INSECTICIDE BASED BAIT FORMULATION AGAINST TOBACCO CATERPILLAR *Spodoptera litura* (FABRICIUS) (LEPIDOPTERA: NOCTUIDAE)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"INSECTICIDE BASED BAIT FORMULATION AGAINST TOBACCO CATERPILLAR *Spodoptera litura* (FABRICIUS) (LEPIDOPTERA: NOCTUIDAE)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis of award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara
20-06-2018

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CERTIFICATE

Certified that this thesis **entitled "INSECTICIDE BASED BAIT FORMULATION AGAINST TOBACCO CATERPILLAR *Spodoptera litura* (FABRICIUS) (LEPIDOPTERA: NOCTUIDAE)"** is a record of research work done independently by Ms. Shahanaz M.R. under my guidance and supervision and that it is not previously formed the basis for award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. Introduction

India is basically an agrarian country whose economy depends largely on agriculture. Damage by insects to crops incur huge loss to this agrarian economy. It is estimated that, more than 10,000 species of insects are involved in damaging food plants. However, less than 10 per cent of total identified insect pests can be classified as major pests. Herbivorous insects are said to be responsible for destroying one -fifth of the world's total crop production. In India, economic loss worth US Dollar 2285.29 million, accounting to 15 per cent of total yield, is caused by insects (Dhaliwal *et. al.,*2015).

Spodoptera litura (Fab.) (Lepidoptera: Noctuidae), a polyphagous pest with a host range of about 120 species, cause severe defoliation in economically important crops such as vegetables, cotton, tobacco, etc. On most crops, damage arises due to extensive feeding of larvae, leading to complete defoliation of plants. This noctuid lepidopteran has high reproductive potential with an ability to move long distances. After hatching, first and second instar larvae feed gregariously, later they migrate from plant to plant and cause complete defoliation. The grown up larvae hide near the base of the plants and bunds during the day time and cause damage during night. The current management strategy for this pest relies heavily on insecticide sprays which may not effectively reach the pest, thereby affecting the mortality of the pest.

Extensive use of insecticides has resulted in wide spread development of insecticide resistance (Armes *et al.*, 1997; Kranthi *et al.*, 2002; Shankarganesh *et al.*, 2012). Development of resistance is a result of the selection pressure exerted on sprayed population leading to an increase in the frequency of resistant individuals (Torres – Vila *et. al.,* 2002).

Indiscriminate use of pesticides indirectly affects various non target organisms and also will lead to problems like resurgence, resistance and secondary pest outbreak. Further it will cause environmental hazards and health hazards to humans and animals. *Spodoptera litura*, has therefore, become increasingly difficult pest to manage with conventional insecticidal sprays, all over the world. To tide over the problems caused by insecticides, efforts have been directed to investigate an effective poison bait against *S. litura.*

The use of materials that elicit feeding could aid in pest control by altering the behavior of early instars. Apparently, such a material would help in the control of *S. litura*. This concept might be useful in the integrated management of this polyphagous defoliator.

Baiting technique comprises of an attractive food along with an insecticide to lure insect pests. Use of poison baits can reduce the adverse effects of insecticide sprays, as the baits are taken up only by the target species without affecting the non target organisms (Shankaragouda *et al.*, 2015). Also, the amount of insecticide active ingredient applied per unit area with the use of bait is much lower than that of blanket insecticide sprays (Renju *et al.*, 2009).

Barbara and Capinera (2003) has identified several advantages of baits over other pesticide application methods. Runoff and drift problems in conventional insecticide sprays will be low by the use of poison baits. Use of poison baits can be helpful in preserving beneficial insects as they provide greater selectivity compared to dusts and liquids.

The easy availability and low cost of bait materials, easy preparation and application will aid the farmers in controlling this pest in an environment friendly manner. Keeping this in view, the present investigation on 'Insecticide based bait formulation against tobacco caterpillar *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)' has been under taken with following objectives:

I. Standardisation of base material for poison baiting of *S. litura*
II. Standardisation of phagostimulants for poison baiting of *S. litura*
III. Laboratory evaluation of poison baits against *S. litura*
IV. Field evaluation of selected poison baits against *S. litura*

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Review of Literature

2. Review of literature

Poison baits as a technique for insect pest management was in vogue for over a century. Literature available on evaluation of different base materials, phagostimulants and insecticides as poison baits in both lab and field conditions is reviewed in this chapter.

2.1. Efficacy of different base materials in bait composition

Saw dust and wheat bran were evaluated as a carrier for poison baiting of black cutworm *Agrotis ipsilon* by Davis and Turner (1918). Molasses, lemon and water was added to the base material to prepare the bait. Wheat bran based baits were found to be superior over saw dust.

Bait prepared with apple pomace was found to be more attractive than wheat bran for the control of army worm, *Mythimna* (= *Pseudaletia*) *separata* (Walker) in wheat (Sechriest and Moore, 1968).

In another study, Gholson and Showers (1979) assessed the feeding behaviour of cut worm *A. ipsilon* infesting corn seedlings in the presence of baits in green house. Bait pellets containing apple-grape, bran and grape were attractive to cut worm larvae. Damage by fifth and sixth instar larvae was lower to corn seedlings when bait material was present in the greenhouse. Though there was no significant difference, larvae preferred wet baits over dry baits.

Baits prepared with rice bran or wheat flour with 20 per cent molasses was attractive to full grown larvae of *S. litura* hiding in soil crevices (Jayaraj, 1983).

Moustafa (1983) tested various base materials for the efficacy of baits with fenvalerate and chlorpyriphos against *A. ipsilon*. Maize cob pith was found to be superior followed by groundnut shell or wheat bran.

Viswanadham *et.al.*, (1986) evaluated the superior base material and effective proportion of jaggery with bran for the preparation of poison baits. Rice bran was found to be more superior followed by rice fine husk, jowar flour and ragi flour. Rice bran and jaggery in 8:2 ratio was more effective than other proportions.

Bait material prepared with 50 kg rice bran, 4 kg jaggery and 8 litres of water for a hectare of area was used for the preparation of poison baits against *S. litura* in groundnut (Shankaragouda *et.al.,* 2015).

Mudassar *et.al.* (2017) conducted a study to standardise the composition of food bait for the management of *S. litura.* The best compositions were rice bran + jaggery (20%) + yeast (0.1%) and rice bran + molasses (10%).

2.2. Efficacy of phagostimulants in enhancing bait preference

Wheat flour containing 20 per cent molasses acted as an effective bait to attract fourth instar larvae of *S. litura*. But the attractiveness of the bait decreased after four hours (Parasuraman *et al.*, 1985).

Cucurbitacin was found to improve the attractiveness of baits to dibroticine beetles. Addition of eugenol to this bait was found to increase the response of the beetles (Metcalf *et al.*, 1987)

Bartelet *et.al.* (1990) demonstrated that *Ostrinia nubillalis* (Hubner) larvae will respond to feeding stimulants that have been incorporated into starch. The artificial diet for the species, corn foliage, corn oil and artificial feeding stimulant coax were the potential phagostimulants used in the study. Relative feeding preferences of the larvae were measured and the commercial phagostimulant coax was found to be the most effective phagostimulant.

Hiremath *et al.* (1990) standardized the bait preparation procedure for army worm *Mythimna separata*. For a hectare of area, 50 kg of rice bran or wheat bran, 625 ml of monoctotophos (36SL) and 4 kg of jaggery was dissolved in 6-8 litres of water and used after 48h of fermentation. The authors were of the opinion that aroma from fermented jaggery is acted as a phagostimulant to the insect.

The feeding behaviour of six lepidopteran pests like *Lymantria dispar* (L.), *Helicoverpa zea* (Boddie), *Spodoptera frugiperda* (J. E. Smith), *Spodoptera exigua* (Hubner), *O. nubilalis* and *Plutella xylostella* (L.) were tested on different artificial feeding stimulants *viz.,* Pheast, Coax, Gusto, Entice, and Mo-Bait. Pheast elicited

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the greatest response and the least response was with Mo-Bait (Farrar and Ridgway, 1994).

Castillejos *et.al.,* (2002) evaluated whether the efficacy of bio insecticides that act by ingestion could be enhanced by the use of phagostimulants. Addition of phagostimulants could increase the intake of nucleopolyhedrovirus resulting in improved control of *Spodoptera frugiperda.* Formulation consisting of pregelatinised flour, starch, maize cob, maize oil, and water was recognised as highly palatable.

Eduku (2014) conducted an experiment to investigate an effective cassava bait for the control of pests of cocoa beans using coffee bean weevil, *Araecerus fasciculatus* (De Geer) as model. The test insect preferred sun dried chips over fresh chips, fermented dough, flour and cocoa beans and also reported that soaking of sun-dried chips in brown sugar solution (500g per litre of water) improved the preference.

Thirteen different feeding stimulants for increasing the activity of *S. exigua* multiple nucleopolyhedrovirus was tested by Lasa *et al.,* (2009). The wheat germ oil and soya flour were identified as potential phagostimulants which resulted in increased mortality compared to the use of virus alone.

Mudassar *et.al.,* (2017) conducted a study in laboratory to standardise the composition of food bait using *Spodoptera litura.* Jaggery, yeast and molasses were used as phagostimulants in rice bran. Among the different phagostimulants used, more number of larvae were attracted to the food bait with jaggery (20%) followed by molasses (10%) and yeast (0.1%).

2.3. Efficacy of different insecticides in baits in laboratory and field conditions

Fernald (1914) reported an impressive control of *Mythimna unipuncta* (Guenee) using baits prepared from paris green, molasses and water. Wheat bran and saw dust bait containing Paris green was used in a field infested heavily with army worm (Davis and Turner, 1918). There was 100 per cent mortality of the larvae when bran bait was used and the mortality was 75 per cent when saw dust bait was used.

Dhams and Fenton (1942) prepared a bait mixture using two quarts sodium arsenate per 100 pounds of wheat bran and sufficient water for the control of armyworm, *M. unipuncta*. Another inorganic pesticide Paris green in bran (3:100 or 4:100) was broadcasted @ 20 to 30 lb per acre to reduce the infestation of *M. unipuncta* by 90 per cent in 72 h (Scott, 1945).

Tunblad (1947), prepared a bait containing wheat bran, sugar, cryolite and water (50:2:3:40) against *Agrotis(= Euxoa) segetum* (Denis & Schiffermüller) in young stocks of apple in Sweden. The bait, distributed along rows of apple in the evening, gave 90 per cent mortality of the larvae.

Poison baiting was found to be more effective than drenching the fields with insecticides for managing the outbreak of cutworm *Agrotis. segetum* in cotton and ragi fields. Bait was prepared by mixing dry bran (10 kg), jaggery (0.91 kg) and sodium silicoflouride (0.45 kg) with water sufficient to moisten the bait. Bait applied in field at evening induced 62.50 per cent mortality after 24 h (Usman, 1953).

The bait consisting of bran, molasses, water and insecticide was properly mixed and broadcasted in cotton seedlings. Among various poison baits tested against *A. ipsilon*, dieldrin resulted in cent per cent mortality followed by endrin (Kamel and Shoeb, 1958). Poison baits prepared with soybean cake and benzene hexa chloride were highly effective against last instar larvae of *Heliothis armigera (*Hubner) in cotton (Hsu *et al*., 1958).

Baits containing insecticides like phosalone, methidathion, fenthion, aminocarb, carbaryl, BHC, trichlorfon, diazinon, barium fluosilicate and sodium fluosilicate were found to give complete mortality of *Spodoptera littoralis* (Boisduval) in 72 h (Delrivero and Planes, 1966).

Abate, mirex, ethyl parathion, DDD (dichloro diphenyl dichloro ethane), carbaryl and trichlorfon were effective poisons in bait prepared against *A. ipsilon* infesting maize (Sechriest, 1968).

Morgan and French (1971) tested 15 compounds in poison baits against granulate cutworm, *Feltia subterranea* (F.) on pea nuts and more than 90 per cent mortality were obtained by using abate, dursban, monocrotophos, methomyl trichlorfon, and monitor within 24 h after application.

Insecticides like abate, carbaryl, endosulfan, methomyl and trichlorfon were effective in providing 90 per cent mortality of *S. litura*, when used in poison baits (Devaiah, 1973).

Agrotis exclaminationis (L.) and *A. segetum* infesting potatoes were effectively controlled by using a poison bait consisting of wheat bran, sugar and trichlorfon as toxicant (Erfurth, 1973). A high protein food bait containing maize meal, non- fat dried milk, defattened soybean flour, refined soybean oil, vitamins and minerals with methomyl as insecticide was effective against *Heliothis zea* when applied @ 0.25 lb/acre in tomato fields (Creighton *et al.*, 1973).

A commercial Japanese bait Nekiriton containing one per cent trichlorfon was evaluated against three noctuid larvae *viz.*, *Mamestra brassicae*, *A. ipsilon* and *S. litura*. The bait was effective against *M. brassicae* and *A. ipsilon* when placed on soil surface. Bait was effective against *S. litura* also, when applied to Chinese cabbage leaves(Yokoi *et al.*, 1975).

Pelleted bait formulations containing six different insecticides were evaluated against *A. ipsilon* infesting corn (Sechriest and Sherrod, 1977). Carbaryl (0.84 kg a.i./ha), chlorpyriphos (0.34 kg a.i./ha), fonofos (1.12 kg a.i./ha), biothion (0.34 kg a.i./ha), methomyl (0.17 kg a.i./ha) and trichlorfon (1.12 kg a.i./ha) was effective in controlling cut worm larvae, when applied soon after seedling emergence.

Gharib (1979) reported the control of third to fifth instar larvae of *S. litura* using bait consisting wheat bran 100kg, lindane (25% DP) 1 kg and 50 litres of water at the rate of 70-80kg/ha.

Poison bait containing rice bran (5 kg), jaggery or molasses (0.5 kg), water (3 litres) and carbaryl (50% WP) 0.5 kg was recommended by Abdul Kareem and Viswanathan (1980) for the management of *S. litura*.

Hill *et al*., (1983) evaluated the efficacy of poison baits against larvae of *A. ipsilon*. Bait consisting carbaryl (5 per cent) in wheat bran or kibbled wheat was superior to the other commercial baits at the rate of 10kg/ha.

Poison balls containing dipterex attracted and killed more larvae of red hairy caterpillar compared to BHC and DDT poisoned balls (Dhandapani and Abdul Kareem, 1983).

Ascher and Rubin (1983) assessed wheat bran bait containing chlorpyriphos against *S. littoralis*. The mortality of the larvae decreased from 100 to 85 per cent within 16 days.

Effectiveness of baits containing *Bacillus thuringiensis* was tested in laboratory conditions against *S. littoralis* (El-Nockrashy *et al*., 1986). Bait containing cotton seed kernels extracted with ethanol and acetone-hexane-water enhanced the potency of *B. thuringiensis*.

Viswanadham *et.al.,* (1986) evaluated chlorpyriphos, monocrotophos, quinalphos and carbaryl as poison baits at 0.5, 1.0, 1.5 and 2.0 per cent concentrations against *S. litura*. Monocrotophos at 0.5 per cent showed high mortality of the pest.

Efficacy of fenthion, endosulfan, monocrotophos and quinalphos in baits were evaluated against *Mythimna separata* (Giraddi and Kulkarni 1987). Bait was prepared with jaggery (500g), wheat bran (40kg) and insecticide in five litres of water for a hectare of area. Prepared bait was thoroughly mixed and dried under shade for one hour and tested against *M. separata*. Quinalphos was found to be more effective followed by monocrotophos, among the four insecticides tested.

Baits containing dry cucurbitacin were applied against diabroticine beetles in sweet corn and cucurbits. Organophosphate and carbamate pesticides like methomyl, carbaryl, carbofuran and bendiocarb (0.1%) were more effective than the pyrethroids permethrin, cypermethrin, fenvalerate and flucythrinate (0.01%) (Metcalf *et al.,*1987).

Mohan *et al.*, (1989) reported effective management of *S. litura* in cauliflower fields using pellet based poison baits containing BHC 50 WP, carbaryl 50 WP, fenthion 80 EC and malathion 50 EC.

Five chemicals in poison baits were evaluated to manage *S. litura* in tobacco nurseries (Ramaprasad *et. al.*, 1989). Application of endosulfan or monocrotophos or chlorpyriphos or fenvalerate or quinalphos (1/3rd of their recommended dose) with rice bran and jaggery at 4:1 proportion controlled later instars of *S. litura* economically.

The monocrotophos based poison bait resulted in 98 per cent mortality of armyworm, *M. separata* (Hiremath *et al.,* 1990).

Among seven insecticides tested against *S. litura* on potato; monocrotophos, chlorpyriphos and quinalphos poison bait treatments resulted in lesser tuber loss (Chandrasekhar, 1992).

Shakur *et.al.*, (2007) conducted a study on management of potato cutworm *A. ipsilon* using insecticides such as Steward (Indoxacarb), Lannate (Methomyl) and poison bait (dipterex + sugar + rice husk). Poison bait was more effective with only 1.3 per cent infestation than the other two treatments Lannate (1.6%) and by Steward (1.8%). Poison baiting with monocrotophos against *Agrius convolvuli* in green gram was moderately effective in controlling the pest (Jayaram *et. al.*, 2007).

Renju *et.al.*, (2009) evaluated new insecticides as poison baits against *M. separata.* Spinosad (45 SC), indoxacarb (14.5 SC), lambda cyhalothrin (5 EC), profenofos (50 EC) and chlorpyriphos (20 EC) was the chemicals used along with the standard chemical monocrotophos (36 SL). Chlorpyriphos (20 EC) at 75 per

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cent recommended dose was found to be the superior, which resulted in 100 per cent mortality after 48h of exposure. Spinosad at 75 per cent recommended dose gave cent per cent mortality of larvae after 72 h of exposure.

Incidence of *S. litura* in potato fields baited with carbaryl in rice bran and jaggery lead to lower defoliation (27.83 per cent) and tuber damage (Shashi Bhushan *et al.*, 2010). When biopesticides, chemical pesticides and poison baits were tested in potato fields for the management of *S. litura*, though reduced yield and higher number of larvae per plant were observed with posion baits containing methomyl and monocrotophos, benefit cost ratio was highest with poison baits (Basavaraju *et. al.,* 2010).

Eduku, (2014) tested six insecticides in poison baits prepared with sun dried chips of cassava soaked in brown sugar solution and fermented for 12 h. Cassava bait containing deltamost (2.5% deltamethrin + 0.3% bioallethrin + 11% piperonyl butoxide) was superior at the three levels (25, 50 and 75% recommended dose) to both confidor (imidacloprid) and fastrack (alpha cypermethrin).

Seven essential oils and four insecticides were tested in poison baits by mixing it with wheat bran and molasses for controlling third nymphal instars of the desert locust, *Schistocerca gregaria* (Forskal). At the level of LC_{50} values methomyl was the potent insecticide followed by fenvalerate, fenitrothion and among plant oils, cumin was the highest toxic (Mansour and Abdel–Hamid, 2015).

Shankaragouda *et.al.,* (2015) studied new insecticide molecules as poison bait against *S. litura* in groundnut. Cent percent mortality was showed by chlorpyriphos (20 EC) at 100 and 75 per cent of recommended dose after 72h in first set of insecticides which consisted of lambda cyhalothrin (5EC), profenofos (50 EC), chlorpyriphos (20 EC), novaluron (10 EC) and methoxyfenozide (20SC). In set two, insecticides like indoxacarb (14.5 SC), chlorfenapyr (10 SC), fipronil (5 SC), spinosad (45 SC) and chlorantraniliprole (18.5 SC), along with the standard insecticide monocrotophos (36 SL), were evaluated and the bait formulation containing chlorfenapyr resulted in cent per cent mortality at 25 per cent of the recommended dose after 72 h.

Sreedhar and Nageswararao (2016) conducted a study in flue cured Virginia (FCV) tobacco (*Nicotiana tabacum*) cv. Kanchan for the control of tobacco caterpillar, *S. litura*. Five pesticides, such as emamectin benzoate (5 SG), SL NPV, *Bacillus thuringiensis* var. *kurstaki* and insect growth regulators novaluron (10 EC), lufenuron (5 EC) were evaluated as poison baits and compared with a standard check chlorpyriphos (20 EC). Infestation in tobacco plants were found to be least, and highest cured leaf yield (1982 kg/ha) was recorded in emamectin benzoate baited plots.

Mudassar *et.al.,*2017 evaluated different poisoned food baits against *S. litura* in field planted with palak. Jaggery bait poisoned with spinosad was more effective than molasses bait containing spinosad. Molasses and jaggery bait containing quinalphos and malathion were inferior to jaggery bait with spinosad.

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Materials and Methods

3. Materials and methods

The work was carried out at the Department of Agricultural Entomology, College of Horticulture, Kerala Agricultural University, Vellanikkara and the Department of Forest Biology and Tree Improvement, College of Forestry, Kerala Agricultural University, Vellanikkara. The methodology employed and various materials used for the study is given in this chapter.

3.1. Test insect

Culture of *Spodoptera litura* was established in the laboratory from egg mass (Plate1) and larvae (Plate 2) collected from the Banana Research Station, Kannara and from farmers fields near Kannara and Mattathurkunnu, Thrissur district, Kerala, India. *S. litura* larvae obtained from field were reared separately on both fresh leaves of castor (Plate 3) and semi-synthetic diet (Plate 4) (Mani and Rao, 1998) in plastic containers (18 cm diameter and 5 cm height). The top of the container was covered with muslin cloth (Plate 5). The containers were cleaned daily, to maintain hygienic condition and to avoid contamination. Semi-synthetic diet prepared as per table 1, was prepared and provided to larvae.

Larvae were provided with artificial diet twice a day. Pupae (Plate 6) were transferred to oviposition jars and the emerged adults were fed with honey solution (honey and water in 1:1 ratio). A capsule of vitamin E was also added to the honey solution to increase the oviposition. Paper folds and castor leaves were provided inside the oviposition jar (Plate 7) for egg laying. Third instar (6 day old) larvae (Plate 8), thus obtained, were used for further studies.

Table 1: Composition of semi- synthetic diet

Ingredient	Quantity
Kidney bean	65.0 g
Wheat bran	65.0 g

Plate 1. Egg mass

Plate 2. *Spodoptera litura* larvae

Plate 3. Rearing on fresh castor leaves

Plate 4. Rearing on semi- synthetic diet

Plate 5. Rearing trays

Plate 6. *Spodoptera litura* pupa

Yeast extract powder	25.0 g
Agar powder	12.0 g
L- Ascorbic acid	4.0 g
Sorbic acid	0.9 g
Methyl para hydroxybenzoate	0.4 g
Casein	3.0 g
Streptomycin sulfate	1.0 g
Multi- vitamin capsule	1 capsule
Cholestrol	0.3 g
Formaldehyde (35%)	2 ml
Vegetable oil	1 ml
Distilled Water	600 ml

3.2. Standardisation of base material

Rice, wheat and maize bran were evaluated for their effectiveness as base material in poison baits for *S. litura*. Baits were prepared by using different bran as base material along with jaggery and water in different ratios. All the constituents for the preparation of base material were procured from local market.

Three different ratios (on w/w basis) of bran, jaggery and water *viz*., 12.5:1:1, 12.5:1:4 and 4:1:4 were evaluated. Bait was kept for fermentation for a period of 48 hours.

One gram each of prepared and fermented bait was weighed and transferred to clean Petri plates. Six day old *S. litura* larvae were released into Petri plates for feeding (three larvae/ Petri plate) (Plate 9). All the three treatments were replicated five times. Larvae were allowed to feed for 48 h and the weight of the bait remaining in each Petri plate was taken after the removal of faecal pellets. Observation on weight of the bait consumed was recorded by calculating the difference between the initial weight and final weight of the base material. The base material which recorded the highest consumption by *S. litura* larvae was chosen for further studies.

Data was analysed in SPSS 16.0 in CRD and means were separated by Tukeys test.

3.3 Identification of suitable phagostimulants

Standardisation of base material was followed by the evaluation of phagostimulants with an objective to increase the attractiveness of bait material. Yeast (1%), starch (0.2%) and coconut oil (1%) were evaluated as phagostimulant for the standardised base material. Yeast, starch and coconut oil were procured from the local market.

Weighed quantity of phagostimulants were added to the selected base material and was kept for fermentation for a period of 48 h. One gram each of the fermented bait was weighed and taken in petri plates. Six day old larvae were released @ 3/ Petri plate. The study was replicated five times. Bait consumed in each replicate was calculated by weighing the remaining quantity of bait after a period of 48 h. Faecal pellets were removed from each Petri plate before weighing. Bait prepared without the addition of any phagostimulant served as control.

Data were analysed in SPSS 16.0 in CRD and means were separated by Tukeys test.

3.4. Evaluation of poison baits

The best bait combination identified from the previous experiments were used for preparation of poison baits with chemical insecticides/microbials (Table 2). Three concentrations of each chemical and microbial pesticide were evaluated. The concentrations prepared were 75, 50 and 25 per cent of the recommended dose. The quantity of pesticide required was calculated based on the recommended dose of each pesticide for a hectare of area and the quantity of bait required for a hectare as per Viswanadham *et al*., 1986. The recommended dose of each pesticide along with the quantity required for preparing 100 g bait was calculated (Table 2. Poison baits prepared in the selected base material was kept for fermentation for a period of 48 h. 1.5 g each of the prepared poison bait were transferred to Petri plates. Six day old *S. litura* larvae (3 larvae/ Petri plate) were released into the Petri plate (Plate 9). Each of the eleven treatments were replicated thrice along with an unpoisoned bait as control. Mortality of larvae were recorded after 12, 24, 36, 48 and 72 h of exposure to the poisoned baits. In the case of microbials mortality was recorded for a period of seven days after the release of larvae into Petri plates.

Per cent mortality was calculated and the data was analysed in SPSS 16.0 after arc sine transformation and means were compared by Tukey's test.

Table 2: Insecticides/microbials evaluated in poison baits

Pesticide	**Manufacturer**	**Recommended dose (a.i./ha)**	**Quantity of insecticide used in 100 g bait (100% conc.)**
T_1 : Chlorpyriphos (20% EC)	K.P.R. Agrochem Limited, Andhra Pradesh, India	500 g	2 ml
T_2 : Thiodicarb (75% WP)	Bayer Crop Sciences, Thane, India	750 g	2 g
T_3 : Lambda cyhalothrin (5% EC)	Syngenta India Ltd., Pune, India	15 g	0.6 ml
T_4 : Fipronil (5% SC)	ADAMA India Private Limited, Hyderabad, India	50 g	2 ml
T_5 : Spinosad (45% SC)	Dow Agro Sciences India Ltd., Mumbai, India	73 g	0.324 ml
T_6 : Emamectin benzoate (5% SG)	Syngenta , India Ltd. , Pune, India	10 g	0.4 g

T7: Flubendiamide (39.35% SC)	Bayer Crop Sciences, Thane, India	50 g	0.254 ml
T_8 : Chlorantraniliprole (18.5% SC)	E.I. DuPont India Pvt. Ltd., Gurgaon, India	30 g	0.324 ml
T_9 : NPV of *S. litura* (0.5% AS)	Kerala Agricultural University, Vellanikkara	1500 ml	3 ml
T_{10} : *Bacillus thuringiensis* (5% WP)	State Biocontrol Laboratory, Mannuthy	1 kg	5 ml

3.5. Field evaluation of selected poison baits

From the laboratory tests, five best poison baits were selected and tested in cowpea ecosystem (Plate 10). Cowpea (variety - Anaswara) was planted at a spacing of 45 x 30 cm in plots of size 11m^2. Experimental plots were laid out in randomized block design (Fig. 1) and each plot had about 20 plants each. There were seven treatments which was replicated thrice. Along with the selected five poison baits, one control (with an unpoisoned bait) and one absolute control (without any bait material) were evaluated in the field. Baits were evaluated once the crop was 30 days old. In order to prevent the movement of larvae from one plot to another, each plot was separated by polythene sheets. Sheets of 1 m width were used to construct the barrier (Plate 11) around the field. The sheets were fixed along the borders of each plot in such a way that half of the width of the sheet (50 cm) was below the ground.

Five plants in each plot, equidistant from the centre of the plot, was randomly selected and tagged before the release of the larvae. Poison baits, prepared as per the methodology described earlier, were placed in bait stations (dried leaf) (Plate 12) near the base of the tagged plants. Five bait stations were there for each plot and 11 g each of poisoned bait balls was kept in each bait station (Plate 13). Twenty five *S. litura* larvae (six day old) were released at the centre of each plot (Plate 14), in order to ensure uniform distribution of larvae. Owing to the

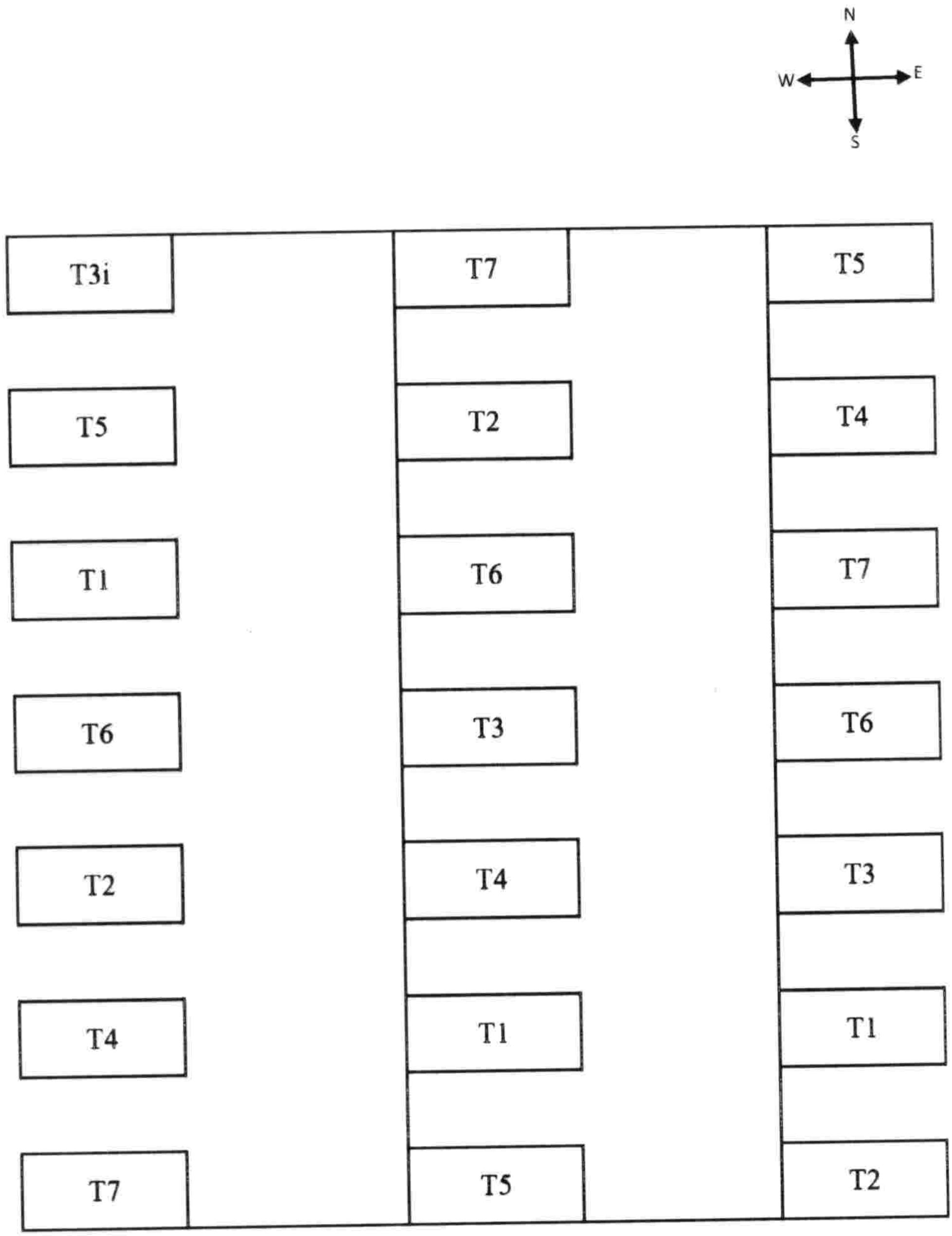


Fig. 1: Field layout

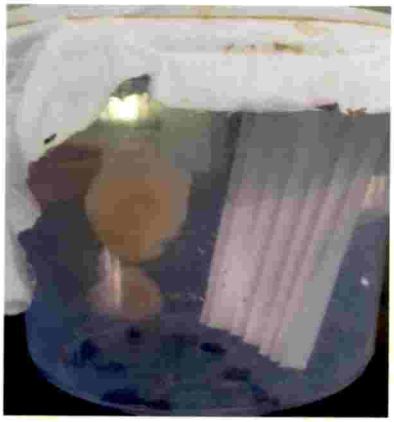


Plate 7. Oviposition jar

Plate 8. Six day old *Spodoptera litura* larvae

Plate 9. Six day old larvae released

Plate 10. Cowpea field

Plate 11. Fencing with polythene sheet

Plate 12. Bait station (dried leaf) with bait

Plate.13: Bait balls

Plate.14
Release of larvae in the middle of plot

Plate 15. Side leaf and central leaf

Plate 16. Trifoliate leaf

polyphagous nature of *S. litura*, the plot was kept weed free, so that the larvae had only cowpea plants or bait material to feed upon.

After 10 days of release of larvae, length and width of fully opened individual leaves in the tagged plants were measured and recorded. The leaf area was measured using a leaf area meter to assess the extent of defoliation by larval feeding. The weight of bait from each bait station was weighed and recorded after 48 hours of release of the larvae.

For assessing the initial leaf area, length and breadth of leaves were measured, before recording leaf area using leaf area meter. Leaf area of side leaves and centre leaves of the trifoliate leaves were measured separately, as the side leaves and centre leaves had different shapes (Plate 15 and 16). Based on the length, breadth and leaf area measured, regression equations were worked out separately for centre leaf and side leaves.

Regression equation for centre leaf: Leaf area = -27.889 + (11.797 × breadth)

Regression equation for side leaf: Leaf area = -27.584 + (11.754 × breadth)

Based on the regression equation, initial leaf area was assessed and area defoliated was measured based by subtracting final leaf area measured using leaf area meter from the initial leaf area. Total leaf area consumed in all the 5 tagged plants were added up to get the total leaf area consumption. Data was analysed in SPSS 16.0 in RBD and means were separated by Tukey's test.

Results

4. Results

The results of the various experiments conducted to standardise a poison bait for the management of *Spodoptera litura* is presented in this chapter. The chapter is organised under the following sub headings *viz.,*

4.1 Standardisation of base materials

4.2 Standardisation of phagostimulants

4.3 Evaluation of poison baits in laboratory

4.4 Evaluation of poison baits in field

4.1. Standardisation of base material

Three types of commonly available bran material *viz,* rice bran, wheat bran and maize bran were evaluated for their effectiveness as base material at three different proportions, 12.5:1:1, 12.5:1:4 (Hiremath *et. al.*, 1990) and 8:2 (Viswanadham *et. al.,* 1986) of bran, jaggery and water.

At the proportion of 12.5:1:1, heavy cannibalism was observed in all the treatments. Larval cannibalism was also observed in the bait prepared at 12.5:1:4 proportion, but the cannibalistic behaviour was low when compared to the previous proportion tested. The bait prepared in the ratio 8:2 of bran and jaggery, with water sufficient enough to make the bait into a ball was found to be superior without any cannibalism among larvae. Hence, further studies were conducted with bait prepared in 8:2 proportion of bran and jaggery.

Baits were prepared with different bran materials and kept for fermentation for a period of 48 h and one gram each of the bait was kept in Petri plates followed by the release of *S.litura* 6-day old larvae. The mean consumption of bait material in different treatments is presented in the table.3 after 48 h of feeding by *S. litura* larvae. Among the various base materials tested, significantly higher amount of bait was consumed in the treatment, wheat bran. Larvae consumed on an average 0.1980 g of bait after 48 hours of feeding in wheat bran based bait. The mean consumption of bait was 0.1753 g and 0.1493 g in maize bran and rice bran respectively.

Table 3. Consumption of bait after 48 h of feeding by *S. litura*

Base material	Weight of bait consumed (g)
Rice bran	0.1493 [c]
Wheat bran	0.1980 [a]
Maize bran	0.1753 [b]

(Values followed by same letter are not significantly different at 5% level)

4.2. Standardisation of phagostimulants

Standardisation of base material was followed by the evaluation of phagostimulants for increasing the palatability and acceptance of the bait. Starch (0.2%), coconut oil (1%) and yeast (1%) were tested as phagostimulants along with control.

Among the various treatments, starch (0.2%), coconut oil (1%), yeast (1%) and a control (without phagostimulants), bait containing starch 0.2 per cent and coconut oil 1 per cent were found to be significantly superior over yeast and control (Table 4). Even though there was no significant difference between starch (0.3842 g) and coconut oil (0.3725 g), more consumption was recorded in starch based bait.

Addition of yeast (1%) did not improve the palatability of the bait, as the consumption was 0.1975 g in both control and the bait containing yeast.

Table 4. Consumption of bait with phagostimulants after 48 h of feeding by *S. litura*

Base material + phagostimulants	Weight of bait consumed (g)
Wheat + yeast 1%	0.1975 [b]

Wheat + starch 0.2%	0.3842[a]
Wheat + coconut oil 1%	0.3725[a]
Control (without phagostimulants)	0.1975[b]

(Values followed by same letter are not significantly different at 5% level. Means were separated by Tukey's test)

4.3. Laboratary evaluation of poison baits

The efficacy of ten different pesticides belonging to different classes were evaluated in the laboratory as poison baits. Among ten pesticides, eight were chemical insecticides and the other two were microbials. The evaluated insecticides belonged to different class such as organophophate (chlorpyriphos), carbamate (thiodicarb), synthetic pyrethroid (lambda cyhalothrin), phenyl pyrazole (fipronil), avermectins (emamectin benzoate), spinosyns (spinosad), phthalic diamide (flubendiamide) and anthranilic diamide (chlorantraniliprole). The microbials evaluated were nuclear polyhedrosis virus of *S. litura* and *Bacillus thuringiensis var. kurstaki*.

Standardised bait material from the previous experiments (wheat bran based bait with starch as phagostimulant) was mixed separately with insecticides at three different concentrations (25%, 50% and 75% of recommended dose at field level) in a ratio of 8:2, wheat bran and jaggery with sufficient amount of water to make balls. Starch (0.2%) was added to the bait as phagostimulant. Efficacy of each insecticide was recorded after 12, 24, 36, 48 and 72h in case of chemical insecticides, while observations were extended up to seven days in the case of microbial pesticides.

4.3.1. Effect of poison bait containing chlorpyriphos (20% EC) on *S. litura*

Mortality of *S. litura* larvae fed with bait poisoned with chlorpyriphos is given in table 5. After 12 h of treatment itself, the bait resulted in cent percent mortality of *S. litura* compared to control at 25 per cent, 50 per cent and 75 cent of the recommended dose. There was no mortality in control at different observation intervals.

Table 5. Effect of poison bait containing chlorpyriphos (20%EC) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	**24 h**	**36 h**	**48 h**	**72 h**
25% of RD	100.00 (88.35)	-	-	-	-
50% of RD	100.00 (88.35)	-	-	-	-
75% of RD	100.00 (88.35)	-	-	-	-
Control	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)

(As the values were zero and hundred data was not analysed, RD = recommended dose)

4.3.2. Effect of poison bait containing thiodicarb (75% WP) on *S. litura* larvae

In bait containing thiodicarb (75% WP), complete mortality was recorded at all the three concentration level within 12h of treatment. (Table 6). Mortality was not recorded in control at different time intervals.

Table 6. Effect of poison bait containing thiodicarb (75% WP) on *S. litura*

Dose	Mortality (%) *S. litura* at different time intervals				
	12 h	**24 h**	**36 h**	**48 h**	**72 h**
25% of RD	100.00 (88.35)	-	-	-	-

50% of RD	100.00 (88.35)	-	-	-	-
75% of RD	100.00 (88.35)	-	-	-	-
Control	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)	0.00 (1.65)

(As the values were zero and hundred data was not analysed. RD = recommended dose)

4.3.3. Effect of poison bait containing lambda cyhalothrin (5% EC) on *S. litura*

After 12 h, in bait containing lambda cyhalothrin 5% EC, mortality of larvae was not observed at all the concentrations evaluated 25, 50 and 75 per cent recommended dose (Table 7). After 24 h, though the mortality was zero at the lowest dose of 25 per cent recommended dose, it was 4 per cent at both 50 and 75 per cent recommended dose. Mortality of 8 per cent could be observed at 25 per cent recommended dose and the mortality increased with the dose to 22.67 per cent and 24.00 per cent respectively at 50 per cent and 75 per cent recommended dose of lambda cyhalothrin. Per cent mortality was 22.67, 38.67 and 41.33 at the 25, 50 and 75 per cent recommended dose, respectively, after 48 hours. At 72 h, mortality was 37.33 per cent at the lowest dose (25 per cent recommended dose), which increased to 46.67 per cent and 52.00 per cent with the increase in dose to 50 per cent and 75 per cent, respectively.

If we peruse the per cent mortality of *S. litura* larvae at 25 per cent recommended dose, none of the larvae died at the first two observation intervals of 12 and 24 h. Mortality was 8.00, 22.67 and 37.33 per cent at 36, 48 and 72 h after treatment, respectively. Similar to the lowest dose mortality of *S. litura* larvae were zero after 12 h. Four per cent mortality could be observed after 24 h, which increased to 22.67 per cent after 36 h, 38.67 after 48 h and 46.67 after 72 h. As with 50 per cent recommended dose the highest dose evaluated (75 per cent recommended dose) also caused 4.00 per cent mortality after 24 h while none of the larvae died after 12 h. Mortality increased to 24.00 per cent after 36 h and after 48 h and 72 h mortality was 41.33 per cent and 52.00 per cent, respectively.

Mixing lambda cyhalothrin in a wheat bran based bait did not yielded substantial mortality of *S. litura* larvae at any of the dose evaluation. Even at the highest dose and after 72 h mortality was 52.00 per cent. There was no mortality of the larvae in control. Mortality was significantly higher over control at all the tested concentration after 48 and 72 h. There was no significant difference between mortality at different concentrations after 12 h and 24 h with lambda cyhalothrin poisoned bait. Mortality was significantly higher over control after 36 h and 48 h.

Table 7. Effect of poison bait containing lambda cyhalothrin (5% EC) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	0.00^{a} (1.65)	0.00^{a} (1.65)	8.00^{b} (9.71)	22.67^{b} (23.94)	37.33^{b} (34.77)
50% of RD	0.00^{a} (1.65)	4.00^{a} (5.68)	22.67^{a} (24.51)	38.67^{a} (36.68)	46.67^{ba} (41.92)
75% of RD	0.00^{a} (1.65)	4.00^{a} (5.68)	24.00^{a} (25.85)	41.33^{a} (38.24)	52.00^{a} (45.60)
Control	0.00^{a} (1.65)	0.00^{a} (1.65)	0.00^{b} (1.65)	0.00^{c} (1.65)	0.00^{c} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.3.4. Effect of poison bait containing firpronil (5% EC) on *S. litura*

Per cent mortality of *S. litura* larvae were zero after 12 and twenty four hours with poison bait containing fipronil (Table 8). After 36 h, 10.67 per cent mortality was observed which increased suddenly to 100.00 per cent by 48 h. A similar trend in mortality was observed at 50 per cent recommended dose also, where in the mortality was 0.00, 0.00, 10.67 and 100.00 per cent after 12, 24, 36, 48 and 72 h of observations, respectively. Though the mortality was zero after 12 h, after 24 h, mortality increased to 32.00 per cent and complete mortality could be observed after 36 h.

After 12 h of observation, mortality of *S. litura* was zero at all the doses evaluated. After 48 h, zero per cent mortality was observed at the lowest two doses, while 75 per cent recommended dose yielded 32.00 mortality. Mortality was 10.67 per cent after 36 h at 25 and 50 per cent recommended dose, while mortality reached 100 per cent at 75 per cent recommended dose. Complete mortality was observed after 48 h at both 25 per cent and 50 per cent recommended dose of fipronil.

Though, bait with fipronil did not resulted in any mortality at different dose after 12 h, cent per cent mortality could be achieved after 48 h with 25 and 50 per cent recommended dose. At 75 per cent recommended dose 100 per cent mortality could be observed after 36 h. Per cent mortality was significantly higher over control after 36, 48 and 72 h of observations at all the three concentrations. After 36 h mortality at 25 and 50 per cent recommended dose was significantly lower to 75 per cent recommended dose, but was at par with each other.

Table 8. Effect of poison bait containing fipronil (5% EC) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	0.00^{a} (1.65)	0.00^{b} (1.65)	10.67^{b} (11.84)	100.00^{a} (88.35)	-

50% of RD	0.00^{a} (1.65)	0.00^{b} (1.65)	10.67^{b} (11.84)	100.00^{a} (88.35)	-
75% of RD	0.00^{a} (1.65)	32.00^{a} (32.79)	100.00^{a} (88.35)	-	-
Control	0.00^{a} (1.65)	0.00^{b} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.3.5. Effect of poison bait containing spinosad (45% SC) on *S. litura*

In spinosad based bait, significantly higher mortality over control was obtained at all the concentrations and at all the observation intervals (table 9). Even at the lowest concentration of 25 per cent recommended dose mortality was 41.33 per cent mortality recorded after 12 h. Mortality was 64.00 per cent, 74.67 per cent, 88.00 per cent and 100.00 per cent after 24 h, 36 h, 48 h and 72 h of observations, respectively at 25 per cent recommended dose.

Significantly higher mortality (56.00 per cent) over control was obtained at 50 per cent recommended dose after 12 h of observation. Mortality was 64 , 82.67, 93.33, 100 per cent after 24, 36 h, 48 h and 72 h respectively.

At the highest dose of 75 per cent recommended dose, complete mortality of larvae could be observed after 48 and 72 h of observation. Mortality was significantly higher after 12 h, 24 h and 36 h, being 77.33 per cent, 90.67 per cent and 98.67 per cent, respectively.

After 12 h of observation, mortality (77.33 per cent) was significantly higher than all the other doses as well as control at 75 per cent recommended dose. Per cent mortality at the lowest dose of 25 per cent recommended dose (41.33 per cent) and 50 per cent recommended dose (56.00 per cent) was significantly higher over control but was at par with each other. Similar trend was observed after 24 h, 36 h and 48 h also, where the mortality was significantly higher at 75 per cent recommended dose. Mortality at 25 and 50 per cent recommended dose was significantly higher over control but significantly lower to 75 per cent recommended dose and mortality at 25 and 50 per cent recommended dose was at par with each other. After 24 hours mortality remained same as 64.00 per cent in 25 per cent recommended dose and 50 per cent recommended dose, which increased significantly with the increase in concentration to 90.67 per cent at 75 per cent recommended dose. Mortality was 74.67 per cent, 82.67 per cent and 98.67 per cent at 25, 50 and 75 per cent recommended concentrations after 36 h. Above 80.00 per cent mortality was observed at all the concentrations evaluated after 48 h. Per cent mortality was 88.00, 93.33 and 100.00 at 25 per cent, 50 per cent and 75 per cent concentrations, respectively. Cent per cent mortality was recorded at all the concentrations after 72 h.

Table 9. Effect of poison bait containing spinosad (45% SC) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	41.33^{b} (37.67)	64.00^{b} (55.44)	74.67^{b} (64.50)	88.00^{b} (71.44)	100.00^{a} (88.35)
50% of RD	56.00^{b} (49.64)	64.00^{b} (55.44)	82.67^{b} (71.44)	93.33^{b} (76.24)	100.00^{a} (88.35)
75% of RD	77.33^{a} (67.75)	90.67^{a} (78.94)	98.67^{a} (87.00)	100.00^{a} (88.35)	-
Control	0.00^{c} (1.65)	0.00^{c} (1.65)	0.00^{c} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.3.6. Effect of poison bait containing emamectin benzoate (5% SG) on *S. litura*

There was complete mortality of *S. litura* larvae in all the three different concentration of recommended dose within 12 h of exposure (Table 10). Per cent mortality was zero with control.

Table 10. Effect of poison bait containing emamectin benzoate (5% SG) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	100.00[a] (88.35)	-	-	-	-
50% of RD	100.00[a] (88.35)	-	-	-	-
75% of RD	100.00[a] (88.35)	-	-	-	-
Control	0.00[b] (1.65)	0.00[b] (1.65)	0.00[b] (1.65)	0.00[b] (1.65)	0.00[b] (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose).

4.3.7. Effect of poison bait containing flubendiamide (39.35% SC) on *S. litura*

At 12 h significantly higher mortality was obtained when larvae were exposed to baits containing 50 and 75% recommended dose of flubendiamide (table 11). There was an increase in mortality with increase in time period of observations. Per cent mortality was significantly higher over control at the lower concentration evaluated (25 per cent recommended dose) at all the observation intervals. Mortality was a low 8.00 per cent after 12 h, which increased to 25.33 per cent after

24 h, 54.67 per cent after 36 h, 80.00 per cent after 48 h and 97.00 per cent after 72 h.

Per cent mortality increased gradually from 53.33 percent at 24 h to 57.33 per cent at 36 h when larvae were fed with bait containing 50 per cent recommended dose of flubendiamide. A higher per cent mortality of 82.67 per cent and 96.00 per cent was observed after 48 and 72 h at 50 per cent recommended dose.

At the highest dose tested (75 per cent recommended dose), mortality was 28.00 per cent after 12 h and recorded a quantum jump to 65.33 per cent after 24 h. Mortality was 73.33 per cent and 85.33 per cent after 36 h and 48 h of observations. After 72 h 75 per cent recommended dose of flubendiamide gave cent per cent mortality.

Though not significant, mortality was lower (28.00 per cent) at 75 per cent recommended dose when compared to per cent mortality at 50 per cent recommended dose (33.33 per cent). Mortality was a significantly lower 8.00 per cent at 25 per cent recommended dose when compared to mortality at the higher doses. After 24 h per cent mortality was 25.33 per cent, 53.33 per cent and 65.33 per cent at 25, 50 and 75 per cent recommended dose of flubendiamide. With the increase in concentration mortality gradually increased form 54.67 per cent at 25 per cent recommended dose to 57.33 per cent at 50 per cent recommended dose and finally to 73.33 percent at the highest dose of 75 per cent recommended dose of flubendiamide. Though not significant to each other mortality was above 80.00 per cent at all the concentration tested. Per cent mortality was 80.00 per cent, 82.67 per cent and 85.33 per cent after 25, 50 and 75 per cent recommended dose of flubendiamide, respectively. After 72 h, with the increase in concentration from 25 per cent to 50 per cent mortality showed a slight decrease from 97.33 per cent to 96.00 per cent, which was not significant. Hundred per cent mortality was attained at the highest and dose after 72 h.

Table 11. Effect of poison bait containing flubendiamide (39.35% SC) on *S. litura*

Dose	Mortality (%)of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	8.00 b (9.15)	25.33 b (24.93)	54.67 b (48.29)	80.00 a (68.75)	97.33 a (85.66)
50% of RD	33.33 a (27.05)	53.33 a (46.95)	57.33 b (49.84)	82.67 a (71.44)	96.00 a (84.31)
75% of RD	28.00 a (31.30)	65.33 a (56.22)	73.33 a (62.02)	85.33 a (73.56)	100.00 a (88.35)
Control	0.00 b (1.65)	0.00 c (1.65)	0.00 c (1.65)	0.00 b (1.65)	0.00 b (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose).

4.3.8. Effect of poison bait containing chlorantraniliprole (18.5% SC) on *S. litura*

Exposure of *S. litura* larvae to bait formulation containing chlorantraniliprole led to a significantly higher mortality over control at all the time intervals and at different concentrations evaluated. Mortality showed a gradual increase from 8.00 per cent (12 h) to 22.67 per cent (24 h), 44.00 per cent (36 h) and 54.67 per cent (48 h). Complete mortality was attained after 72 h at the lowest dose of 25 per cent recommended dose.

At 50 per cent recommended concentration also, mortality increased gradually from 12 h and reached 100 per cent after 72 h. Per cent mortality recorded 16.00, 29.34, 44.00 and 50.66 per cent after 12 h, 24 h, 36 h and 48 h, respectively.

At 75 per cent recommended dose complete mortality of *S. litura* larvae was achieved by 48 h. At 12 h, 24 h and 36 h of observations, per cent mortality of *S. litura* larvae were 26.66 per cent, 57.33 per cent and 72.00 per cent, respectively.

At the initial observation time of 12 h significantly higher at all the treatment doses over control. Per cent mortality doubled from 8.00 per cent to 16.00 per cent as the dose doubled from 25 per cent recommended dose to 50 % recommended dose. Per cent mortality at the highest dose of 75 per cent recommended dose was 26.66 per cent after 12 h. Per cent mortality after 24 h showed an increasing trend with the increase in concentration. Mortality was 22.67 per cent, 29.34 per cent and 57.33 per cent at 25 per cent, 50 per cent and 75 per cent recommended dose, respectively. Identical per cent mortality of 44.00 per cent was obtained after 36 h at 25 and 50 per cent recommended dose and mortality was 72.00 per cent at the highest concentration tested. Mortality after 48 h of consumption of bait containing chlorantraniliprole was 54.67 per cent and 50.66 per cent at 25 per cent and 50 per cent recommended concentration, respectively. Mortality was complete at the highest dose after 48 h. After 72 h none on of the larvae survived in any of the concentrations evaluated.

Table 12. Effect of poison bait containing chlorantraniliprole (18.5% SC) on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals				
	12 h	24 h	36 h	48 h	72 h
25% of RD	8.00^{bc} (9.72)	22.67^{b} (23.38)	44.00.^{b} (39.80)	54.67^{b} (44.82)	100.00^{a} (88.35)
50% of RD	16.00^{ab} (17.79)	29.34^{b} (28.97)	44.00^{b} (40.93)	50.66^{b} (47.72)	100.00^{a} (88.35)

75% of RD	26.66[a] (26.84)	57.33[a] (50.42)	72.00[a] (61.81)	100.00[a] (88.35)	-
Control	0.00[c] (1.65)	0.00[c] (1.65)	0.00[c] (1.65)	0.00[c] (1.65)	0.00[b] (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose).

4.3.9. Effect of poison bait containing NPV of *Spodoptera litura* on *S. litura*

In the case of microbials, observations were extended for a period of 7 days (168 h). In NPV based bait, there was no mortality in first time interval (12 h) in 25 and 50 per cent of recommended doses (Table 13) while 10.67 per cent mortality was recorded in 75% of recommended dose. After 24 h, significantly higher mortality was observed at 50 and 75 per cent recommended dose, which was 17.33 per cent and 32.00 per cent, respectively. But none of the larvae died at 24 h in the lowest dose (25 % of recommended dose). After 48 h all the three concentrations were significantly superior over control. Per cent mortality was 43.33 per cent, 44.00 per cent and 57.33 per cent at 25 per cent, 50 per cent and 75 per cent recommended dose after 48 h of observation. After 72 h significantly higher mortality of 74.67 per cent was obtained at the highest dose of 75 per cent recommended dose. While at 25 per cent and 50 per cent recommended dose, mortality was 53.33 per cent and 58.67, respectively, which was not significantly different.

By 96 h, complete mortality was achieved at the highest dose tested (75 per cent recommended dose), which was significantly superior over other concentrations and control. Per cent mortality (74.67 per cent) after 96 h at 50 per cent recommended dose was significantly superior over 25 per cent recommended dose and control. Per cent mortality after 96 h of feeding of *Sl* NPV fed diet was

64.00 per cent. After 5 days of observation significantly higher mortality of 96.00 per cent and 100.00 per cent over control and lowest dose (25 per cent recommended dose) was observed at 50 per cent and 75 per cent recommended dose, respectively. At the lowest dose of 25 per cent recommended dose, mortality was 72.00 per cent. Mortality reached cent per cent at both 25 and 50 per cent recommended dose after 144 h.

At the lowest dose of 25 per cent recommended dose, there was no mortality of *S. litura* larvae fed with bait containing *Sl* NPV upto 24 h. Per cent mortality was to 28.00 per cent after 48 h, which showed a gradual increase to 53.33 per cent, 64.00 per cent and 72.00 percent after 72 h, 96 h and 120 h, respectively. All the larvae died after 144 h at 25 per cent recommended dose.

At 50 per cent recommended dose also, there was no mortality of the larvae after 12 h. After 24 h, 36 h, 48 h, 72 h, 96 h, and120 h per cent mortality was 17.33 per cent, 33.33 per cent, 44.00 per cent, 58.67 per cent, 74.67 per cent and 96.00 per cent, respectively. None of the larvae survived after 144 h at 50 per cent recommended dose.

At the highest dose cent per cent mortality of *S. litura* larvae was achieved by 96 h. Per cent mortality was 10.67 per cent, 32.00 per cent, 42.67 per cent, 57.33 per cent and 74.67 per cent after 12 h, 24 h, 36 h, 48 h and 72 h, respectively with *Sl* NPV baits.

Table 13. Effect of poison bait containing *Sl* NPV on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals								
	12 h	24 h	36 h	48 h	72 h	96 h	120 h	144 h	168 h
25% of RD	0.00 [b] (1.65)	0.00 [c] (1.65)	28.00 [b] (29.32)	41.33 [a] (39.94)	53.33 [b] (47.51)	64.00 [c] (54.88)	72.00 [b] (61.81)	100.00 [a] (84.32)	-

50% of RD	0.00^{b} (1.65)	17.33^{b} (19.13)	33.33^{ab} (33.06)	44.00^{a} (40.36)	58.67^{b} (51.19)	74.67^{b} (63.93)	96.00^{a} (84.32)	100.00^{a} (84.32)	-
75% of RD	10.67^{a} (11.84)	32.00^{a} (31.66)	42.67^{a} (39.59)	57.33^{a} (44.82)	74.67^{a} (64.50)	100.00^{a} (88.35)	-	-	-
Control	0.00^{b} (1.65)	0.00^{c} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)	0.00^{c} (1.65)	0.00^{d} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.3.10. Effect of poison bait containing *Bacillus thuringiensis* fed to *Spodoptera litura* larvae at different concentrations

Similar to NPV, the other microbial *Bacillus thuringiensis* also lead to delayed mortality of larvae. After 12 h there was no mortality at the lowest dose (25 per cent recommended dose). Once the dose was increased to 50 per cent recommended dose 5.33 per cent mortality could be achieved, which increased to a significantly higher mortality of 30.67 per cent at 75 per cent recommended dose. After 24 h, significantly higher mortality of 46.67 per cent was achieved at the highest dose of 75 per cent recommended dose. Mortality was 10.67 per cent and 13.33 per cent, respectively at 25 and 50 per cent recommended dose, respectively.

Cent per cent mortality was recorded in treatments 25, 50 and 75 per cent recommended dose at 168 h, 144 h and 96 h respectively (table 14). There was no mortality after 12 h at the lowest dose. In 25 per cent recommended dose less than 50 per cent mortality was observed till 96 h, which increased to almost 100 per cent after 144 h. When larvae were fed with 50 per cent recommended dose of *B. thuringiensis*, mortality increased from 5.33 per cent at 12 h to 100.00 per cent in 144 h. More than half the larvae (64.00%) died at this dose after 72 h. Significantly higher mortality was observed at the highest dose at all the time intervals. Within 36 h, mortality was 53.33 per cent and all the larvae died after 4 days.

Table 14. Effect of poison bait containing *Bacillus thuringiensis* 10% on *S. litura*

Dose	Mortality (%) of *S. litura* at different time intervals								
	12 h	**24 h**	**36 h**	**48 h**	**72 h**	**96 h**	**120 h**	**144 h**	**168h**
25% of RD	0.00^{b} (1.65)	10.67^{bc} (12.41)	14.67^{b} (19.13)	18.67^{c} (21.25)	37.33^{c} (35.39)	42.67^{c} (38.59)	62.67^{b} (54.66)	98.67^{a} (87.00)	100.00^{a} (88.35)
50% of RD	5.33^{b} (7.02)	13.33^{b} (15.10)	38.67^{a} (35.55)	45.33^{b} (40.58)	64.00^{b} (54.88)	78.67^{b} (66.84)	96.00^{a} (84.32)	100.00^{a} (88.35)	100.00^{a} (88.35)
75% of RD	30.67^{a} (28.40)	46.67^{a} (41.92)	53.33^{a} (46.73)	72.00^{a} (57.78)	81.33^{a} (68.75)	100.00^{a} (88.35)	100.00^{a} (88.35)	100.00^{a} (88.35)	100.00^{a} (88.35)
Control	0.0^{b} (1.65)	0.00^{c} (1.65)	0.00^{c} (1.65)	0.00^{d} (1.65)	0.00^{d} (1.65)	0.00^{d} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)	0.00^{a} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.3.11 Mortality of *S. litura* caused by insecticides at different levels

If we compare the insecticides at different time intervals, we can observe that at the shortest time interval of 12 h, complete mortality of larvae could be observed with chlorpyriphos, thiodicarb and emamectin benzoate (Table 15). There was no mortality after 12 h with lambda cyhalothrin, fipronil, *Sl* NPV and *Btk*. Though there was a mortality of 8.00 per cent with the diamide pesticides, flubendiamide and chlorantraniliprole, it was not significant. However, there was a mortality of 41.33 per cent after 12 h with spinosad.

Even after one day no mortality was observed in larvae fed with 25 per cent recommended dose of insecticides with lambda cyhalothrin, fipronil and *Sl* NPV. Mortality was a low 10.67 per cent with *Bt* followed by 25.33 per cent and 22.67 per cent with flubendiamide and chlorantraniliprole, respectively. With spinosad mortality was 64.00 per cent at 24 h of feeding.

Significantly higher mortality of 74.67 per cent was observed with spinosad after 36 h. Mortality caused by flubendiamide and chlorantraniliprole was not significant at an exposure period of 36 h which recorded per cent mortality of 54.67 per cent and 44 per cent respectively. Significantly lower mortality of 8.00, 10.67 and 14.67 per cent was observed with lambda cyhalothrin, fipronil and *Bt.* After 48 h, complete mortality was observed with fipronil. Per cent mortality was 88.00 per cent with spinosad and 80.00 per cent with flubendiamide. Mortality caused by diamide pesticide, chlorantraniliprole (44.00 %) and by *Sl* NPV (41.33 %) was not significantly different. Significantly lower mortality of 22.67 per cent and 18.67 per cent was recorded with lambda cyhalothrin and *Bacillus thuringiensis*, respectively.

Cent per cent mortality was achieved after 5 days with spinosad and chlorantraniliprole. Significantly higher mortality of 97.33 per cent was recorded with flubendiamide bait. Mortality was 53.33 per cent with Sl NPV. Mortality caused by the synthetic pyrethroid lambda cyhalothrin and *Bt* was 37.33 per cent, which was significantly lower.

Table 15. Mortality of *S. litura* at different time intervals at 25 per cent recommended dose of insecticides

Insecticide	Mortality (%) of *S. litura* at different time intervals								
	12 h	**24 h**	**36 h**	**48 h**	**72 h**	**96 h**	**120 h**	**144 h**	**168h**
Chlorpyriphos	100.00[a] (88.35)								
Thiodicarb	100.00[a] (88.35)								

Lambda cyhalothrin	0.00^{c} (1.65)	0.00^{e} (1.65)	8.00^{ef} (9.71)	22.67^{d} (23.94)	37.33^{c} (34.77)				
Fipronil	0.00^{c} (1.65)	0.00^{e} (1.65)	10.67^{ef} (11.84)	100.00^{a} (88.35)					
Spinosad	41.33^{b} (37.67)	64.00^{b} (55.44)	74.67^{b} (64.50)	88.00^{b} (64.50)	100.00^{a} (88.35)				
Emamectin benzoate	100.00^{a} (88.35)								
Flubendiamide	8.00^{c} (9.71)	25.33^{c} (24.93)	54.67^{c} (48.29)	80.00^{b} (68.75)	97.33^{a} (85.66)				
Chlorantraniliprole	8.00^{c} (9.71)	22.67^{c} (23.94)	44.00^{c} (40.36)	54.67^{c} (48.29)	100.00^{a} (88.35)				
NPV	0.00^{c} (1.65)	0.00^{e} (1.65)	28.00^{d} (29.32)	41.33^{c} (37.67)	53.33^{b} (38.24)	64.00^{b} (55.44)	72.00^{b} (61.81)	100.00^{a} (88.35)	
Bt	0.00^{c} (1.65)	10.67^{d} (11.84)	14.67^{e} (19.13)	18.67^{d} (21.25)	37.33^{c} (34.77)	42.67^{c} (39.59)	62.67^{c} (54.66)	98.67^{a} (87.00)	100.00^{a} (88.35)
Control	0.00^{c} (1.65)	0.00^{e} (1.65)	0.00^{f} (1.65)	0.00^{e} (1.65)	0.00^{d} (1.65)	0.00^{d} (1.65)	0.00^{d} (1.65)	0.00^{b} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

At 50 per cent recommended dose also complete mortality was achieved within 12 h with chlorpyriphos, thiodicarb and emamectin benzoate while there was no mortality with lambda cyhalothrin, fipronil, *Sl* NPV and control (Table 16). Spinosad bait caused 56.00 per cent mortality followed by flubendiamide (33.33 per cent), chlorantraniliprole (16.00 per cent) and *Bt* (5.33 per cent).

In lambda cyhalothrin bait 4.00 per cent mortality was recorded after 24 h but, none of the larvae died in the treatment fipronil and control. Significantly lower mortality of 13.33 per cent and 17.33 per cent was observed with *Bt* and *Sl* NPV. Among the two diamide insecticides flubendiamide showed a significantly higher mortality of 53.33 per cent while chlorantraniliprole bait resulted in 29.34 per cent mortality. However, spinosad recorded 64.00 per cent mortality after 24 h.

After 36 h, highest mortality was observed with spinosad (82.67 per cent), followed by flubendiamide (57.33 per cent), chlorantraniliprole (44.00 per cent), *Bt* (38.67 per cent), *Sl* NPV (33.33 per cent), lambda cyhalothrin (22.67 per cent) and fipronil (10.67 per cent).

Within 48 h complete mortality was observed with fipronil. While in spinosad and flubendiamide caused 93.33 per cent and 82.67 per cent mortality. Mortality resulted by lambda cyhalothrin, chlorantraniliprole, *Sl* NPV and *Bt* were 38.67, 50.66, 44.00 and 45.33 per cent, respectively, which were at par with each other.

After 72 h mortality reached 100.00 per cent with chlorantraniliprole and spinosad, while it was 96.00 per cent in flubendiamide, 64.00 per cent in *Bt*, 58.67 per cent in *Sl* NPV and 46.67 per cent in lambda cyhalothrin. With the two microbials *Sl* NPV and *Bt* complete mortality was achieved at 144 h.

Table 16. Mortality of *S. litura* at different time intervals at 50 per cent recommended dose of insecticides

Insecticide	Mortality (%)of *S. litura* at different time intervals								
	12 h	24 h	36 h	48 h	72 h	96 h	120 h	144 h	168h
Chlorpyriphos	100.00^{a} (88.35)								
Thiodicarb	100.00^{a} (88.35)								
Lambda cyhalothrin	0.00^{e} (1.65)	4.00^{ef} (5.68)	22.67^{ef} (23.94)	38.67^{c}	46.67^{c}				
Fipronil	0.00^{e} (1.65)	0.00^{f} (1.65)	10.67^{fg} (11.84)	100.00^{a} (88.35)					
Spinosad	56.00^{b} (49.64)	64.00b (55.44)	82.67^{b} (71.44)	93.33 (76.24)	100.00^{a} (88.35)				
Emamectin benzoate	100.00^{a} (88.35)								
Flubendiamide	33.33^{c} (27.05)	53.33^{b} (46.95)	57.33^{b} (49.84)	82.67^{b} (71.44)	96.00^{a} (84.31)				
Chlorantraniliprole	16.00^{d} (17.79)	29.34^{c} (28.97)	44.00^{cd} (40.36)	50.66^{c} (47.72)	100.00^{a} (88.35)				

NPV	0.00^{e} (1.65)	17.33^{cd} (19.13)	33.33^{de} (33.06)	44.00^{c} (40.36)	58.67^{b} (51.19)	74.67^{b} (64.50)	96.00^{a} (84.32)	100.00^{a} (88.35)	
Bt	5.33^{e} (7.02)	13.33^{de} (15.10)	38.67e (35.55)	45.33^{c} (40.58)	64.00^{b} (55.44)	78.67^{b} (66.84)	96.00^{a} (84.32)	100.00^{a} (88.35)	
Control	0.0^{e} (1.65)	0.00^{f} (1.65)	0.00g (1.65)	0.00d (1.65)	0.00^{d} (1.65)	0.00^{c} (1.65)	0.00^{b} (1.65)	0.00^{b} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

At the highest dose evaluated also the organophosphate (chlorpyriphos), carbamate (thiodicarb) and the avermectin (emamectin benzoate) gave complete mortality within 12 h (Table 17). But there was no mortality with lambda cyhalothrin and fipronil after 12 h. Mortality was 77.33 per cent with spinosad, 30.67 with *Bt,* 28.00 per cent with flubendiamide, 26.66 per cent with chlorantraniliprole and 10.67 per cent with *Sl* NPV.

After 24 h of treatment, the order of toxicity was spinosad (90.67 %) > flubendiamide (65.33 %) > chlorantraniliprole (57.33 %) >*Bt* (46.67 %) > *Sl* NPV (30.00 %) > lambda cyhalothrin (4.00 %). Complete mortality was achieved within 36 h in fipronil which was not significantly different from spinosad (98.67 %). Mortality caused by flubendiamide (73.33 %) and chlorantraniliprole (72.00 %) did not differ significantly. Comparable mortality of 42.67 per cent and 53.33 per cent was observed with *Sl* NPV and *Bt*, respectively. Mortality was a low 24.00 per cent with lambda cyhalothrin.

Within two days chlorantraniliprole and spinosad gave complete mortality at the highest dose. This was followed by flubendiamide (85.33%) and that of *Bt* (72.00 %), *Sl* NPV (57.33 %) and lambda cyhalothrin (41.33 %).

After 72 h also, the pyrethroid lambda cyhalothrin, gave only 52.00 per cent mortality while *Sl* NPV and *Bt* gave a better mortality of 74.67 per cent and 81.33 per cent, respectively. Within 96 h *Sl* NPV and *Bt* also gave complete mortality of *S. litura* larvae.

Table 17. Mortality of *S. litura* at different time intervals at 50 per cent recommended dose of insecticides

Insecticide	Mortality (%)of *S. litura* at different time intervals					
	12 h	**24 h**	**36 h**	**48 h**	**72 h**	**96 h**
Chlorpyriphos	100.00^{a} (88.35)					
Thiodicarb	100.00^{a} (88.35)					
Lambda cyhalothrin	0.00^{d} (1.65)	4.00^{e} (5.68)	24.00^{d} (25.85)	41.33^{e} (38.24)	52.00^{c} (45.60)	
Fipronil	0.00^{d} (1.65)	32.00^{d} (32.79)	100.00^{a} (88.35)			
Spinosad	77.33^{b} (67.75)	90.67^{a} (78.94)	98.67^{a} (87.00)	100.00^{a} (88.35)		
Emamectin benzoate	100.00^{a} (88.35)					
Flubendiamide	28.00^{c} (31.30)	65.33^{b} (56.22)	73.33^{b} (62.02)	85.33^{b} (73.56)	100.00^{a} (88.35)	
Chlorantraniliprole	26.66^{c} (26.84)	57.33^{b} (49.84)	72.00^{b} (61.81)	100.00^{a} (88.35)		
NPV	10.67^{d} (11.84)	32.00^{c} (31.66)	42.67^{c} (39.59)	57.33^{d} (49.84)	74.67^{b} (64.50)	100.00^{a} (88.35)
Bt	30.67^{c} (28.40)	46.67^{cd} (41.92)	53.33^{c} (46.95)	72.00^{c} (57.78)	81.33^{b} (68.75)	100.00^{a} (88.35)
Control	0.00^{d} (1.65)	0.00^{e} (1.65)	0.00^{e} (1.65)	0.00^{f} (1.65)	0.00^{d} (1.65)	0.00^{b} (1.65)

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

4.4. Evaluation of poison baits in field

Five superior insecticides selected from the laboratary experiment such as thiodicarb 75% WP (25% of RD), chlorpyriphos 20% EC (25% of RD), emamectin benzoate 5% SG (25% of RD), fipronil 5% SC (75 % of RD), spinosad 45% SC (75 % of RD) were evaluated in field for their efficacy along with a control (unpoisoned bait) and absolute control (without any bait). Leaf area consumption was recorded after 10 days of release of larvae. Leaf area was assessed using leaf area meter.

Among the seven treatments, in emamectin benzoate baited plots, leaf area consumed was least (2.95 sq.cm/5 plants/plot) after 10 days of treatment (Table 18) followed by thiodicarb bait (8.44 sq.cm/5 plants/plot), chlorpyriphos bait (12.38 sq.cm/5 plants/plot), fipronil bait (12.69 sq.cm/5 plants/plot) and spinosad bait (30.61 sq.cm/5 plants/plot). All the plots with insecticide treated baits were significantly superior over control and absolute control, in reducing the leaf area consumption. There was high infestation of leaves (540.56 sq. cm/5 plants/plot) in plots where baits were not used. Though not significant over absolute control, leaf area consumption was lower in control plots, where unpoisoned baits were used.

Table 18. Leaf area consumption by *S. litura* in different poison baits

Treatments (Baits)	Leaf area consumption (sq.cm)
T_1 : Thiodicarb	8.44^{b}
T_2 : Chlorpyriphos	12.38^{b}
T_3 : Emamectin benzoate	2.95^{b}
T_4 : Fipronil	12.69^{b}
T_5 : Spinosad	30.61^{b}
T_6 : Control (without poison)	316.67^{a}
T_7 : Absolute control (without bait)	540.56^{a}

(In a column, per cent mortality followed by a common letter are not significantly different at 5% level. Means were separated by Tukey's test. Values in parenthesis are arcsine transformed values. RD = recommended dose)

Discussion

5. DISCUSSION

The study was carried out to identify a potential poison bait formulation for the management of *Spodoptera litura*. Before identification of an ideal poison bait, efforts were made to identify the superior combination of base material along with a phagostimulant. The results thus obtained is discussed in this chapter based on the previous studies carried out using bait formulation for the management of lepidopteran insect pests.

5.1. Identification of base material for the preparation of base materials

Various base materials were evaluated by different scientists for the preparation of poison baits. In this study, different commonly available brans such as rice bran, maize bran and wheat bran along with jaggery and water were tested in various proportions. Various proportions of bait material were tried by different authors such as 12.5:1:2 rice or wheat bran, jaggery, water (Hiremath. *et.al.,*1990), 12.5:1.25:1 rice bran, jaggery and water (Basavaraju, *et.al.,* 2010) 8:2, rice bran and jaggery (Viswanadham et.al., 1986) and 4:1:2 rice bran, jaggery and water (Sreedhar and Nageswararao, 2016). We had evaluated various bran material, jaggery and water in three proportions *viz*., 12.5:1:1, 12.5:1:2 and 4:1:4.

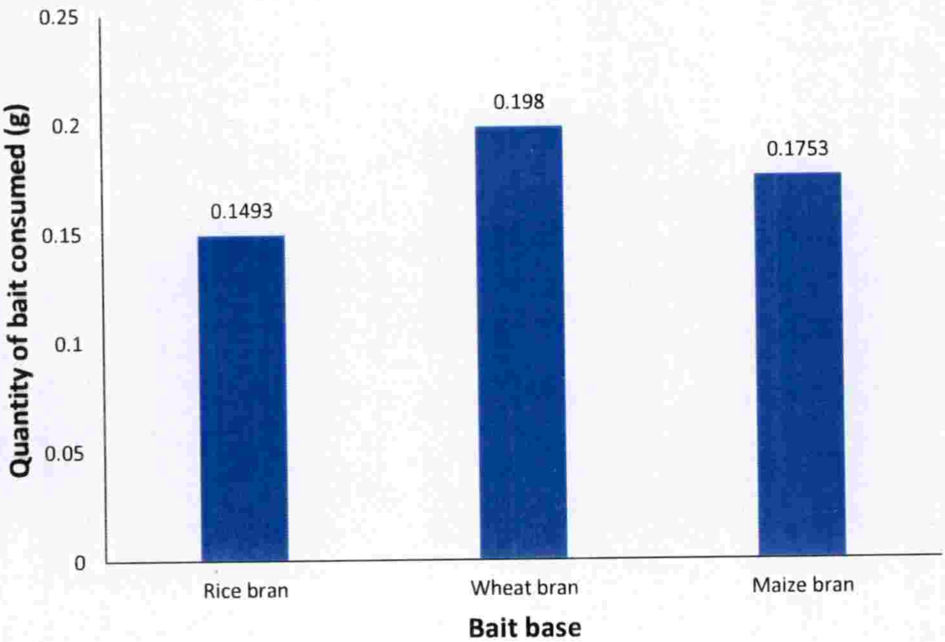
Cannibalism was observed when bran and jaggery was mixed in the ratio 12.5:1:1 and 12.5:1:2. The bait prepared in the ratio 4:1:4 was accepted to *S.litura* larvae which is similar to the results from experiments conducted by Viswandham *et.al.,* (1986).

Increase in proportion of jaggery was found to improve the acceptance of bait material as 4:1:4 proportion of bran, jaggery and water was acceptable by the larvae and there was no cannibalism. Jaggery, a proven phagostimulant to insects (Dhandapani *et al.,* 1993; Singh and Battu, 2006 and Doddabasappa *et al.,* 2013) might have attracted the larvae to the bait (Abdul Kareem and Viswanadham, 1980; Sreedhar and Nageswararao, 2016; Basavaraju *et.al.,* 2010; Hiremath *et.al.,* 1990 and Renju *et.al.,* 2009) and the results were in agreement with the studies of Viswanadham *et al*., (1986). Similar results, as in the present study, significantly higher number of *S. litura* larvae were attracted to bait containing 20 per cent jaggery in rice bran in comparison to bait containing 10% jaggery, molasses 20 per cent, yeast (0.1 and 0.2 per cent) and agar (Muddasar *et al.*, 2017). Jaggery was added to bait as a phagostimulant in several studies. Molasses was also used as an attractant in baits by Jayaraj (1983) and Davis and Turner (1918). Sugars like sucrose, maltose, D-fructose, D-glucose and raffinose were found to have phagostimulatory effect to *Spodoptera littoralis* (Meisner *et al.*, 1972).

Increasing the moisture content of bait was found to be superior in current investigation, similar to the work of Viswanadham *et al.,* (1986). Significantly higher number of *A. ipsilon* larvae were found to be attracted to wet baits over dry baits (Gholson and Showers, 1979). Palatability and consumption was significantly higher when wheat bran with higher moisture content was used as bait against cutworms *A. ipsilon* (Martin, 1980). In the present investigation also, moist baits attracted more larvae. Preparation of extremely dry baits without enough moisture might reduce the palatability of bait.

Among the various bran evaluated for the preparation of bait, wheat bran found superior over rice bran and maize bran, in the present study (Fig. 2). Viswanadham *et al.,* (1986) evaluated rice coarse husk, rice bran, ragi flour, jowar flour, horse gram flour, bajra flour and powdered ground nut shells mixed in different proportions and found out rice bran and jaggery in 8:2 ratio as superior and effective proportion of bait material. Rice bran was utilised for poison baiting in most of the studies conducted in our country (Abdul Kareem and Viswanadham, 1980; Jayaraj, 1983; Viswanadham *et al.,* 1986; Jayaram *et al.,* 2007; Renju *et al.,* 2008; Basavaraju *et al.,* 2010; Shankaragouda *et al.,* 2015; Sreedhar and Nageswararao, 2016 and Muddasar *et al.,* 2017). But Hiremath *et al.,* (1990) recommended either rice bran or wheat bran for the preparation of baits. The studies cited above were not conducted as a comparative study on the effectiveness of various bran for the preparation of baits. However, Parasuraman *et al.*, (1985) had evaluated rice bran and wheat flour for preparation of bait with different concentration of molasses as phagostimulant. Wheat flour with 20 per cent

Fig. 2: Consumption of bait (g) by *S. litura* after 48 h



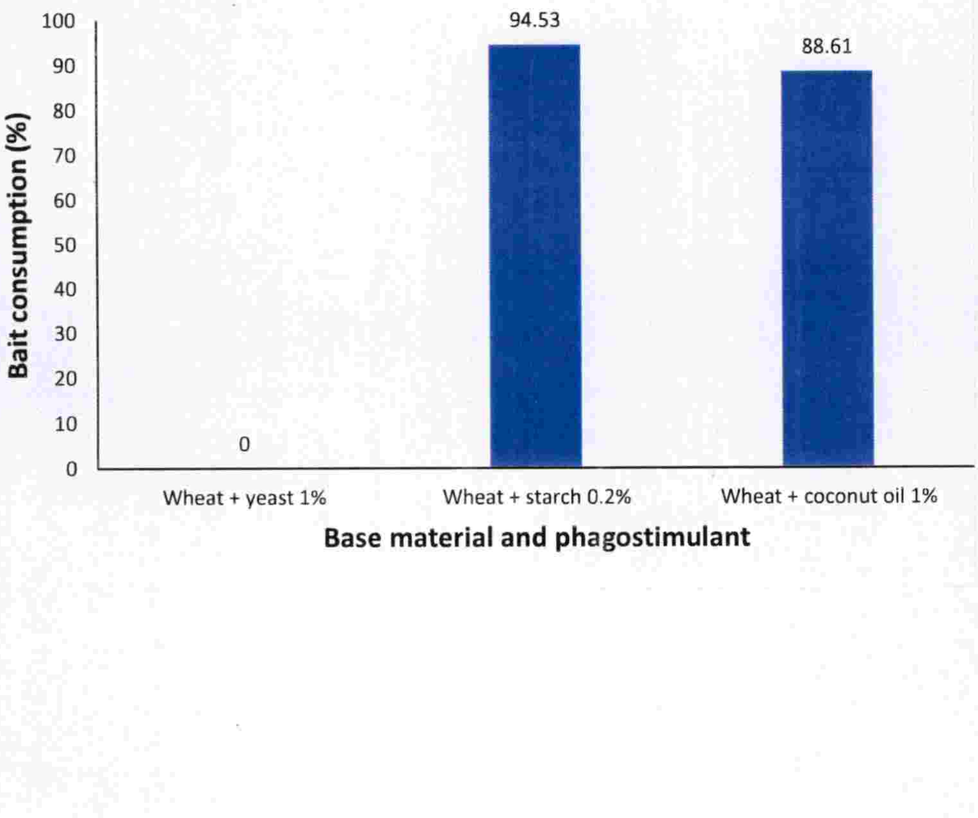
molasses was superior in attracting and maintaining the larvae in baits, where in, wheat bran was the superior base material in the present investigation.

Martin (1980) evaluated wheat bran, kibbled wheat and corn flour as the base material for the preparation of bait against *A. ipsilon* and found wheat bran was more palatable. Martin (1980) hypothesised that, the increased acceptability of wheat bran might be due to its shape or crushed nature of grain. Wheat bran as chosen for the preparation of bait for the management of armyworms in wheat (Dhams and Fenton, 1942), cut worms in tobacco (Turner, 1950) and mole crickets, greasy cut worms and grasshoppers in various crops (Barbara and Capinera, 2008). As the efficacy of any bait depended upon the palatability of various bait components, it became imperative to assess various commonly available materials like bran for their phagostimulatory effect, palatability and effectiveness (Barbara and Capinera, 2003). Hence, our study had identified wheat bran as the most accepted base material over the commonly used rice bran.

Addition of phagostimulants could increase the consumption rate and thereby increases the mortality of insects (Luna-Santillana *et al.*, 2011). In order to further improve the consumption and palatability of bait, yeast 1 per cent, starch 0.2 per cent and coconut oil 1 per cent was added to wheat bran based bait. Addition of starch 0.2 per cent, almost doubled the consumption of bait over bait without phagostimulant (Fig. 3). Addition of coconut oil also significantly improved the consumption of bait, while there was no difference in consumption of bait upon addition of yeast (1%). Addition of corn starch to formulations containing *Bacillus thuringiensis* was found to increase insect feeding response of lepidopterous larvae (Dunkle and Shasha 1988; Bartelt *et al.* 1990; McGuire *et al.* 1990, 1996; McGuire and Shasha 1990, 1992; Gillespie *et al.* 1994; Ridgway *et al.*, 1996; Tamez-Guerra *et al.* 1996 and Rosas-Garcia *et. al.* 2009), confirming the phagostimulant effect of starch to lepidopteran larva.

Yeast extract was added to stimulate feeding of *Earias insulana* larvae to a bait containing *B. thuringiensis* (Navon *et. al.*, 1997). Muddasar *et al.*, 2017, evaluated jaggery, molasses, yeast and agar at different levels and found that

Fig. 3: Effect of phagostimulants on bait consumption by *S. litura*



addition of jaggery (20%) and molasses (10%) were superior over yeast and agar. Addition of yeast was not found to increase the consumption of rice bran based diet, similar to the current findings.

Lasa *et. al.,* (2009) evaluated vegetable oil (1%), starch (0.2%) and yeast (1%) as phagostimulants with *Spodoptera exigua* NPV. Though yeast was found to be superior over vegetable oil and starch, as a phagostimulant, its effectiveness disappeared when larvae were reared on lettuce, which revealed that the influence of previous dietary experience of the insect on the attractiveness of the phagostimulant. So selection of phagostimulant should be done after thorough understanding of the feeding pattern of the pest. Addition of starch, pregelatinized flour, ground maize cob, maize oil and water to a nucleopolyhedrovirus formulation was found to enhance the phagostimulant effect to *Spodoptera frugiperda* in maize (Castillejos *et al.*, 2002). Corn oil, cotton seed oil and soybean oil were used as phagostimulants in baits to various lepidopterous larvae *viz., Ostrinia nubilalis, Heliothis* spp. and *Spodoptera littoralis* (Ave, 1995). Addition of coconut oil, which significantly enhanced the feeding by *S. litura* larva could be due to the phagostimulant action of vegetable oils.

5.2. Laboratory evaluation of poison baits against *Spodoptera litura*

Once the bait material was standardised, pesticides were evaluated in baits at three levels *viz.,* 25, 50 and 75 per cent of their recommended dose. Eight chemical pesticides belonging to different groups such as organophosphate (chlorpyriphos), carbamate (thiodicarb), synthetic pyrethroid (lambda cyhalothrin), phenyl pyrazoles (fipronil), avermectins (emamectin benzoate), spinosyns (spinosad), phthalic diamide (flubendiamide) and anthranilic diamide (chlorantraniliprole); two microbials, *Sl* NPV and *B. thuringiensis* var. *kurstaki* were evaluated. Per cent mortality was recorded after 12, 24, 36, 48 and 72 h for chemical insecticides and up to 7 days for microbials.

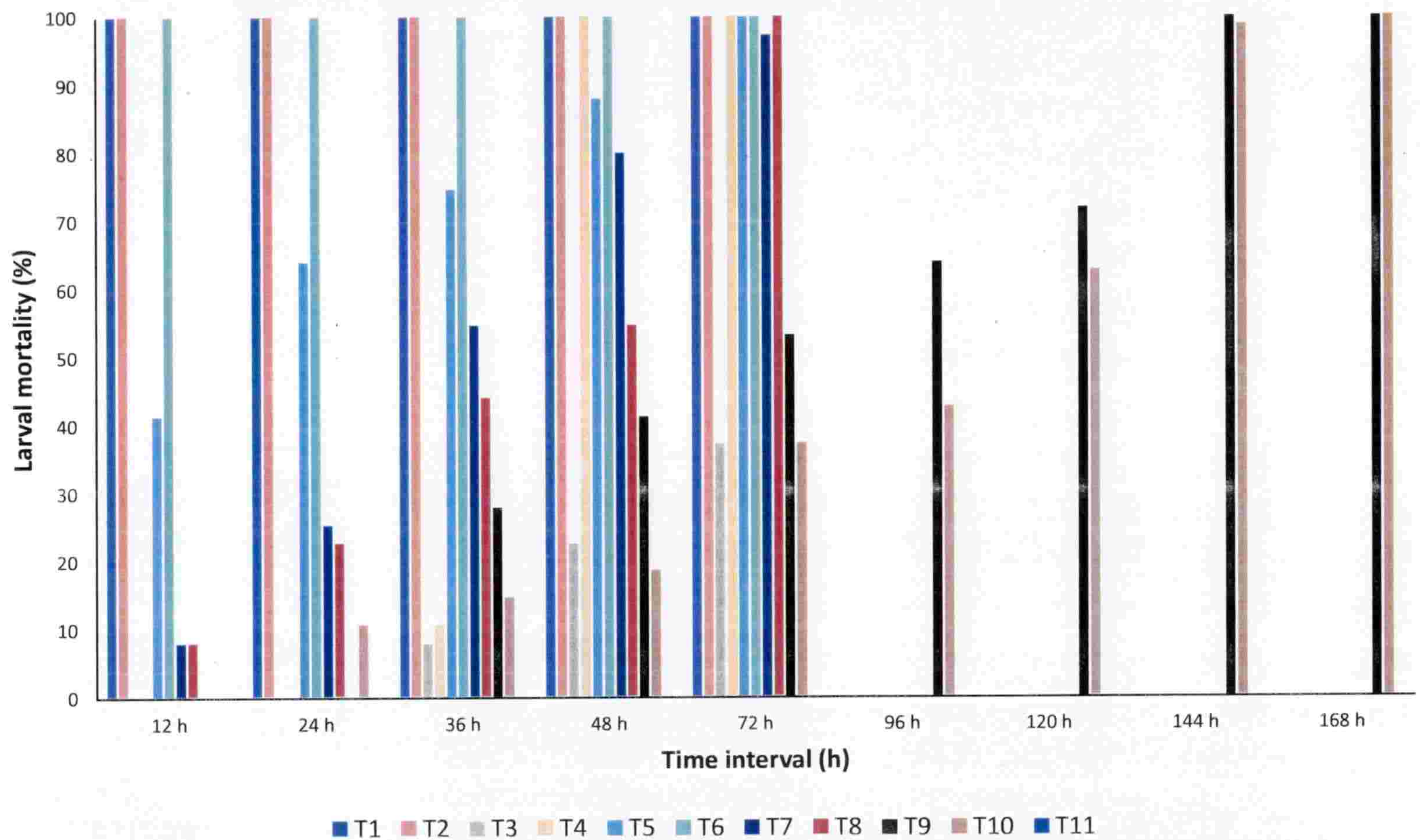
At the lowest dose of 25 per cent recommended dose, chlorpyriphos, thiodicarb and emamectin benzoate gave cent per cent mortality within 12 h (Fig. 4). Viswanadham *et al.,* (1986), evaluated monocrotophos, carbaryl, quinalphos, chlorpyriphos and endosulfan at different concentrations against fifth instar *S. litura* larvae. Consumption of chlorpyriphos poisoned diet lead to 100 per cent mortality of the larvae within 48 h at 1.0, 1.5 and 2.0 per cent concentration. As six day old larvae were used in the present investigation complete mortality could be observed within 12 h. Older larvae might be more tolerant to pesticides, as was evident from the study by Sammour *et. al.*, 2017, where mortality of fourth instar *S. littoralis* larvae fed with chlorpyriphos lead to lower mortality in comparison with second instar larvae.

The carbamate insecticide thiodicarb, which also gave complete mortality within 12 h (Table 19), primarily due to its stomach action with moderate contact toxicity (Sousa *et al.*, 1977). Foliage treated with thiodicarb fed to fall armyworm *S. frugiperda* lead to >95 per cent mortality within 3 h (Marenco *et. al.,* 1991), similar to the results obtained in the current study.

Table 19. Time taken to achieve complete mortality of *Spodoptera litura* larvae at different concentrations of poison baits

Treatment	**Time taken (h) for 100 per cent mortality of *S. litura***		
	25 % RD	**50 % RD**	**75 % RD**
T1: Bait + Chlorpyriphos 20% EC	**12 h**	12 h	12 h
T2: Bait + Thiodicarb 75% WP	**12 h**	12 h	12 h
T3: Bait + Lambda cyhalothrin 5% EC	-	-	-
T4: Bait + Fipronil 5% SC	48 h	48 h	**36 h**
T5: Bait + Spinosad 45% SC	72 h	72 h	**48 h**
T6: Bait + Emamectin benzoate 5% SG	**12 h**	12 h	12 h
T7: Bait + Flubendiamide 39.35%SC	-	-	72 h
T8: Bait + Chlorantraniliprole 18.5% SC	72 h	72 h	48 h

Fig. 4: Effect of pesticides in bait (25% of recommended dose) on *S. litura*



T1 = Chlorpyriphos, T2 = Thiodicarb, T3 = Lambda cyhalothrin, T4 = Fipronil, T5 = Spinosad, T6 = Emamectin benzoate, T7 = Flubendiamide, T8 = Chlorantraniliprole, T9 = *Sl* NPV, T10 = *Bacillus thuringiensis*, T11 = Control

T9: Bait + NPV of *S. litura* 0.5% AS	144 h	144 h	96 h
T10: Bait + *Bacillus thuringiensis* 10%	168 h	144 h	96 h
T11: Control (Bait)	-	-	-

Another insecticide which gave cent per cent mortality within 12 h was emamectin benzoate (Table 19), an avermectin acting on the gamma amino butyric acid gated chloride channels. As in the current study, ingestion of a diet with 0.5 mg/L a.i. of emamectin benzoate resulted in 100 per cent mortality of second instar *S. exigua* larvae (Bengochea *et al.*, 2014).

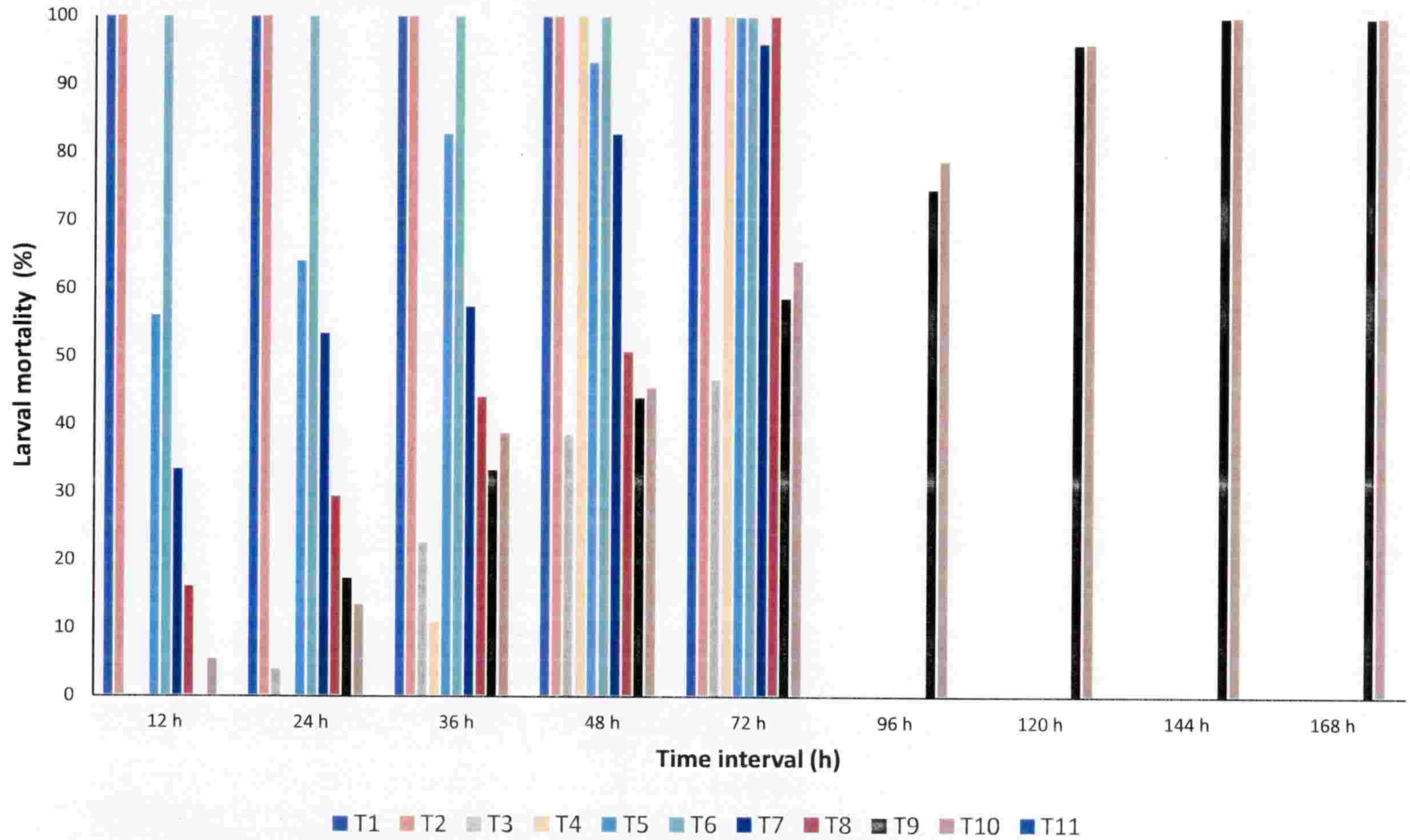
Consumption of bait containing phenyl pyrazole insecticide fipronil led to 100 per cent mortality in 36 h (Table 19) at 75 per cent recommended dose (fig. 6) and after 48 h at 25 and 50 per cent recommended dose (Fg. 4 and 5). The findings that toxicity of fipronil was less compared to emamectin benzoate against *S. exigua*, *Heliothis virescens*, *P. xylostella* and *Trichoplusia ni* (Argentine *et al.*, 2002) confirm the results obtained in the present study.

Spinosad, fermentation product of *Saccharopolyspora spinosa*, when formulated as a poison bait, resulted in complete mortality of *S. litura* larvae within 3 days at 25 and 50 per cent recommended dose (Fig. 5 and 6). While, at the highest dose, cent per cent mortality could be achieved within 48 h (Table 19). Wang *et. al.*, (2009), while studying the susceptibility of *H. armigera* in China to spinosad, reported that LC_{50} values were lower after 72 h than after 48 h of exposure, similar findings were recorded in the present study also. Leaf dip bioassay of *S. litura* larvae with spinosad gave an LT_{50} value of 33.6 h, which is almost nearer to the current findings (Ahmad *et. al.*, 2006).

Mortality was delayed in two diamide insecticides, flubendiamide and chlorantraniliprole, upon exposure to poisoned baits. At the lowest two doses, flubendiamide could not achieve cent per cent mortality within 3 days (fig. 4 and 5), while mortality was 100 per cent in chlorantraniliprole within 72 hours at these two doses (Table 19). At 75 per cent recommended dose, chlorantraniliprole gave complete mortality within 48 hours, while flubendiamide gave complete mortality

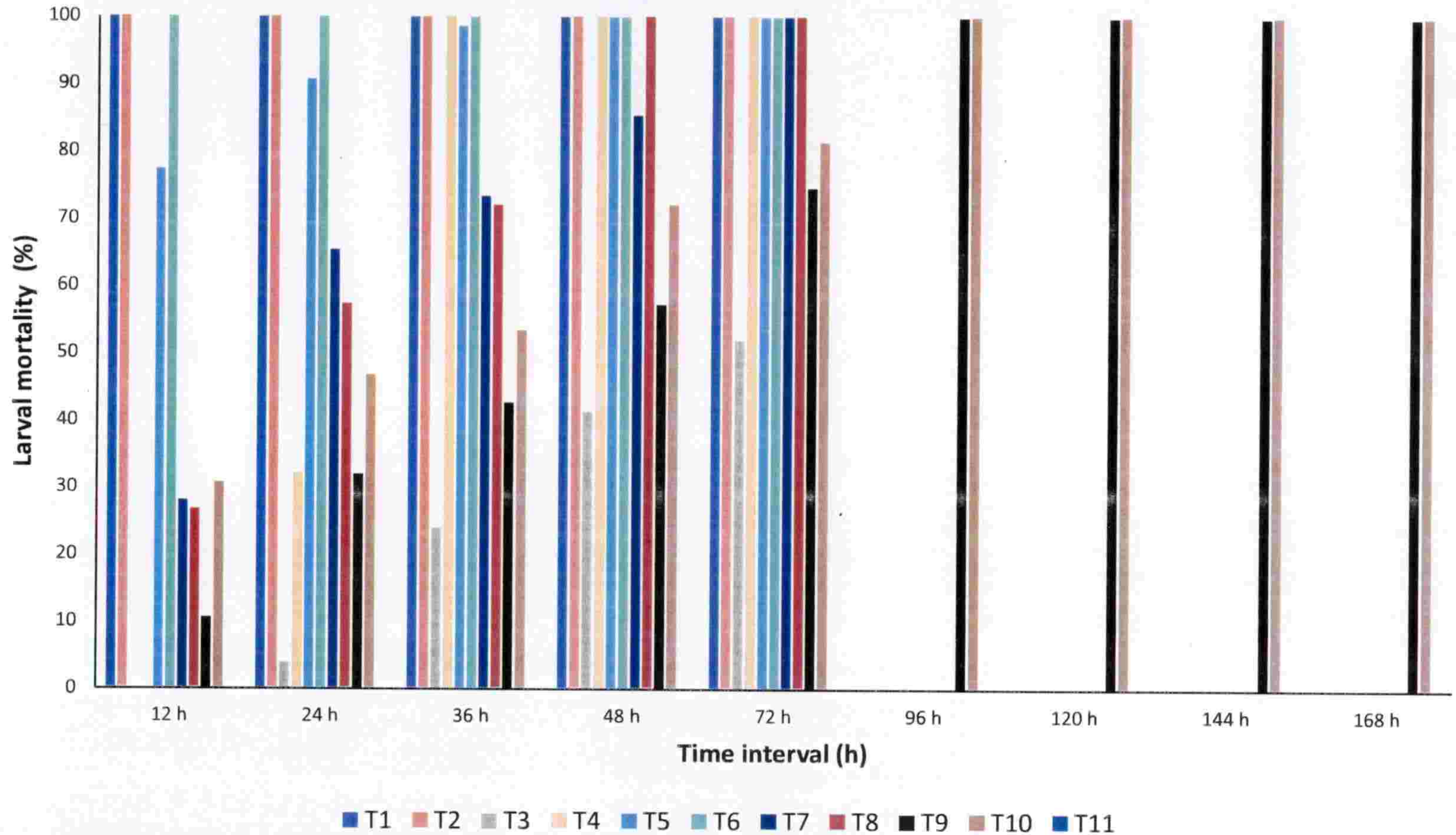
70

Fig. 5: Effect of pesticides in bait (50% of recommended dose) on *S. litura*



T1 = Chlorpyriphos, T2 = Thiodicarb, T3 = Lambda cyhalothrin, T4 = Fipronil, T5 = Spinosad, T6 = Emamectin benzoate, T7 = Flubendiamide, T8 = Chlorantraniliprole, T9 = *Sl* NPV, T10 = *Bacillus thuringiensis*, T11 = Control

Fig. 6: Effect of pesticides in bait (50% of recommended dose) on *S. litura*



T1 = Chlorpyriphos, T2 = Thiodicarb, T3 = Lambda cyhalothrin, T4 = Fipronil, T5 = Spinosad, T6 = Emamectin benzoate, T7 = Flubendiamide, T8 = Chlorantraniliprole, T9 = *Sl* NPV, T10 = *Bacillus thuringiensis*, T11 = Control

within 72 h. Activity of flubendiamide was low when compared to chlorantraniliprole when tested against *H. armigera* (Vivan *et. al.*, 2016) and did not cause 100 per cent mortality of second, third and fourth instar larvae of *H. armigera*. Consumption of flubendiamide and chlorantraniliprole based diet by larvae would lead to immediate cessation of feeding due to muscular paralysis, but mortality of larvae occurred only after 1-3 days (Lahm *et al.*, 2009). When chlorantraniliprole was used against brinjal shoot and fruit borer, *Leucinodes orbonalis*, LT_{50} was 5.00 days, showing delayed mortality with chlorantraniliprole (Sharma *et al.*, 2018).

Among the chemical pesticides evaluated, the synthetic pyrethroid lambda cyhalothrin gave comparatively the poorest response (Table 19). Though an excellent contact poison, mortality could not be recorded at any of the doses of pyrethroid evaluated after 12 h (Fig. 4, 5 and 6). Even after 72 h, at the highest dose evaluated, mortality reached 52.00 per cent only. However, insect repellent and antifeedant effects of synthetic pyrethroids were widely recorded (Ruscoe, 1977; Hall, 1989; Tan, 1981; Gist and Pless, 1985 and Blair, 1991). Gist and Pless (1985) evaluated nine synthetic pyrethroids and all were found to be effective feeding deterrents at 50 ppm. Lambda cyhalothrin was found to have repellent or antifeedant properties at any concentration against *A. segetum* in tobacco (Blair, 1991). Time for feeding cessation by *S. exigua* was a mere 5.4 min with lambda cyhalothrin, revealing its antifeedant activity (Hannig *et al.,* 2009). The antifeedant and repellent properties of lambda cyhalothrin may be the reason for reduced mortality of *S. litura* in our study. Potential insecticide candidates for poison baits must be an excellent stomach poisons without any antifeedant and repellent effect.

Providing *Sl* NPV as poison bait to *S. litura* did not cause any appreciable mortality up to 24 h at any of the concentrations evaluated. But, by 96 h, cent per cent mortality could be observed at 75 per cent recommended dose and 144 h at the lower two doses (Fig. 4, 5 and 6). Vivan *et al.,* (2017) recorded lower mortality of *H. armigera*, when fed with diet coated with NPV as the larval age increased.

Fourth and fifth instar larvae fed with NPV-treated diets exhibited 100 per cent survival, while mortality was low with third instar larvae.

Bacillus thuringiensis was superior or at par with NPV at the highest two doses evaluated. Similar to NPV, mortality was low during initial observation intervals. Mortality reached 100 per cent in 96 h at the highest two doses, while at the lowest dose of 25 per cent recommended dose, cent per cent mortality could be achieved within 144 h only (Table 19). Mean per cent mortality of second instar lavae of *H. armigera* exposed to *B. thuringiensis aizawai* was 50.00 after 72 h (Aggarwal *et. al.*, 2006), similar to the results obtained in the present study.

Seventeen insecticides including *Bt* and NPV were evaluated against different instars of *H. armigera* as diet feeding bioassay. Chemical pesticides included flubendiamide, chlorpyriphos, chlorantraniliprole, spinosad and thiodicarb, which were included in our study also (Vivan *et. al.,* 2017). Of these insecticides tested, thiodicarb, chlorantraniliprole and chlorpyriphos led to 100 per cent mortality within 48 h, similar to the present study where, low mortality obtained with flubendiamide in the current study was observed in the study by Vivan *et al.*, (2017). Both the microbials *Bt* and NPV, resulted in significant mortality of *H. armigera* larvae at the early instars only (Vivan *et. al.,* 2017).

Extremely high mortality of *S. litura* larvae was observed in leaf dip bioassay with emamectin benzoate in comparison to chlorantraniliprole. Ten-day old *S. litura* larvae did not show any mortality when fed with chlorantraniliprole (Thodsare and Srivastava, 2014). These results confirm our findings, where emamectin benzoate was the superior poison bait.

Third instar larvae of *H. armigera* was fed with insecticides like *Bt,* chlorantraniliprole, chlorpyriphos, flubendiamide, lambda cyhalothrin and spinosad at three different doses. After five days, 100 per cent mortality could be observed at the lower dose tested for each insecticides *viz.,* chlorpyriphos, spinosad, flubendiamide and fipronil but mortality was low with lambda cyhalothrin and chlorantraniliprole (Carneiro *et. al.,* 2014).

Field collected *S. litura* larvae were used for leaf disc bioassay against insecticides like chlorpyriphos, spinosad, emamectin benzoate and fipronil and LT_{50} was calculated. LT_{50} was lowest with emamectin benzoate (21.8 h) followed by chlorpyriphos (22.5 h), fipronil (29.4 h) and spinosad (33.6) (Ahmad *et. al.*, 2006). In the current study, emamectin benzoate and chlorpyriphos caused cent per cent mortality, while fipronil caused 32.00 per cent and spinosad caused 90.67 per cent mortality at the highest dose after 24 h. The slight difference in toxicity of spinosad and fipronil could be due to the difference in susceptibility of the field collected larvae, used by Ahmad *et. al.*, (2006) to these pesticides.

Leaf dip bioassay of *S. litura* revealed higher toxicity of emamectin benzoate (LC_{50} – 0.0000175) over spinosad (LC_{50} – 0.025) and flubendiamide (LC_{50} – 0.0312). While, topical application resulted in lower toxicity of emamectin benzoate (LC_{50} – 0.01024), spinosad (LC_{50} – 20.56) and flubendiamide (LC_{50} – 0.1249). The difference in toxicity by two methods of bioassay confirmed emamectin benzoate, spinosad and flubendiamide as excellent stomach poisons (Sharma and Pathania, 2014). The time for feeding cessation of *S. exigua* was 5.4 min, 25.3 min and 139 min for lambda cyhalothrin, chlorantraniliprole and emamectin benzoate (Hannig *et. al.*, 2009). For a poison bait to be effective, there should be greater time of feeding of bait while reduced feeding could lead to decreased mortality of the larvae. The increased feeding duration of emamectin benzoate could be correlated with superior toxicity of emamectin benzoate obtained in our study.

Rice bran based bait with spinosad and lambda cyhalothrin could not lead to complete mortality of *Mythimna separata* in 25 and 50 per cent recommended dose of insecticide. While, chlorpyriphos bait resulted in cent per cent mortality at 50 and 75% recommended dose after 48 and 72 h respectively (Renju *et al.,* 2009). Complete mortality of larvae, even at the lowest dose, with chlorpyriphos in the present study could be due to the use of a more preferred base material (wheat bran) as base material with starch as phagostimulant.

Shankaragouda *et al.,* (2015) evaluated insecticides like lambda cyhalothrin, profenophos, chlorpyriphos, novaluron, methoxyfenozide, indoxacarb, chlorfenapyr, fipronil, spinosad, chlorantraniliprole and monocrotophos in rice bran based poison baits against *S. litura*. Among the various insecticides evaluated cent per cent mortality was observed only with chlorpyriphos and chlorfenapyr. Complete mortality with chlorpyriphos was obtained only after 72 h of feeding. Fipronil, spinosad and chlorantraniliprole could not achieve cent per cent mortality, even at the recommended dose, after 72 h of observation. The deviation of the current study with that of Shankaragouda *et. al.,* (2015) could be due to the difference in base material selected and also due to absence of any phagostimulant. Significantly higher consumption of bait with wheat bran base over rice bran base was recorded in the present investigation and the addition of starch (0.2%) as a phagostimulant was found to increase the consumption of bait by almost two folds. Increased consumption of base material would increase the toxicity of stomach poisons also.

5.3. Field evaluation of poison baits for the management of *Spodoptera litura*

Five poison baits with insecticides *viz.,* chlorpyriphos, thiodicarb, emamectin benzoate, fipronil and spinosad were selected for field evaluation. Chlorpyriphos, thiodicarb and emamectin benzoate were evaluated at 25 per cent recommended dose and fipronil and spinosad were evaluated at 75% recommended dose. Significantly lower consumption of leaf area was obtained with all five poison baits in comparison with unpoisoned bait control and absolute control.

Calculation on the per cent decrease leaf area consumption over control, it was observed that, there was 99.07 per cent reduction in leaf area consumption with emamectin benzoate bait in cowpea plots (Table 20). Per cent decrease in leaf area consumption over control in thiodicarb baited plots was 97.33 per cent. In chlorpyriphos baited plots, the decrease in leaf area consumption was 96.09 per cent. Per cent decrease in leaf area consumption over control was 95.99 per cent and 90.33 per cent with fipronil bait and spinosad bait, respectively.

Rice bran based bait containing emamectin benzoate, *Sl* NPV, *B. thuringiensis var. kurstaki*, novaluron, lufenuron and chlorpyriphos were evaluated for three seasons in flue cured Virginia (FCV) tobacco against leaf eating caterpillar, *S. litura*. Comparable to the present study mean number of leaves damaged and per cent leaf area damaged were lowest in fields baited with emamectin benzoate (Sreedhar and Nageswararao, 2016). Per cent leaf damage was not significantly different between emamectin benzoate poison bait and chlorpyriphos bait, which was the case with current study. Leaf area damage was highest with baits containing the microbials *Sl* NPV and *Bt kurstaki.*

Table 20. Effect of poison baits on defoliation by *S. litura* in cowpea

Treatments (Baits)	Reduction in leaf area consumption (%)
T_1 : Thiodicarb	97.33
T_2 : Chlorpyriphos	96.09
T_3 : Emamectin benzoate	99.07
T_4 : Fipronil	95.99
T_5 : Spinosad	90.33

Mean per cent damage of potato by cutworm *A. ipsilon* was lowest with a bait containing dipterex, sugar and rice husk in potato fields of Pakistan (Shakur *et al.*, 2007). It was suggested to apply poison baits for the management of cutworm in potato because of its effectiveness and safety, even though it was labour intensive.

In comparison with foliar spray of insecticides, a rice bran based bait containing monocrotophos was inferior in managing *Agrius convolvuli* in green gram (Jayaram *et al.*, 2007). Monocrotophos and chlorpyriphos baits prepared in rice bran and jaggery resulted in significantly higher mortality of *M. separata* in sorghum fields (Renju *et al.*, 2009). Chlorpyriphos was a superior bait in present field studies.

Damage of spinach leaves by *S. litura* was lowest with two bait formulations containing molasses or jaggery with spinosad in comparison with malathion and quinalphos (Muddasar *et al.*, 2017). Spinosad was a superior bait in reducing leaf damage of cowpea in the present study too.

The present study could identify a potent wheat bran based poison bait with starch (0.2%) as phagostimulant in combination with 25 per cent recommended dose of chlorpyriphos or thiodicarb or emamectin benzoate or 75 per cent recommended dose of fipronil or spinosad. Use of poison baits could significantly reduce the defoliation by *S. litura* in cowpea.

Summary

6. Summary

The purpose of the research entitled "Insecticide based bait formulation against tobacco caterpillar *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)" was to identify an effective poison bait for the management of *Spodoptera litura*. In order to achieve this objective, base material for the preparation of poison bait was standardised in the first experiment. Three different bait proportions were evaluated *viz.,* 12.5:1:1, 12.5:1:2 and 4:1:4, base material, jaggery, and water. The base material evaluated was commonly available bran materials such as rice bran, wheat bran and maize bran. The bait composition, 4 parts of base material, 1 part of jaggery and 4 parts of water was found to be the best and preferred by the larvae and there was no cannibalism among the *S. litura* larvae. In the other two proportions studied, there was cannibalism among larvae. Increasing the amount of jaggery and water was found to increase the palatability of the bait by the larvae.

After identifying the best bait proportion, each bran was evaluated for its effectiveness as base material. Among three bran used, significantly high amount of consumption was recorded in wheat bran based (0.198 g) bait followed by maize bran (0.175 g) and rice bran (0.149 g). In order to increase the palatability of the bait to the larvae, another experiment was conducted to identify an ideal phagostimulant. Three phagostimulants *viz.,* starch (0.2%), coconut oil (1%) and yeast (1%) were evaluated for their effectiveness. The addition of starch (0.2%) to the bait increased the consumption of bait by 94 per cent over control (without any phagostimulants). Coconut oil 1% was also a superior phagostimulant, but as starch is cheaper than coconut oil, starch was taken up for further studies for the preparation of poison baits.

Pesticides, belonging to various groups, such as chlorpyriphos (20% EC), thiodicarb (75% WP), lambda cyhalothrin (5% EC), fipronil (5% SC), spinosad (45% SC), emamectin benzoate (5% SG), flubendiamide (39.35% SC) and chlorantraniliprole (18.5% SC), NPV of *S. litura* (0.5% AS), and *Bacillus thuringiensis* (5% WP) were evaluated at three different concentrations for their effectiveness as poison baits for *S. litura*. Each pesticide was evaluated at three dose *viz.,* 25 per cent, 50 per cent and 75 per cent of recommended dose. The results showed that emamectin benzoate (5% SG), thiodicarb (75% WP) and chlorpyriphos (20% EC) as superior poison baits which showed 100 per cent mortality at 25 % concentration of recommended dose within 12h, followed by fipronil (5% SC) in 24 h (75% concentration) and spinosad 45% SC in 48h (75% concentration). These five superior insecticides in their effective concentrations were chosen for field level evaluation.

Poison baits were evaluated in 30 day old cowpea field (Var. Anaswara) which was laid out in randomized block design and replicated thrice with an absolute control (without bait) and a control plot (with unpoisoned bait). In order to prevent the movement of larvae from between plots, each plot was separated by polythene sheets and plot was kept weed free. In a plot, five plants were tagged and 55 g of bait/plot was placed at the base of tagged plant. Observation on leaf area consumption were assessed using leaf area meter. Initial leaf area was assessed by working out a regression equation based on the breadth of the leaf. Among the seven treatments, in emamectin benzoate baited plots, leaf consumption was very low (2.95 cm^2/ 5 plants) after 10 days of treatment followed by thiodicarb bait (8.44cm^2), chlorpyriphos bait (12.38 cm^2), fipronil bait (12.69 cm^2) and spinosad bait (30.61cm^2). The consumption of leaf was significantly lower with insecticide poisoned baits compared to both control and absolute control.

Poison baits prepared using wheat bran, jaggery and water in 4:1:4 proportion containing starch (0.2%) as phagostimulant and insecticides such as emamectin benzoate or thiodicarb or chlorpyriphos or fipronil or spinosad reduced the leaf feeding by *S. litura* in cowpea.

References

REFERENCES

Abdul Kareem, A. and Viswanadaham, T. 1980. A general account of the integrated approach for the control of bollworms on cotton. *Andhra Agri. J.* 27: 123-124.

Aggarwal, N., Holaschke, M. and Basedow, T. 2006. Evaluation of bio-rational insecticides to control *Helicoverpa armigera* (Hübner) and *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) fed on *Vicia faba* L. *Mitt. Dtsch. Ges. Allg. Angew. Ent.* 15: 245-250.

Ahmad, M., Saleem, M.A., Ahmad, M. and Sayyed, A.H. 2006. Time trends in mortality of conventional and new insecticides against leaf worm, *Spodoptera litura* (Lepidoptera: Noctuidae). *Pak. J. Biol. Sci.* 9: 360-364.

Argentine, J.A., Jansson, R.K., Halliday, W.R., Rugg, D. and Jany, C.S. 2002. Potency, spectrum and residual activity of four new insecticides under glasshouse conditions. *Fla. Entomologist*. 85: 552-562.

Armes, N.J., Wightman, J.A., Jadhav, D.R., and Rao, R. 1997. Status of insecticide resistance in *Spodoptera litura* in Andhra Pradesh India. *Pestic. Sci.* 50: 240–248.

Ascher, K.R.S. and Rubin, A. 1983. Laboratory and field decay experiments with insecticides poisoned wheat bran baits for the control of *Spodoptera littoralis* Fab. (Lepidoptera : Noctuidae). *Int. Pest Cont.*, 24: 156-160.

Ave, D.A. 1995. Stimulation of feeding: Insect control agents. In: Chapman, R. F. and Gerrit de Boer (eds), *Regulatory Mechanisms in Insect Feeding*. Springer. pp. 345-363.

Barbara, K.A. and Capinera, J. 2003. Development of a toxic bait for control of eastern lubber grasshopper (Orthoptera: Acrididae). *J. Econ. Entomol.* 96: 584-591.

Barbara, K.A. and Capinera, J. 2008. Food-based poisoned baits for insect control. In: Capinera, J.L. (ed.), *Encyclopedia of Entomology*. Springer, pp. 1495-1503.

Bartelt, R.J., McGuire, M.R. and Black, D.A. 1990. Feeding stimulants for the European corn borer (Lepidoptera: Pyralidae): additives to a starch-based formulation for *Bacillus thuringiensis*. *Environ. Entomol.* 19: 182–189.

Basavaraju, B.S., Shashank, P.R., Doddabasappa, B., Vijayakumar, L. and Chakravarthy, A. K. 2010. Efficacy of poison baits and biopesticides against *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) in potato. *Pest Manag. Hort. Ecosyst.* 16: 64-68.

Bengochea, P., Sanchez-Ramos, I., Saelices, R., Amor, F., del Estal, P., Vinuela, E., Adan, A., Lopez, A., Budia, F. and Medina, P. 2014. Is emamectin benzoate effective against the different stages of *Spodoptera exigua* (Hübner) (Lepidoptera, Noctuidae)? *Irish J. Agr. Food Res.* **53**: 37-49.

Blair, B.W. 1991. The concentration of lamda cyhalothrin and its effect on the cutworm *Agrotis segetum* (Lepidoptera: Noctuidae). *Bull. Entomol. Res.* **81**: 143-145.

Carneiro, E., Silva, L.B., Maggioni, K., dos Santos, V.B., Rodrigues, T.F., Reis, S.S. and Pavan, B.E. 2014. Evaluation of insecticides targeting control of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Am. J. Plant Sci.* **5**: 2823-2828.

Castillejos, V., Trujillo, J., Ortega, L.D., Santizo, J.A., Cisneros, J., Penagos, D.I., Valle, J. and Williams, T. 2002. Granular phagostimulant nucleopolyhedrovirus formulations for control of *Spodoptera frugiperda* in maize. *Biol. Control.* 24: 300-310.

Chandrasekhar. 1992. Studies on soil borne pests of potato in Karnataka with reference to biology and management of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). MSc(Ag) thesis, University of Agricultural Sciences, Bangalore.

Creighton, C.S., Mcfadden, T.L. and Cuthbert, R.B. 1973. Tomato fruit worm: control in South Carolina with chemical and microbial insecticides. *J. Econ. Entomol.* 66: 473-475.

Dahms, R.G. and Fenton, F.A. 1942. Experiments with poisoned bait to control armyworms in wheat. *J. Econ. Entomol.* 35: 439-440.

Davis, J.J. and Turner, C.F. 1918. Popular and practical entomology, Experiments with cutworm baits. *Can. Entomol.* 1: 187-192.

Delrivero, J.M. and Planes, S. 1966. Tests on the control of *Spodpotera littoralis* in the laboratory. *Boln. Patrol Veg. Entomol. Agric.* 29: 293-306.

Devaiah, M.A. 1973. Studies on cutworm in Mysore state and their control. MSc(Ag) thesis, University of Agricultural Sciences, Bangalore.

Dhaliwal, G.S., Jindal, V. and Mohindru, J. 2015. Crop losses due to insect pests: global and Indian scenario. *Indian J. Entomol.* 77:165-168.

Dhandapani, N. and Abdulkareem, A. 1983. Poison bait for red hairy caterpillar. *TNAU News Lett.* 13:1.

Dhandapani, N. and Abdulkareem, A., 1986, Evaluation of poison bait for the red hairy caterpillar, *Amsacta albistriga* (Walker). *Pestology.* 11: 8-10.

Dhandapani, N., Sundara Babu, P.C., Sathiah, N. and Jayaraj, S. 1993. Combined use of nuclear polyhedrosis viruses of *Spodoptera litura* (Fb.) and *Heliothis armigera* (Hb.) on groundnut (*Arachis hypogaea* L.). *J. Appl. Ent.* 116: 523-526.

Doddabasappa, B., Chakravarthy, A.K., Narabenchi, G.B., Gayathri Devi, S.S. and Rajagopal D. 2013. Evaluation and validation of HearSNPV for fruit borer, *Helicoverpa armigera* (Noctuidae: Lepidoptera) management on tomato. *Indian J. Agr. Sci.* 83: 106-112

Dunkle, R.L. and Shasha, B.S. 1988. Starch-encapsulated *Bacillus thuringiensis*: a potential new method for increasing environmental stability of entomopathogens. *Environ. Entomol.* 17: 120-126.

Eduku, A. 2014. Laboratory studies to develop cassava bait to control insect infestation of cocoa beans using coffee bean weevil, *Araecerus fasciculatus* (De Geer) (Coleoptera; Anthribidae) as model. MPhil (Post Harvest Technology) thesis, Kwame Nkrumah University of Science and Technology, Ghana, 89p.

El-Nockrashy, A.S., Salama, H.S. and Taha, R. 1986. Influence of bait formulations on the effectiveness of *Bacillus thuringiensis* against *Spodopotera littoralis* (Fab.). *J. Appl. Entomol.* 101: 381-389.

Erfurth, P. 1973. The situation regarding attack by cutworms, *Agrotis segetum* (Schiff) and methods for the prevention of attack. *Nachrichtenblatt fiit den Pflanzen Schutz dienst der DDR*. **27**: 65-68.

Farrar, R.T. and Ridgway, R.L. 1994. Comparative studies of the effects of nutrient-based phagostimulants on six lepidopterous insect pests. *J. Econ. Entomol.* 87: 44-52.

Fernald, H.T. 1914. The armyworm *Heliophila unipuncta* (Haw.). *Massacusettes State Bd. Agric.* 22: 1-13

Gharib, A. 1979. *Spodoptera littoralis* in Iran. *Entomolo et Phytopathol Appl.* 47: 161-176.

Gholson, L.E. and Showers, W.B. 1979. Feeding behaviour of black cutworm on seedling corn and organic baits in greenhouse. *Env. Entomol.* 8: 552-557.

Gillespie, R.L., McGuire, M.R. and Shasha, B.S. 1994. Palatability of flour granular formulations to European corn borer larvae (Lepidoptera: Pyralidae). *J. Econ. Entomol.* 87: 452-457.

Giraddi, R.S. and Kulkarni, K.A. 1987. Efficacy of insecticidal baits and granules against armyworm, *Mythimna separata* (Walker) in sorghum. *Pesticides*. 21: 27-31.

Gist, G.L. and Pless, C.D. 1985. Feeding deterrent effects of synthetic pyrethroids on the fall armyworm, *Spodoptera frugiperda*. *Florida Entomol.* 68: 456-461.

Hall, F.R., Adams, A.J. and Hoy, C.W. 1989. Correlation of precisely defined spray deposit parameters with biological responses of resistant diamond moth (DBM) field populations. *Aspects Appl. Biol.* 21: 125-127.

Hannig, G.T., Ziegler, M. and Marcon, P.G. 2009. Feeding cessation effects of chlorantraniliprole, a new anthranilic diamide insecticide, in comparison with several insecticides in distinct chemical classes and mode-of-action groups. *Pest Manag. Sci.* 65: 969-974.

Hill, M.G., Atkins, A.W. and Allon, D.I. 1983. Baits for control of greasy cutworm larvae: Field trials. In: *Proceedings of New Zealand Weed and Pest Control Conference*. 36: 171-175.

Hiremath, I.G., Bhuti, S.G., Kachapur, M.D., Viraktamath, S. and Lingappa, S. 1990. Mass killing of moths – A new approach in the management of armyworm, *Mythimna separata* (Walker). *Karnataka J. Agric. Sci.* 3: 128-130.

Hsu, M., Chang, G. and Chu, H. 1958. A study on the cotton bollworm, *Heliothis armigera* (Hubner) (Lepidoptera : Noctuidae). *Acta Oecon-ent . Sin. Ino.* 1: 18-30.

Jayaraj, S. 1983. Ecology based integrated control of *Spodoptera litura* on cotton. In: *ICAR Summer Institute on Microbial Control of Insects and Pest Management.* Tamil Nadu Agricultural University, Coimbatore, June 1-25.

Jayaram, B.D., Hugar, P.S. and Patil, B.V. 2007. Management of Hawkmoth, *Agrius convolvuli* L. (Lepidoptera: Sphingidae) on Greengram. *Karnataka J. Agric. Sci.* 20: 655-656.

Kamel, A.A.M. and Shoeb, A. 1958. The chemical control of the greasy cutworm. *Agric. Res. Rev.* 36: 24-39.

Kranthi, K.R., Jadhav D.R., Wanjari, R.R., Ali, S.S., and Russel, D. 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Prot.* 21: 449– 460.

Lahm, G.P., Cordova, D. and Barry, J.D. 2009. New and selective ryanodine receptor activators for insect control. *Bioorg. Med. Chem.* 17: 4127-4133.

Lasa, R., Williams, T., and Caballero, P. 2009. The attractiveness of phagostimulant formulations of a nucleopolyhedrovirus-based insecticide depends on prior insect diet. *J. Pest. Sci.* 82: 247-250.

Luna-Santillana, E. J., Rodriguez-Perez, M. A., Ali-Mahmoud, A. M., Morales-Ramos, L. H., Gopal, H. and Arevalo-Nino, K. 2011. Evaluation of potential microencapsulated agents for oral entomopathogens with phagostimulant activity against *Spodoptera exigua* (Hüber). *Southwest. Entomol.* 36: 433-442.

Mani, C. and Rao, P.J. 1998. Comparitive biology of *Spodoptera litura* (Fab.) on semi-synthetic diet and natural food. *Shashpa.* 5:141-144.

Mansour, A.S. and Abdel–Hamid, N.A. 2015. Residual toxicity of bait formulations containing plant essential oils and commercial insecticides against desert locust, *Schestocerca gregaria. Ind. Crops Prod.* 76: 900-909.

Marenco, R.J., Foster, R.E. and Sanchez, C.A. 1991. Residual activity of methomyl and thiodicarb against fall Armyworm in sweet corn in southern Florida. *Fla. Entomologist.* 74: 69-74.

Martin, N.A. 1980. Factors influencing the palatability of baits to greasy cutworm larvae. *Proc. 33rd N. Z. Weed and Pest Control Conf.* 221-224.

McGuire, M.R. and Shasha, B.S. 1990. Sprayable self-encapsulating starch formulations for *Bacillus thuringiensis*. *J. Econ. Entomol.* 83: 1813-1817.

McGuire, M.R. and Shasha, B.S. 1992. Adherent starch granules for encapsulation of insect control agents. *J. Econ. Entomol.* 85: 1425-1433.

McGuire, M.R., Shasha, B.S., Eastman, C.E. and Oloumi-Sadeghi, H. 1996. Starch and flour-based sprayable formulations: effect on rainfastness and solar stability of *Bacillus thuringiensis*. *J. Econ. Entomol.* **89**: 863-869.

McGuire, M.R., Shasha, B.S., Lewis, L.C., Bartelt, R.J. and Kinney, K. 1990. Field Evaluation of Granular Starch Formulations of *Bacillus thuringiensis* against *Ostrinia nubilalis* (Lepidoptera: Pyralidae). *J. Econ. Entomol.* 83: 2207-2210.

Meisner, J., Ascher, K.R.S. and Flowers, H.M. 1972. Feeding response of the larva of the Egyptian cotton leafworm, *Spodoptera littoralis* Boisd., to sugars and related compounds. I Phagostimulatory and deterrent effects. *Compo Biochem. Physio*. 42A: 899-914.

Metcalf, R.L., Ferguson, J.F., Lampman, R. and Rinderson, J.F. 1987. Dry cucrbitacin containing baits for controlling diabroticite beetles. *J. Econ. Entomol.* 80: 870-875.

Mohan, S., Varadharajan, N. and Balasubramanian, M. 1989. Development and testing of pesticide bait pellets for tobacco cutworm, *Spodoptera litura*, Fab. *Pestology*. 13: 22-23.

Morgan, L.W. and French, J.C. 1971. Granulate cutworm control in peanuts in Georgia. *J. Econ. Entomol.* 64: 937-939.

Moustafa, O.K. 1983. Effects of carrier and soil moisture on the performance of baits used for the control of greasy cutworm, *Agrotis ipsilon*. *Bull. Entomol. Soc. Egypt.* 11: 271-274.

Muddassar, Venkateshalu, Kotikal, Y.K., Patil, S. and Kiran Kumar, K.C. 2017. Evaluation of poison baits against *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) in spinach. *Int. J. Plant. Prot.* 10: 122-127.

Navon, A., Keren, S., Levski, S., Grinstein, A. and Riven, Y. 1997. Granular feeding baits based on *Bacillus thuringiensis* products for the control of lepidopterous pests. *Phytoparasitica*. 25: S101-S110.

Parasuraman, S., Jayaraj, S., Gopalan, M. and Kumaraswamy, T. 1985. Attraction of *Spodoptera litura* Fabr. larvae to baits. *Indian J. Agric. Sci.* 55: 773-774.

Ramaprasad, G., Joshi, B.G., Sitaramaiah, S. and Chari, M.S. 1989. Efficacy of insecticides in bait formulations for control of fourth instar larvae of *Spodoptera litura* Fab. in tobacco nurseries. *Indian J. Plant Prot.* 17: 53-57.

Renju, T., Giraddi, S.R., Hunje, R., and Mantur, S.M. 2009. Evaluation of new insecticidal poison baits against *Mythimna separata* (Walker) in sorghum. *Karnataka J. Agric. Sci.* 22: 773-776.

Ridgway, R.L., Illum, V.L., Farrar, R.R., Calvin, D.D., Fleischer, S. J. and Inscoe, M.N. 1996. Granular matrix formulation of *Bacillus thuringiensis* for control of the european corn borer (Lepidoptera: Pyralidae). *J. Econ. Entomol.* 89: 1088-1094.

Rosas-Garcia, N.M., Villegas-Mendoza, J.M. and Torres-Ortega, J.A. 2009. Design of a *Bacillus thuringiensis*-based formulation that increases feeding preference on *Spodoptera exigua* (Lepidoptera: Noctuidae) larvae. *J. Econ. Entomol.* 102: 58-63.

Ruscoe, C.N.E. 1977. The new NRDC pyrethroids as agricultural insecticides. *Pestic. Sci.* 8: 236--242.

Sammour, E.A., El-Bakry, A.M., Abdel-Aziz, N.F., Kassem, S.M.I. and Abdelgaleil, S.A.M. 2017. Physico-chemical properties and efficacy of chlorpyrifos commercial formulations against *Spodoptera littoralis* under laboratory and field conditions. *Alex. J. Agric. Sci.* 61:161-168.

Scott, L.B. 1945. Arsenical residues in straw and grain from wheat dusted by airplane or treated with poisoned bait. *J. Econ. Entomol.* 38: 464-466.

Sechriest, R.E. 1968. Greenhouse experiments with baits for control of the black cutworm. *J. Econ. Entomol.* 61: 591-593.

Sechriest, R.E. and Moore, S.N. 1968. A field experiment with insecticides impregnated baits to control the armyworm. *J. Econ. Entomol.* 61: 879-880.

Sechriest, R.E. and Sherrod, D.W. 1977. Pelletted bait for control of the black cutworm in corn. *J. Econ. Entomol.* 70: 699-700.

Shakur, M., Ullah, F., Naem, M., Amin, M., Saljoqi, A.U.R., and Zamin, M. 2007. Effect of various insecticides for the control of potato cutworm (Agrotis ipsilon Huf., Noctuidae: Lepidoptera) at Kalam Swat. *Sarhad J. Agric.* 23: 423-425.

Shankaragouda, K.R., Somesekhar, A., Prabhuraj, and Hosamani, A.C. 2015. Effect of different insecticides molecules as poison bait against *Spodoptera litura* (Fab.) in groundnut. *Karnataka J. Agric. Sci.* 28: 202-205.

Shankarganesh, K., Walia, S., Dhingra, S., Subrahmanyam, B., and Ramesh Babu, S. 2012. Effect of dihydrodillapiole on pyrethroid resistance associated esterase inhibition in an Indian population of *Spodoptera litura* (Fabricius). *Pestic. Biochem. Physiol.* 102: 86-90.

Sharma, P.C. and Pathania, A. 2014. Susceptibility of tobacco caterpillar, *Spodoptera litura* (Fabricius) to some insecticides and biopesticides. *Ind. J. Sci. Res. and Tech.* 2: 24-30.

Sharma, S., Chandel, Y.S. and Sharma, P.C. 2018. Residual toxicity of different insecticides against brinjal shoot and fruit borer Leucinodes orbonalis Guenee (Lepidoptera: Pyralidae). *J. Entomol. Zool. Stud.* 6: 2115-2118.

Shashi Bhushan, V., Ramesh Babu, V., Dharmareddy, K. and Umamaheswari, T. 2010. Efficacy of certain insecticides against *Spodoptera litura* (Fab.) on potato. *Karnataka J. Agric. Sci.* 23: 195-196.

Singh, V. and Battu, G.S. 2006. Effect of selected sunshine protectants on persistence of *nucleopoly-hedrovirus* (Hear NPV, PAU-1 strain) against *Helicoverpa armigera* (Hubner) on Egyptian Clover. *Pestic. Res. J.* 18: 183-185.

Sousa, A.A., Frazee, J.R., Weiden, M.H.J. and D'Silva, T.D.J. 1977. UC 51762, a new carba:mate insecticide. *J. Econ. Entomol.* 70: 803-807.

Sreedhar, U. and Nageswararao, K. 2016. Management of tobacco caterpillar, *Spodoptera litura* in Virginia tobacco with insecticide baits. *Indian J. Plant Prot.* 44: 427-430.

Tamez-Guerra, P., McGuire, M.R., Medrano-Roldan, H., Galan-Wong, L.J., Shasha, B.S. and Vega, F.E. 1996. Sprayable granule formulations for *Bacillus thuringiensis*. *J. Econ. Entomol.* 89: 1424-1430.

Tan, K-H. 1981. Antifeeding effect of cypermethrin and permethrin at sub-lethal levels against *Pieris brassicae* larvae. *Pestic. Sci.* 12: 619-626.

Thodsare, N.H. and Srivastava, R.P. 2014. Bioefficacy of abamectin, chlorantraniprole and emamectin benzoate against tobacco caterpillar, *Spodoptera litura* (Fab.). *J. Ent. Res.* 38: 273-278.

Torres–Vila, L.M., Rodriguez-Molina, M.C., Lacasa-Plasencia, A. and Bielza, P. 2002. Insecticide resistance of *Helicoverpa armigera* to endosulfan, carbamates and organophosphates: the Spanish case. *Crop Prot.* 21: 1003-1013.

Tunblad, B. 1947. Poison bran against cutworms in a nursery. *Vaxtskyddsnotiser.* 4: 53-55.

Turner, N. 1950. *Control of Tobacco Insects.* The Connecticut Agricultural Experiment Station, New Haven, Connecticut. 16p.

Usman, S. 1953. Outbreak of cutworm in ragi and cotton fields can be effectively controlled by poison baits. *Mysore Agric. Cal.* 1: 98-99.

Viswanadham, J.K., Punnaiah, K.C. and Rao, C.R.S. 1986. Studies on certain bait compositions against tobacco caterpillar, *Spodoptera litura* Fabricus (Noctuidae : Lepidoptera). *Andhra Agri. J.* 33: 16-19.

Vivan, L.M., Torres, J.B. and Fernandes, P.L.S. 2016. Activity of selected formulated biorational and synthetic insecticides against larvae of *Helicoverpa armigera* (Lepidoptera: Noctuidae). *J. Econ. Entomol.* 110: 118-126.

Wang, D., Qiu, X., Ren, X., Zhang, W. and Wang, K. 2009. Effects of spinosad on *Helicoverpa armigera* (Lepidoptera: Noctuidae) from China: tolerance status, synergism and enzymatic responses. *Pest Manag. Sci.* **65**: 1040-1046.

Yokoi, S., Omino, T. and Tsuji, H. 1975. Experiment studies on behavioural differences among three Noctuid species larvae, *Agrotis ipsilon*, *Mamestra brassicae* and *Spodoptera litura* in relation to the efficacy of commercial bait. *Japanese J. App. Entomol. Zool.* 19: 11-16.

INSECTICIDE BASED BAIT FORMULATION AGAINST TOBACCO CATERPILLAR *Spodoptera litura* (FABRICIUS) (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

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Abstract

Spodoptera litura Fab. (Lepidoptera: Noctuidae) is a polyphagous pest with cosmopolitan distribution, causing severe defoliation in economically important crops. The current management strategy for this pest relies heavily on blanket spraying of insecticides which may not reach the target. Indiscriminate use of pesticides indirectly affects various non-target organisms and also will lead to the problems like resurgence, resistance and secondary pest outbreaks.

Baiting technique comprises an attractive food along with an insecticide to lure insect pests and kill. The amount of insecticide active ingredient applied per unit area with the use of bait is much lower than that of blanket insecticide sprays. Hence, the present study was undertaken to identify a potential insecticidal bait for the management of *S. litura*.

The study was conducted during 2017-2018 at the Department of Agricultural Entomology, College of Horticulture Vellanikkara, Kerala Agricultural University, Thrissur. In order to identify a base material preferred by *S. litura*, baits were prepared by using different substrate, *viz.,* rice bran, maize bran and wheat bran along with jaggery and water. Mean consumption of bait by the *S.litura* larvae after 48h were recorded and results revealed superiority of bait containing wheat bran and jaggery in 8:2 ratio, followed by maize bran. *Spodoptera litura* larvae consumed 0.1980 g of wheat bran based bait in a period of 48 hours.

After screening the base material for bait the standardisation of phagostimulants, such as yeast (1%), starch (0.2%), and coconut oil (1%) as an additive to the bait to increase the attractiveness of bait was done. Bait containing starch (0.2%) was found to be very attractive and resulted in doubling of the consumption of bait (0.3842 g) in comparison to the control. Hence, wheat bran based diet with starch (0.2%) was chosen for further studies.

Insecticides, *viz*., chlorpyriphos (20% EC), thiodicarb (75% WP), lambda cyhalothrin (5% EC), fipronil (5% SC), spinosad (45% SC), emamectin benzoate (5% SG), flubendiamide (39.35% SC) and chlorantraniliprole (18.5% SC) were evaluated along with two microbials, NPV of *S. litura* (0.5% AS), and *Bacillus thuringiensis* (5% WP). All the pesticides were evaluated at the doses *viz.,* 25 per cent, 50 per cent and 75 per cent of recommended dose. The results showed that emamectin benzoate (5% SG), thiodicarb (75% WP) and chlorpyriphos (20% EC) as superior poison baits which showed 100 per cent mortality at 25 % concentration of recommended dose within 12 h. Fipronil 5% SC in 24 h (75% recommended dose) and spinosad 45% SC in 48 h (75% recommended dose) also lead to cent per cent mortality in the

shortest time. The above five insecticides were chosen for the evaluation of poison baits in field.

Poison baits were evaluated in field planted with cowpea (var. Anaswara). The experiment was laid out in randomized block design and replicated thrice with an absolute control (without bait) and a control plot (with unpoisoned bait). In order to prevent the movement of larvae from one plot to another plot were separated by polythene sheets. In each plot 5 plants were tagged, which were equally distributed from the centre of the plot. Twenty five six day old larvae were released at the centre of each plot. After 10 days defoliation was measured using leaf area meter. Two regression equations were worked out for central leaf and side leaves of the trifoliate leaf of cowpea. Initial leaf area was assessed by measuring the length and breadth of the leaf and substituting the breadth of the leaf in the regression equation. Observation on leaf defoliation revealed that in emamectin benzoate baited plots consumption was very low (2.95 cm^2/5 plants/plot) after 10 days of treatment followed by thiodicarb (8.44 cm^2/5 plants/plot), chlorpyriphos (12.38 cm^2/5 plants/plot), fipronil (12.69 cm^2/5 plants/plot) and spinosad (30.61 cm^2/5 plants/plot). Poison baiting with insecticides was found to be beneficial in reducing the damage caused by *S. litura* at levels lower than the recommended dose with minimum disturbance to non-target organisms.