observations made by Shahout *et al.* (2011) who has reported duration of 15.55 days larval period. Several workers opined that larval development of *S. litura* varied greatly depending on the host plants and temperature (Zhu *et al.*, 2000; Chen *et al.*, 2002; Seema *et al.*, 2004). Xue *et al.* (2009) has observed variations in the biology of *S. litura* based on the duration of host plant. In a short duration crop like Chinese cabbage, the larval period was found to be reduced to 13.3 days and survival percentage was increased to 81.70 per cent when compared to crops like cowpea and long duration crops like tobacco and potato.

Kumar *et al.* (1992) observed that environmental temperature is another factor that affected the life cycle of *S. litura*. They concluded that longer life stages occur at lower temperature.

Population build up of *S. litura* in cabbage and cauliflower when monitored during two consecutive years revealed that both in cabbage and cauliflower the pests did not attack the cotyledons and seedlings. The population analysis during 2011-12 revealed that the pest build up commenced from the early true leaf stage i.e. 5 weeks after planting (WAP). The mean number of caterpillars per plant was 2.63 in cabbage and 22.90 in cauliflower. The population seemed to increase slowly and steadily reached the peak level 24.10 in cabbage at head fill stage (13 WAP). Correspondingly in cauliflower the peak population (42.30 caterpillars per plant) was observed at the curd development stage (12 WAP). Thereafter, the pest population showed a gradual decline (23.37 caterpillars per plant) when the head reached maturity (15 WAP). In cauliflower also when curds

were fully developed the population gradually declined and reached the minimum level (15.67), when the curds attained maturity (15 WAP).

In summing up the above observations, it was evident that population of *S.litura* in cauliflower was two to three fold more when compared to cabbage, strongly indicating its preference to cauliflower (Fig.3). The mean weekly population during different growth stages showed that the seedling stage is unaffected and that the bearing stage of the crop is most favourable for population build up. It also signifies a strong influence of crop stage and nutritional status on the population build up of the pest.

These results were in conformity with those obtained earlier by Dhanaraj (2000) who observed that *S. litura* population on cabbage appeared after seedling stage (15 days after transplanting) and subsequently it attained peak on 100 day old crop. Badjena and Mandal (2005) who found that incidence of *S. litura* in cauliflower was absent in the seedling stage and that the population was quite high (21.3 caterpillars per plant), when the crop was at 90 days after transplanting. Ahuja *et al.* (2012) while working with the population dynamics of this pest reported its first occurrence after the seedling stage and it ranged from 5.47 to 13.5 with a slow decline towards the end of the crop.

Keeping in view of the economic importance of *S. litura*, investigations were carried out to study the population dynamics of the pest in relation to abiotic factors. During 2011-12, minimum temperature and evening relative humidity (RH) showed a significant negative correlation with the population. Though the maximum temperature and morning RH showed a positive association with population growth, the correlation coefficients were insignificant. Similarly, the negative association observed with total rainfall was also insignificant. As against that observed during the first year, correlation coefficients expressed a significant positive association of the population with evening RH and a strong negative association with morning RH during 2012-13. Pooled analysis of data for the two consecutive years , revealed that maximum temperature, morning RH and

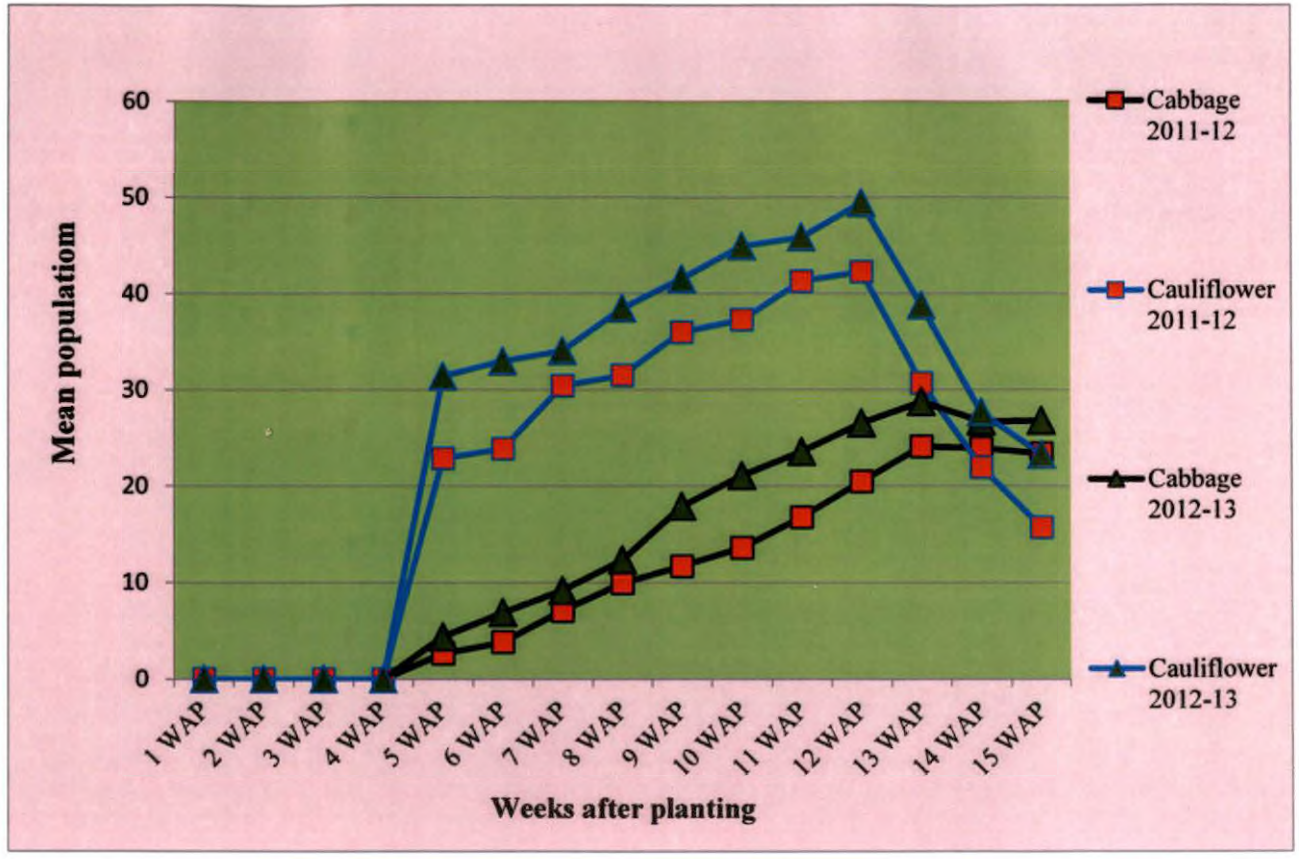


Fig. 3. Population build up of *Spodoptera litura* at different growth stages of cabbage and cauliflower.

sunshine hours are positively correlated with *S. litura* population in cabbage, whereas minimum temperature, evening RH and rainfall are the factors that can bring down the pest population.

Chalapathirao *et al.* (2000) reported that maximum and minimum temperature had significant positive effect on larval population of *S. litura*. Chen *et al.* (2002) reported a nonsignificant correlation of *S. litura* with mean temperature and relative humidity. Kumar *et al.* (2007) observed that *S. litura* population was positively correlated with mean temperature but negatively correlated with relative humidity. Patait *et al.* (2008) observed *S. litura* was correlated with minimum temperature and negatively correlated with morning RH. Selvaraj *et al.* (2010) reported that the build of *S. litura* population showed positive correlation with RH, sunshine hours and dewfall and negatively correlated with wind velocity. However, the above conclusions were based on the observations made for a single year. More over these works were carried out at different parts of the world where there may be variation in the geographic strain of the pest and the biotic factors too.

Shukla and Patel (2011) studied the effect of various abiotic factors on *S. litura* for two consecutive years and found that the pest showed a non significant positive correlation with mean temperature and mean relative humidity during the first year, but during the second year a non significant negative correlation with mean temperature and mean relative humidity. Their findings are in conformity with the present findings. However, they did not work out the correlation of the pooled data for the two years.

In the present work, the correlation of *S. litura* population with abiotic factors did not give any consistent results neither in the two years nor in the analysis of pooled data. It is strongly evident from the above observations that fluctuation of population is governed by various factors like temperature, relative humidity, rainfall as well as biotic factors. In nature, combination of two or more factors become responsible for determining the population or one factor may mask the effect of another. The inconsistency in correlation of *S. litura* population

with abiotic factors was also reported by earlier workers (Chen *et al.*, 2002; Shukla and Patel, 2011).

Manipulation of abiotic components for achieving reduction in the pest population especially on a highly polyphagous pest like *S. litura* is extremely complex. For consistent conclusions correlation studies may have to be extended over a number of years and on its different host plants separately.

S. litura, the polyphagous and highly destructive pest of tropical regions has been reported from 150 species of crop plants (Thangapandian *et al.*, 2011). Due to development of resistance to many of the chemical insecticides (Armes *et al.*, 1992), alternative strategies to control the insects are gaining importance.

Entomopathogenic fungi play an important role and have higher potential for biological control of defoliators. Efficacy of *M. anisopliae* @ 1.6 x 10^7 spore ml^{-1} aginst *S. litura* was reported by Sahayaraj and Borgio (2010). Evaluation of the strains Ma-L-1 and Ma-L-2 and Ma-F-1 on *S.litura* by Udayababu *et al.* (2012) revealed that the most virulent strain was Ma-L-1@ 1.6 × 10^6 conidia ml^{-1}. Many other workers also have reported its efficacy against *S. litura* (Sachin *et al.*, 2012; Petlamul and Prasertsan, 2012). However, in the present study, screening the entomopathogens under laboratory conditions revealed that, the isolate no. 4 of *Metarhizium anisopliae* and isolate no.5 of *Beauveria bassiana* could not cause pathogenicity in the third instar larvae of *S. litura*. Insect defence mechanism is an important factor that affects the susceptibility of an insect to a pathogen. Moulting process, humoral defence etc. play a role and it is presumed that variations in melanisation can contribute to the infectivity of *B. bassiana* to the different species of *Spodoptera*. The non infectivity of *B. bassiana* noted in the present study may be attributed to such defence mechanisms of the insect or due to the differences in the infectivity of isolates of the pathogen. Moreover as opined by Petlamul and Prasertsan (2012), the chitin deacetylase activity could play a role in self defence.

Botanical insecticides are safer alternatives to synthetic insecticides. They are rich source of bioactive organic chemicals which have insecticidal properties (Pradhan *et al.,* 1962; Gujar and Mehrotar, 1983; Dwivedi and Sharma, 2003; Raja *et al.,* 2005). As they contain a mixture of biologically active substances, chances of developing resistance by pests is negligible (Isman, 2006; Pavela, 2007).

Overall effect of aqueous extracts of botanicals *viz.* Neem Seed Kernel Extracts (NSKE) 2 and 5%, Anona Seed Extracts (ASE) 2 and 10%, Sweet Flag Extracts (SFE) 2 and 10%, Garlic Extracts (GE) 2 and 4%, Bird chilli Extracts (BE) 2 and 4% against the third instar larvae of *S. litura* revealed that all the botanicals tested, needed three days to yield a notable result. Higher concentrations of GE and NSKE were the treatments which yielded better mortality rates (82.15 per cent) after 60 h of treatment. However, after three days of treatment, cent per 100 per cent mortality was recorded with both the lower and higher concentrations of GE. Higher concentrations of SFE resulted in 88 - 96 per cent mortality. BE and ASE were found to be less effective in causing mortality of *S. litura*.

The observation from the present study that, all the tested botanicals took three days to yield a notable result, is in agreement with the findings of Mane *et al.* (2011) who reported that, it took three to five days to result in 50 per cent mortality of third instar larvae of *S. litura* when treated with NSKE 10 %.

Patil (2000) tested sixteen botanicals against *S. litura* in laboratory and found that NSKE (5%) caused highest mortality of 87.20 per cent after 72 h of treatment followed by *Vitex negundo* leaf extract (55.52 per cent) .

Reports on the insecticidal activity of crude extract of garlic, date back to 1980, when Deb-Kirtaniya *et al.* (1980) found it to be highly toxic to the third instar larvae of *S. litura* under laboratory conditions. Efficacy of even the lower concentration of garlic extract (2%), observed in the present study was found to be

agreeable with the earlier report of Meriga *et al.* (2012). They found that 1000 ppm of aqueous garlic extract can cause 84 per cent larval mortality of *S. litura*.

An incongruity was observed with the effect of sweet flag, *A. calamus* reported by Thangapandian *et al.* (2011) and Singh *et al.* (2012). They found that the most effective botanical insecticide was sweet flag when compared to neem, pepper, ginger, turmeric etc. In the present investigation, sweet flag was less effective at two per cent (32.89 per cent mortality at 60 h). The disparity might be because of the difference in the solvent used for extraction. As against the aqueous extracts used in the present study, they used the ethanolic and chloroform extracts which might have been more efficient in extracting the active principles. Nevertheless, a botanical insecticide to be farmer friendly should be easily available, simpler in preparation and cost effective.

Raman *et al.* (2006) evaluated the concentrated crude extracts of different plant parts of *Annona* and found that it was the seed extract that was most effective against *S. litura* resulting in the highest antifeedant activity of 95.65 per cent after 48 h of treatment. His findings, in comparison with the present conclusion that annona seed extract was not effective at 2 and 10%, implies that the bioactive acetogenin compounds like annonin I and squamoside which were responsible for toxicity are highy non polar in nature. This fact is again substantiated by the reports of Leatemia and Isman (2004) and Prathibha *et al.* (2010), who found that the ethanol extract of annona was effective against *S. litura* larvae.

Related works under laboratory conditions were carried out by Sharma *et al.* (2009). Their findings are in accordance with the present finding that botanicals at higher concentrations increase the efficacy against *S.litura*. Such dose dependant mortality of *S. litura* larvae was also observed by Thangapandian *et al.* (2011). Mane *et al.* (2012) also found that 10 % aqueous extract of neem was equally effective as those of *Eupatorium* and *Hyptis,* whereas two per cent extracts were least effective.

Though the botanicals are eco friendly and safer to human beings, they are slow in action. Hence their efficacy in terms of time taken for mortality is an important criterion for including them in IPM programme. Analysis of the time taken to cause 50 per cent mortality (LT_{50}) revealed that as the concentration of the extract increased, the time taken for mortality decreased except with GE where both the concentrations were equally effective. The lowest LT_{50} values recorded were for 2 and 4% GE which did not vary significantly. LT_{50} values of 5% NSKE and 10% SFE were not significantly different among them. LT_{50} values for botanical insecticides were not seen worked out by any of the earlier workers.

Botanical insecticides are well known for their antifeedant and repellent action. Therefore, in addition to their evaluation based on mortality, effect on feeding activity was also observed during the study. It was found that, on the first day itself, higher concentration of NSKE had some antifeedant effect, whereas with the lower concentration, it took more than two days to have reduced rate of feeding. GE at both the concentrations and SFE at 10 per cent concentration also prevented the caterpillars from feeding after two days. Eventually on the third day, all the caterpillars that were fed with higher concentrations of GE, NSKE and SFE stopped feeding and the mortality rate also ranged from 90 to 100 percent. At lower concentrations, only GE and NSKE were observed to have antifeedant action. The antifeedant activity of neem was earlier reported by many workers (Kaur *et al.,* 2001; Singh, 2006; Rao *et al.*, 2009). It is attributed to the presence of alkaloid, azadirachtin, triterpenoids like nimbin, salanin and derivatives there of (Pavella *et al.*, 2004).

Purwar and Nagesh (2006) conducted experiments on antifeedent activity of commercial product of azadirachtin, neemaazal with different concentration against *S. litura* in laboratory and found that, the feeding activity was least at the highest concentration (300ppm). Higher antifeedant effects of neem at a higher concentration (10 %) were also reported by Sharma *et al.* (2009). Patil *et al.* (2009) also reported the increased efficacy of higher concentration of NSKE in comparison to lower concentrations, in controlling *S. litura*. *Acorus calamus* is

reported to have repellent, antifeedant and ovicidal activity against *S. litura* (Murthy *et al.*, 2006), but was found to have a delayed action as indicated by higher LT_{50} values (96.26 h) observed in this study.

Wide range of insecticides that were in use against *S. litura* has resulted in development of resistance (Mathirajan and Reghupathy, 2002; Chalam *et al.*, 2003). Newer molecules have the advantage of being safe to non target organisms because of their novel mode of action. Hence, in the present investigation toxicity of newer molecules against *S. litura* was studied.

Under laboratory conditions, the synthetic insecticides tested *viz.* indoxacarb 0.008%, cypermethrin 0.003%, spinosad 0.06%, chlorfenapyr 0.02%, fipronil 0.008% and emamectin benzoate 0.002% were equally effective causing 96.99 to 100 per cent mortality to third instar larvae, after 12 h of treatment, even though significant variations were noticed during the early hours of treatment. But, based on LT_{50} values, cypermethrin 0.03% and indoxacarb 0.008% were as superior as the treated check malathion 0.15%.

Many of the preceding studies revealed the efficacy of these new generation insecticides in managing *S. litura* under laboratory conditions. Ahmad *et al.* (2005) reported that emamectin benzoate as the superior insecticide followed by lufenuron, spinosad and indoxacarb, respectively in their time-oriented mortality against *S. litura* and abamectin as the least effective one. Stanley *et al.* (2006) reported high toxicity of emamectin benzoate at 0.40ppm causing 85.90 per cent mortality and spinosad 125 ppm causing 87.45 per cent mortality of *S. litura* caterpillars after 24 h of treatment. Prasad *et al.*(2007) observed emamectin benzoate and novaluron as the best and indoxacarb, the second when compare to other insecticides like cypermethrin, deltamethrin, triazophos, chlorpyriphos and quinalphos based on LC_{50} values worked at 24, 48 and 72 h of treatment. Dhawan *et al.* (2007) reported the higher relative toxicity of emamectin benzoate, indoxacarb, pyridalyl, and spinosad when compared to chlorpyriphos against *S.lituira* . Efficacy of spinosad, emamectin, and indoaxacarb, based on LC_{50} has earlier been proved by Prasad *et al.* (2007).

Ghosh *et al.* (2008) observed relative toxicity of six insecticides against the third instar larvae of *S. litura*. The order of relative toxicity after 24 hours of exposure was emamectin benzoate, indoxacarb, fipronil, novaluron, lufenuron and methoxyfenozide. Ramanagouda and Srivastava (2009) studied the bioefficacy of five insecticides *viz.*, indoxacarb, methomyl, fipronil, thiamethoxam and imidacloprid on 7day old larvae of *S. litura* by contact and leaf dip methods. Indoxacarb was the most toxic insecticide at 24h exposure when tested at 7, 15 and 126 ppm. Emamectin benzoate, indoxacarb, spinosad and flubendiamide were also found to be effective against first instar based on LC_{50} values Sharma and Ankit (2012).

However, the efficacy of these chemicals in terms of LT_{50} is not seen evaluated previously, except the finding of Venkateswari *et al.* (2008) who reported a high LT_{50} value for abamectin when compared to emamectin. In a short duration and highly remunerative crop like cabbage and cauliflower, the attack of a destructive pest like *S. litura*, with a very low ETL of one caterpillar per plant (Mallapur, 1988 and Dhanaraj, 2000) , it is highly essential to consider the time taken by the insecticide to give the result. From the above mentioned results it is obvious that, even though indoxacarb, cypermethrin, spinosad, chlorfenapyr, fipronil and emamectin benzoate were equally effective, indoxacarb and cypermethrin are faster in action.

The foregoing results are based on the performance under laboratory conditions, where there is cent per cent exposure of the test insect with the treatments.

Field studies conducted using the botanical insecticides, GE 2 %, NSKE 5%, SFE 10% and the synthetic insecticides cypermethrin 0.03% and indoxacarb 0.008% with malathion 0.15% as check, revealed that all the treatments were effective in controlling the population when compared to the untreated check.

The overall reduction in population of *S. litura* in cabbage after spraying, during the true leaf, cupping and early head formation stages revealed that highest population reduction was obtained with indoxacarb 0.008% (99.65 per cent) followed by cypermethrin 0.03% (91.51 per cent) and treated check, malathion

0.15% (89.33 per cent). Among the botanicals 2% GE was most effective resulting in 68.47 per cent reduction in population compared to 5% NSKE (59.24 per cent). SFE 10% was the least effective in controlling *S. litura* population.

Based on population reduction obtained in cabbage, the synthetic insecticides indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15% were significantly superior to the botanicals 2% GE and 5% NSKE. However 2% GE and 5% NSKE were significantly superior to untreated control.

Reduction in population obtained in cauliflower after treatment in the true leaf, curd initiation and curd development stages of cauliflower also revealed the supremacy of indoxacarb 0.008% were there was cent per cent reduction in *S. litura* population. Cypermethrin 0.03% resulted in 96.81 per cent reduction. The treated check malathion 0.15% could result in 94.05 per cent reduction in population. Here also, 2% GE was the most effective botanical giving 70.66 per cent reduction caterpillar population. With 5% NSKE, only 60.28 per cent of the caterpillars were reduced.

Overall observations from cabbage and cauliflower revealed that indoxacarb 0.008%, cypermethrin and malathion was almost equally effective in managing the *S.litura* population. However, there was no reinfestation in indoxacarb treated plots, after the first second spraying itself in cauliflower and after the second spraying in cabbage. Among the botanicals 2 % GE and NSKE 5% were effective.

The foregoing results are in conformity with the findings of Rao, *et al.* (2006) who evaluated the new generation insecticides *viz.* indoxacarb, thiodicarb and nimbicidine under field conditions and found that it was indoxacarb that was the most effective in managing *S. litura* in fenugreek. The percentage reduction in population recorded by them was 77.2 per cent. Results of the field experiment conducted by Ghosh *et al.* (2008) also revealed the efficacy of indoxacarb in controlling *S. litura*. The percentage reduction in larval population reported by them was 90.35 in chilli.

The effect of botanicals in managing *S. litura* under field conditions was studied by various workers. Choudhary and Shrivastava, (2007) and Patil *et al.* (2009), worked out the efficacy of 5 % NSKE against *S. litura* caterpillars in soya bean. The percentage reduction in population of *S. litura* recorded by them was in parity with the findings of the present study. It was 51.59 and 62.97 per cent respectively. However, the effect of aqueous garlic extract which was found to be the best botanical insecticide against *S. litura* in this study was not seen studied under field conditions earlier, but garlic in combination with neem, chilli, ginger, tobacco and cow's urine was found to be effective against *S. litura* as reported by Rao *et al.* (1998).

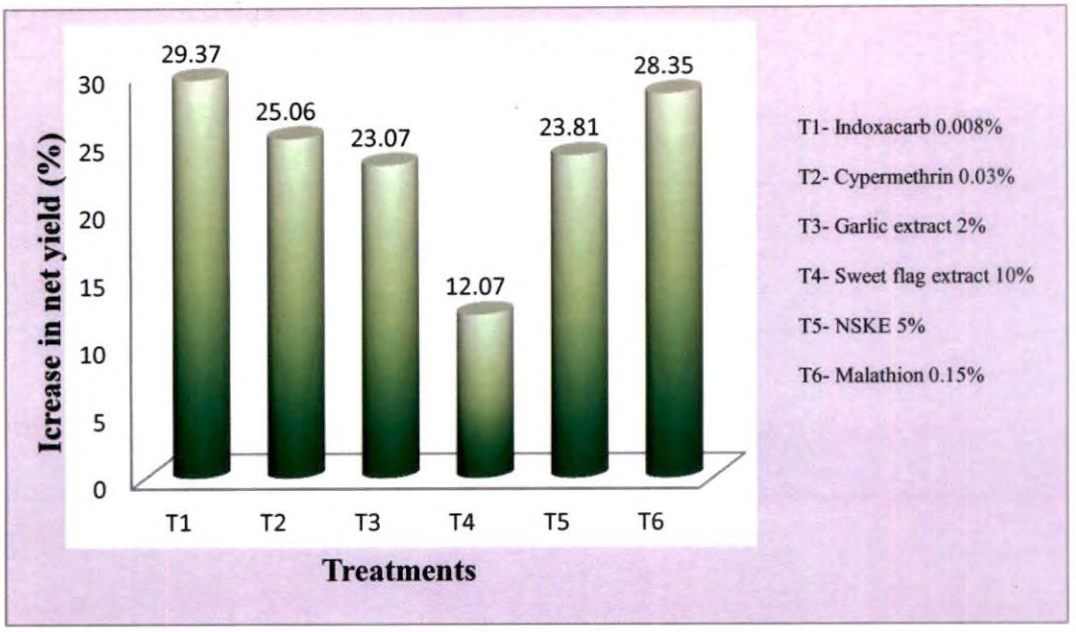
Based on yield of cabbage, all the treatments were significantly superior to control in terms of net weight of heads harvested. Highest net weight was obtained from indoxacarb treated plots. The percentage increase in net yield over the control as presented in Fig.4a. shows there was 29.37 per cent increase in net yield in indoxacarb 0.008% treated plots, followed by malathion 0.15% and cypermethrin 0.03% (28.35 and 25.06). The increase in net yield observed was 23.07 per cent in GE 2% treated plots and 23.81 per cent in NSKE 5%.

The effect of treatments on yield of cauliflower as presented in Fig.4b. indicates that highest percentage increase in marketable curds over control was in indoxacarb 0.008% treated plots (60.07), followed by cypermethrin (57.24) and malathion (53.89) . There was an increase of 53.38 per cent in GE and NSKE 5% treated plots.

The above finding is in conformity to that of Ratnasri (2012) who reported that indoxacarb 15.8 EC is the best treatment in terms of yield in cabbage.

From the results of residue analysis, it is evident that foliar application of indoxacarb 0.008% (Avaunt 15.8 EC) and cypermethrin 0.03% (Lacer 10 EC) at true leaf stage, cupping and curd initiation stages are safe for pest management in cabbage, as their levels in the harvested produce and soil were below detectable level (BDL), as estimated using QuEChERs method. This finding is consistent

A. Cabbage



B. Cauliflower

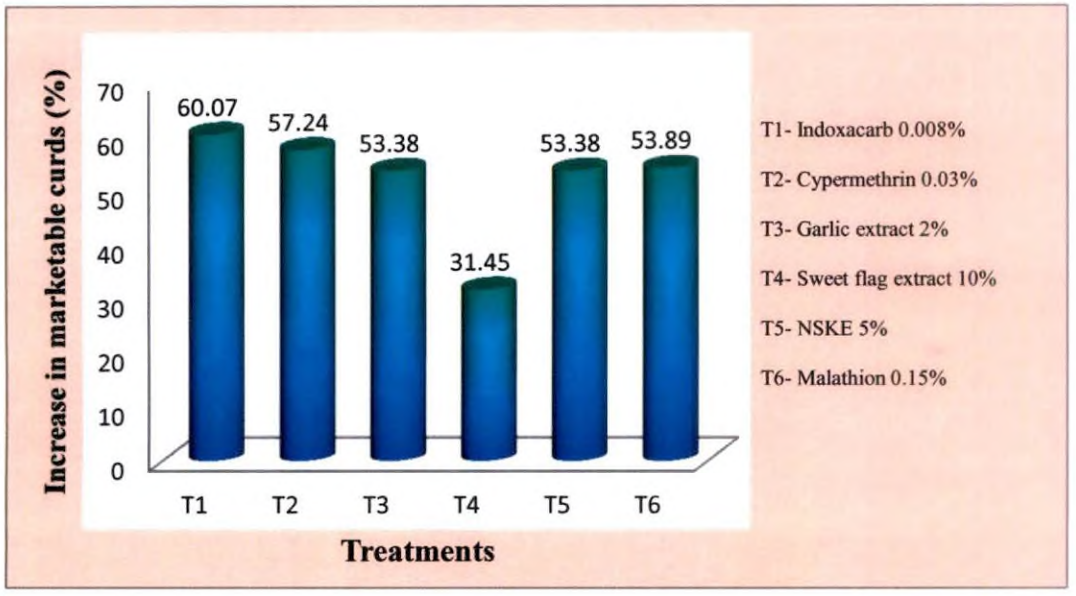


Fig. 4. Percentage increase in net weight over control

with the findings of Zhi-yong *et al.* (2007) who observed that when cabbage was treated four times at the maximal dosage with a five-day's interval, the final residual amount of cypermethrin and chlorpyrifos were below its MRLs on the cabbage. The result of dissipation studies conducted by Urvashi *et al.* (2012) in cabbage is also in parity with the findings of the present investigation. Their study indicated that when indoxacarb (Avaunt 14.8 EC) @ 52.2 and 104.4 g a.i. ha^{-1} was applied, the residues dissipated below its LOQ of 0.01 mg kg^{-1} after 7 and 10 days respectively at single and double dosages.

Taking into account the efficacy in increasing the marketable yield as well as its ability to keep the pest population below ETL, indoxacarb 0.008% is the superior new generation insecticide and garlic 2% and NSKE 5 %, the better botanical insecticides in the management of *S. litura*.

To develop an ecologically and economically viable IPM package for *S. litura* in cabbage and cauliflower, integration of different tools as well as rotation of chemicals is inevitable. GE 2 % as well as NSKE 5 % can be used as the safer methods, whereas in situations that warrant the use of chemicals, new generation insecticide indoxacarb 0.008% can be used in rotation with synthetic pyrethroid cypermethrin 0.03 % and old generation insecticide malathion 0.15 %.

SUMMARY

6. SUMMARY

Pests and natural enemies occurring in the popular cool season vegetables, cabbage and cauliflower, grown in the hilly tracts and in the newly cultivated plains of Kerala, were studied for the first time, at College of Agriculture, Vellayani during 2011-13. Preliminary studies were on the identification of the pests affecting these crops, their occurrence during different the growth stages of the crops, and nature and extent of damage caused by them. Further investigations were focused on the major pest affecting the crop in the plains of Kerala, its biology and abiotic factors affecting population build up were studied. The effect of potential entomopathogens, botanicals and the new generation insecticides recommended by Central Insecticide Board& Registration Committee was evaluated against the major pest. Plant and soil samples were analysed for pesticide residue of the promising insecticides.

Analysis of pest fauna in cabbage and cauliflower, showed that the crops were attacked by eleven pests belonging to Lepidoptera, two each from Hemiptera and Orthoptera and one each from Diptera and Coleoptera. An unidentified species of slug was also recorded. All the pests encountered, were found to attack both cabbage and cauliflower, except the unidentified species of bell moth and slug which fed exclusively on cabbage. Out of the eighteen pests documented *Appias lyncida* Cramer was reported for the first time, feeding on cruciferous crops.

Survey of natural enemies in the crop area led to the identification of two coccinellid predators *viz. Chilomenes sexmaculata* Fabr., *Coccinella transversalis* Fabricius from the colonies of aphid, *Lipaphis erysimi* (Kaltenbach), the syrphid, *Ischiodon scutellaris* (Fabricius) and a larval parasitiod, *Protapanteles* sp. from larvae of *Plusia signata* Fab.

During the seedling stage, DBM *Plutella xylostella* Linnaeus , flea beetle *Phyllotreta chotanica* Duv., leaf miner, *Liriomyza trifolii* (Burgen), short horned grass hopper *Atractomorpha crenulata* (Fabricius), long horn grasshopper and bag

worm (unidentified species) were found to feed on foliage. It was the true leaf stage that was most susceptible to pests. Thirteen insect species were recorded as defoliators during this stage. *Spodoptera litura* Fabricius was the dominating pest, and the other species recorded were *P. chotanica*, the semiloopers, *Plusia signata* Fab. and *Plusia orichalcea* Fab., and hairy caterpillars *viz.*, *Dasychira mendosa* Hb., *Spilosoma obliqua* Walker and *Pericallia ricini* F. The aphid species *Lipaphis erysimi* (Kaltenbach) was found to a lesser extent in plains, while *Brevicoryne brassicae* (Linnaeus) dominated in hilly tracts. Early head formation stage was the most critical stage of the crop. Apart from S.*litura,* bell moth was found to be highly injurious as it fed on the growth primordia of cabbage. Slugs also caused damage to the wrapper leaves of cabbage. When the crop reached the bearing stage, incidence of *S.litura* and *P. xylostella* was high. But, when it attained the maturity stage, *S. litura* and *P. xylostella* were found to decline.

The key pest affecting the crop grown in plains was the cut worm, *S.litura,*and in the hilly tracts it was *P. xylostella*. The Pest Infestation Index of these two pests were very high. The extent of damage caused by *S. litura* was same in cabbage and cauliflower. It caused thirty percent damage to the heads and curds. *P. xylostella* was more destructive to cabbage than cauliflower. The extent of damage caused by it in cabbage was thirty eight per cent and in cauliflower it was twenty six per cent.

Detailed studies on the biology of *S.litura* the polyphagous pest on various crop plants are abundant but that on cabbage is scanty. Instar wise data on survival percentage, duration as well as adult longevity were gathered. Such detailed data are essential for preparing proper models for pest forecasting and adopting integrated management of the pest. Data revealed that high fecundity and survival percentage of the pest, ranging from 80 to 100 might result in rapid build up of the population. Cent per cent survival of the fourth instar larvae denotes an increased potential for injury as they are voracious feeders. Total life cycle being completed within a period of 30 to 40 days, indicates that the pest can undergo

two to three generations within a single crop period and cause substantial yield loss.

During 2011-12, infestation of *S.litura* was not seen in cabbage seedlings. The infestation commenced at five weeks after planting (WAP) when the crop was at the true leaf stage and gradually increased to a significant level during the precupping, cupping and early head formation stages and reached the peak level at 13 WAP, when the crop was at its head fill stage. Thereafter at maturity, the mean larval count showed a slow decline.

In cauliflower also the seedlings were not affected by *S.litura.* The infestation was first noticed at 5 WAP, and reached the peak at curd development stage(12WAP). The mean population during the early true leaf stage and curd initiation stage varied significantly, but the population during curd development stage was on par with that of the curd initiation stage. When the curd attained maturity the population was significantly low.

During 2012 -13 also cabbage as well as cauliflower seedlings were found to be unaffected by *S.litura.* Infestation began at 5 WAP and reached the peak at curd development stage (12WAP), and declined gradually and reached minimum at maturity.

The above observations indicate the strong influence of crop stage on the population of *S. litura.* It also revealed that the population in cauliflower was almost double than in cabbage during all the crop stages, which indicated that *S. litura* preferred cauliflower to cabbage.

Correlation studies revealed that the pest and abiotic factors did not show any consistent association in the first and second year of observation and on the analysis of the pooled data. The relative importance of different factors acting on the pest in different seasons may vary, one masking the effect of another resulting in variations in correlation coefficients from year to year. Data generated from long duration studies alone can lead to consistent results.

Preliminary screening of entomopathogens, under laboratory conditions revealed that, the isolate no. 4 of *Metarhizium anisopliae* (Metsch.) Sorokin and isolate no. 5 of *Beauveria bassiana* (Bals.)Vuill.infestation could not cause pathogenicity to the third instar larvae of *S. litura.*

Overall observations on the effect of aqueous extracts of botanicals on the third instar larvae of *S. litura* indicated that, all the botanicals needed two to three days to yield a notable result. It took 60 h for 5% NSKE and 4% GE to cause 50 per cent mortality and 72 h for causing 88 to 100 per cent mortality. Garlic at 2 and 4% were equally effective in controlling the pest and their LT_{50} values did not vary significantly.

Under laboratory conditions, the synthetic insecticides tested *viz.* indoxacarb 0.008%, cypermethrin 0.03%, spinosad 0.06% , chlorfenapyr 0.02%, fipronil 0.08% and emamectin benzoate 0.002% were equally effective causing 96.99 to 100 per cent mortality after 12 h of treatment even though significant variations were noticed during the early hours of treatment. Chlorantraniliprole 0.002 % was found to be ineffective causing less than 50 per cent mortality. Analysis of LT_{50} values showed that, the time taken for mortality was least in the case of malathion 0.15%, followed by cypermethrin 0.03% and the new generation insecticide, indoxacarb 0.008%.

Field studies conducted in cabbage and cauliflower using the synthetic insecticides indoxacarb 0.008%, cypermethrin 0.03% and malathion 0.15% (treated check) and the botanical insecticides, GE 2%, NSKE 5% and SFE 10% revealed that *S. litura* population could be significantly reduced with synthetic insecticides when compared to botanicals. In cabbage, the mean percentage reduction in population after treatment, was maximum in plots treated with indoxacarb 0.008% (99.65 per cent), followed by cypermethrin 0.03% (91.51 per cent) and the treated check malathion 0.15% (89.33 per cent). Among the botanicals percentage reduction in population was maximum in GE 2% (68.47 per cent) followed by NSKE 5% (59.24 per cent). In cauliflower as presented in fig.

2b the mean percentage reduction in population after treatment, was maximum in plots treated with indoxacarb 0.008% (cent per cent), which was followed by cypermethrin 0.03% (96.81 per cent) and the treated check malathion 0.15% (94.05 per cent). Among the botanicals percentage reduction in population was maximum in GE 2% (70.66 per cent) and it was followed by NSKE 5% (60.28 per cent).

Management of *S. litura* had a significant effect on the yield of cabbage and cauliflower. Spraying new generation insecticide indoxacarb 0.008% resulted in 29.37 per cent increase in net yield of cabbage. The effect of cypermethrin 0.03%, malathion 0.15%, GE 2% and NSKE 5% were also significant in increasing the yield by 23.07 to 28.35 per cent.

Percentage increase in number of marketable curds was maximum in indoxacarb 0.008% (60.07 percent), followed by cypermethrin (57.24) and malathion (53.89).The percentage increase in NSKE 5% andGE2% was 53.38.

The residues of indoxacarb0.008% and cypermethrin 0.03% were below detectable limit in plant as well as soil samples at the time of harvest.

S.litura the key pest in cabbage and cauliflower grown in Kerala can effectively be managed by integrating botanical insecticide, garlic 2% or NSKE 5% with the new generation insecticide indoxacarb 15.8 SC or synthetic pyrthroid, cypermethrin 10 EC or the old generation insecticide malathion 0.015 EC. Treatments at true leaf, cupping and early head formation or curd initiation stages can effectively manage the pest with an increase in yield by 23.07 to 29.37 percent in cabbage and 46.14 to 50 per cent in cauliflower.

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PESTS OF CABBAGE (*Brassica oleracea* L. var. *capitata*) AND CAULIFLOWER (*Brassica oleracea* L. var. *botrytis*) AND THEIR MANAGEMENT

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Abstract of the

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ABSTRACT

Investigations on "Pests of cabbage (*Brassica oleracea* L. var. *capitata*) and cauliflower (*Brassica oleracea* L. var. *botrytis*) and their management" were carried out at College of Agriculture, Vellayani during 2011-13. The main objective of the work was to identify the pests and natural enemies associated with cabbage and cauliflower and to evolve pest management strategies.

Analysis of pest fauna in cabbage and cauliflower revealed that the crops were attacked by eighteen pest species. The occurrence of pierid butterfly *Appias lyncida* Cramer on cruciferous crops is reported for the first time. The key pest affecting the crop grown in plains was the cut worm *Spodptera litura* (Fabricius) and in the hilly tracts it was *Plutella xylostella* (Linnaeus). Damage caused by *S. litura* was 30% in cabbage and cauliflower and that by *P. xylostella* was 38% to heads and 26 % to curds. Two coccinellid predators *Chilomenes sexmaculata* Fabr. and *Coccinella transversallis* Fabricius and the syrphid, *Ischiodon scutellaris* Fabricius were identified from the colonies of aphid, *Lipaphis erysimi* (Kaltenbach). One parasitoid, *Protapanteles* sp. was identified from larvae of *Plusia signata* Fab.

Further investigations were focused on *S. litura*, the major pest in plains. Detailed studies on biology of the pest revealed high fecundity and survival percentage of all the life satges (80 -100), favouring high feeding potential and rapid buildup of population. *S. litura* incidence in cabbage reached the peak level at head fill stage (13WAP) in cabbage and in cauliflower the peak was observed at curd development stage (12WAP). Correlation studies of the population with weather parameters revealed that the pest and abiotic factors did not show any consistent association. The relative importance of different abiotic factors that acted upon the pest varied during the period.

Preliminary screening of entomopathogens, botanicals and new generation insecticides undertaken under laboratory conditions revealed that, GE 2%, NSKE 5 %,

SFE 10 % and the synthetic insecticides, indoxacarb 0.008%, and cypermethrin 0.03% were equally effective as the treated check, malathion 0.15%.

Field studies conducted using the above selected treatments revealed that the reduction in population of *S. litura* was maximum with indoxacarb 0.008%, followed by cypermethrin 0.03% and the treated check, malathion 0.15%. Among the botanicals GE 2% was found to be the most effective in reducing the population, followed by 5% NSKE. Management of *S. litura* had a significant effect on yield of cabbage and cauliflower. Indoxacarb 0.008% resulted in 29.37 per cent increase in net yield of cabbage. The effect of cypermethrin 0.03%, malathion 0.15%, GE 2% and NSKE 5% were also noteworthy in increasing the yield by 23.07 to 28.35 per cent. In cauliflower, there was a yield increase of 53.38 to 60.07 per cent, indoxacarb 0.008%, cypermethrin 0.03%, malathion 0.15%, 10%, NSKE 5% and GE 2%. Samples analysed for residues, at the time of harvest revealed that the mean residue of indoxacarb 0.008%, and cypermethrin 0.03% were below detectable limit.

From the above study it is concluded that, the key pest of cabbage and cauliflower grown in hilly tracts was DBM and that in the plains was *S. litura. S. litura* can effectively be managed by adopting management strategies in the true leaf, cupping and early head formation or curd initiation stages of these crops. Indoxacarb 0.008% and cypermethrin 0.03%, can safely be used as there was no residual problems. Considering the ecological and economic factors, spraying 2 % GE or 5 % NSKE is the safer.

RESULTS

Appendix I. Weather parameters during crop period November 2011 to December 2012.

Crop stage (Weeks after planting)	Weekly mean weather parameter					
	Maximum temperature(°C)	Minimum temperature(°C)	Morning humidity (%)	Evening humidity (%)	Rainfall (mm)	Sunshine (hour)
1-4	30.1	23.2	94.7	67.9	2.1	8.3
5	29.2	23.6	98.4	79.3	22.2	7.2
6	30.7	22.7	97	64.1	0.5	9.3
7	31	23.8	97.4	67.7	5.3	9
8	30.5	22.7	93.7	59.1	0.5	8.4
9	29.6	20.8	99	65.3	36	9.3
10	30.7	20.8	99	60.4	0	9.2
11	30.3	23	98.6	67.6	0	9.2
12	29.4	19.2	98.1	55.3	2.5	9.3
13	30.3	19.9	98.7	57.4	0	9.4
14	31.3	21.2	97.1	55.9	0	9.2
15	30.8	23.5	97.6	71.6	0	8.6

Appendix II. Weather parameters during crop period November 2012 to December 2013.

Crop stage (Weeks after planting)	Weekly mean weather parameter					
	Maximum temperature(°C)	Minimum temperature(°C)	Morning humidity (%)	Evening humidity (%)	Rainfall (mm)	Sunshine (hour)
1-4	30.5	23.1	98.6	72.3	1	8.7
5	30.6	22.7	99	67.7	0	9.2
6	30.5	22.6	99	66.3	0.5	8.7
7	30.6	22.1	99	62.4	0	8.9
8	31.1	22.8	91.4	60.3	0	8.2
9	30.5	23.5	99	71.9	13.3	7.9
10	30.6	23.4	95.4	72	8.8	8.8
11	30	22.6	96.4	74.6	24	8.5
12	30.1	20.8	96	75.1	0	9.4
13	30.5	21.3	96.1	73.6	0	9.4
14	30.4	20.8	94.3	75.4	0	9.3
15	31.2	22.9	93.3	74.3	2.5	9.2

Appendix III. Values of weather parameters during 2011-12 and 12-13(November to December)

Parameters	2011-12 (n=12)			2012-13 (n=12)			Pooled years (n=24)		
	Mean	Variance	CV	Mean	Variance	CV	Mean	variance	CV
Maximum temperature (°C)	30.325	0.3869629	2.051322	30.55	0.1057943	1.064682	30.4375	0.2591146	1.672388
Minimum temperature (°C)	22.03333	2.26888	6.836371	22.38333	0.8081055	4.016144	22.20834	1.569051	5.640305
Relative humidity – morning (%)	97.44166	2.583333	1.649474	96.45834	6.007162	2.540943	96.95001	4.535157	2.196586
Relative humidity – evening (%)	64.3	46.34636	10.58758	70.49166	24.05143	6.957172	67.39584	44.78223	9.929326
Sunshine (hours)	8.866666	0.3822378	6.972789	8.850001	0.2124888	5.208645	8.858332	0.2974599	6.156904
Rainfall (mm)	5.758334	119.1824	189.5873	4.175	52.38855	173.3651	4.966667	86.41222	187.1641

CV- Coefficient variation, n - numbers of weeks