"MANAGEMENT OF *Spodoptera litura* (Fab.) ON POTATO"

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST – AHMEDNAGAR
MAHARASHTRA STATE (INDIA)

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

by

Mr. KORATE ABHIJEET ANANDRAO
Reg. No. O13/250

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY,
COLLEGE OF AGRICULTURE, PUNE
(MAHARASHTRA)

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Dr. S. B. KHARBADE
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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY,
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2015

CANDIDATE'S DECLARATION

I hereby declare that this thesis or a part thereof has not been submitted by me or other person to any other University or Institute for a Degree or Diploma

Place: Pune

Date: / /2015 **(Korate A. A.)**

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Chairman and Research Guide
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Maharashtra State (INDIA)

CERTIFICATE

This is to certify that the thesis entitled, **"MANAGEMENT OF *Spodoptera litura* (Fab.) ON POTATO"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State, India, in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** embodies the results of piece of *bonafide* research work carried out by **MR. KORATE ABHIJEET ANANDRAO** under my guidance and supervision and that no part of the thesis has been submitted to any other university for Degree or Diploma or publication in other form.

The assistance and help received during the course of this investigation and sources of reference have been duly acknowledged.

Place: Pune **(S. B. Kharbade)**
Dated: / /2015 Chairman and Research Guide

Dr. J. V. Patil
Associate Dean,
College of Agriculture, Pune
Maharashtra State (INDIA)

CERTIFICATE

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Place: Pune **(J. V. Patil)**
Date : / /2015 Associate Dean

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I would like to express my sincere appreciation to my brother Atul for his constant inspiration.

Place: Pune

Date: / /2015 *(Abhijeet A. Korate)*

DEDICATION

Affectionately dedicated

To

My beloved Parents, Brother,

And

My Research guide

……Abhijeet

ABSTRACT

"MANAGEMENT OF *Spodoptera litura* (Fab.) ON POTATO"

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Research Guide	:	**Dr. S. B. Kharbade**
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The present investigation was undertaken with an objective to study the bio-efficacy of insecticides *viz.*, *Nomuraea rileyi* (1×10^8 cfu/ml), *Metarhizium anisopliae* (1×10^8 cfu/ml), *Sl*NPV (750 LE/ha), neem oil 1%, lambda-cyhalothrin 5 SC, flubendiamide 39.35 SC, indoxacarb 15.8 EC and profenophos 44 EC against *Spodoptera litura* (Fab.) on potato during *Kharif* season of 2014 at AICRP Potato, NARP, Pune. Among the insecticides, the treatment with flubendiamide 39.35 SC was observed to be most promising

by recording lowest of 0.35 egg masses/meter row length which was found on par with profenophos 44 EC in which 0.39 egg masses/meter row length was observed. The next best treatments in descending order of efficacy were indoxacarb 15.8 EC > lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.46, 0.58, 0.68, 0.74, 0.82 and 0.96 egg masses/meter row length were recorded, respectively.

Among the insecticides, the treatment with flubendiamide 39.35 SC was observed to be most promising by recording lowest larval population of 0.49 larvae/meter row length which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.62 and 0.69 larvae/meter row length was observed. The next best treatments in descending order of their bio-efficacy were lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.93, 1.13, 1.29, 1.75 and 2.04 larvae/meter row length were observed, respectively.

Similarly, for the management of foliar damage the treatment with flubendiamide 39.35 SC was perceived to be superior was recorded lowest 10.18 per cent foliar damage/plant and was found to be on par with profenophos 44 EC and indoxacarb 15.8 EC in which 10.70 and 11.11 per cent/plant foliar damage were observed. The next best treatment was lambda-cyhalothrin 5 SC in which foliar damage of 12.91 per cent/plant was observed and was on par with *Sl*NPV (750 LE/ha) (14.55 per cent/plant). This was followed by *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% > *M. anisopliae* (1×10^8 cfu/ml).

Flubendiamide 39.35 SC was most superior over all the treatments causing lowest tuber damage (8.02 per cent) and was on par with profenophos 44 EC (9.68 per cent) and indoxacarb 15.8 EC (10.00 per cent). The next best treatment was lambda-cyhalothrin 5 SC which was followed by *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml).

Among the treatments, the highest marketable potato yield of 21.80 tonnes/ha was obtained in a treatment with flubendiamide 39.35 SC and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 21.55 and 21.35 tonnes/ha yield observed, respectively. The next best treatment in order of merit was lambda-cyhalothrin 5 SC which was followed by *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml).

Bio-pesticide having no any adverse effects on assassin bug population. In treatments of *M. anisopliae* (1×10^8 cfu/ml), *N. rileyi* (1×10^8 cfu/ml), *Sl*NPV (750 LE/ha) and neem oil 1% were safer to assassin bug. However, insecticides *viz*., lambda-cyhalothrin 5 SC, indoxacarb 15.8 EC, profenophos 44 EC and flubendiamide 39.35 SC were found moderately safe to assassin bug.

The insecticide treatments, did not exhibit any phyto-toxicity symptoms such as injury to leaf tip and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty on potato.

The results of present investigations are indicative for selective and precise use of promising insecticides which is necessary in developing an ecologically sound Integrated Pest Management programme for *S. litura* on potato.

Korate A. A. **Page No. 1 to 69**

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the world's most important tuber crop and cultivated in 129 countries. The potato is highly nutritious food and it provides balanced quantities of carbohydrates, minerals, vitamins and little fat than others major food crops. It is used as vegetable and also used for manufacturing starch, alcoholic beverages and other processed products in industries.

India has taken a giant leap in terms of area and production mainly because of its short duration, nutritional superiority and ability of producing high amount of food per unit area. Potato is grown in India in almost all the states and under very diverse conditions. During 2012, potato was grown in an area of 18.65 m ha with production of 3220 MT and productivity of 27.26 t per ha in world. While in India during 2012, it was grown in an area of 1.9 m ha with production of 45 MT and productivity of 23.68 t/ha. In Maharashtra state, it is grown on area of 0.40 m ha with an average productivity of 22.77 t/ha (Kadian *et al.*, 2013). In the Maharashtra potato is cultivated in hilly areas of Pune, Satara and Ahmednagar districts during *Kharif* season due to suitable climatic condition while it is cultivated in most of all the districts of Maharashtra state during *Rabi* season. The potato crop is heavily attacked and damaged by different types of lepidopteran pests *viz.*, potato tuber moth (*Phthoromea opercullela* Z.), cutworm (*Agrotis ipsilon* Ron.), leaf eating caterpillar (*Spodoptera litura* Fab.) and

Helicoverpa armigera (Hub.), coleopteran pests *viz.*, Epilachna beetle (*Epilachna dodecstigma* M.), White grub (*Holotrichia serrata* F.) and many hemipteran sucking pests *viz.*, aphids (*Myzus persicae* Sulz.), jassids (*Amrasca biguttula* Ishida.), thrips (*Thrips tabaci* Lind.), whitefly (*Bemisia tabaci* Gen.) and non-insect pest mites (*Tetranychus telarius* L.). Out of these pests, leaf eating caterpillar (*Spodoptera litura* Fab.) observed to be one of the most serious sporadic pests infesting *Kharif* potato crop in Maharashtra state.

Spodoptera litura (Fab.) is a polyphagous pest causing 25.8 to 100 per cent losses in different crops based on crop stage and its infestation level in the field. It causing enormous losses to many economically important cultivated crops such as potato, cotton, soyabean, groundnut, tobacco, black gram, sunflower, castor, lucerne, chilli, cauliflower, cabbage, tomato, beans *etc* (Qin *et al.*, 2004). It has high reproductive capacity and can migrate over large distances in its adult stage. This pest has been found to damage crops both in open fields and under protected environment. (Chandel *et al.*, 2011) reported *S. litura* as a sporadic pest of potato in India causing 20 to 100 per cent foliage damage depending on moisture availability. Up to 20 per cent of potato tubers were damaged in the month of August-September and February (Trivedi, 2000).

In the Maharashtra state *S. litura* assumed a very serious and sporadic on potato and causes heavy losses. The female moth of *S. litura* laid the eggs on the lower surface of potato leaves in bunches. The *Spodoptera* larvae scrap succulent leaves causing skeletonisation of leaves. It also attacks exposed tubers when young succulent leaves were unavailable. *Spodoptera* larvae attack on potato crops during night hours and hide during day time in cracks and crevices of soil.

Farmers were using high doses of insecticides repeatedly for controlling the population of *S. litura* on potato crops. Due to which this pest becomes resistant to heavy doses of insecticides. So that it is important to evaluate the insecticides with proper doses for management of *S. litura* in potato. On the other hand with the safer to natural enemies *viz.*, assassin bug (*Rhynocoris fusipes* Fab.) on potato crops.

A number of insecticides have been proved to be effective against this pest. Of which flubendiamide 39.36 SC, profenophos 44 EC, indoxacarb 15.8 EC and lambda-cyhalothrin 5 SC insecticides were mainly used. Flubendiamide is novel insecticide and very effective against lepidopteran insects and other insecticides also effective for reduction of these pest population (Chandel *et al.*, 2011). The mode of entry of these insecticides *via* stomach and contact routes and causes blocking of nervous system of pest. Insecticides *viz.*, flubendiamide 39.36 SC, profenophos 44 EC, indoxacarb 15.8 EC are having good ovicidal activity against egg mass of *S. litura* (Hanan and Samya, 2014).

Several plant products *viz.*, neem oil have potent biological activities and are capable of causing developmental abnormalities in pests. The biological plant protection with entomopathogenic fungi have key role in sustainable pest management programme. Entomopathogens as biocontrol agents have several advantages. These include low cost, high efficiency, safety for beneficial organisms, reduction of residues in environment, and increased biodiversity in human managed ecosystems. The fungi *viz.*, *Metarhizium anisopliae* (1×10^8 cfu/ml) (Metchnikoff) sorokin, *Nomuraea rileyi* (1×10^8 cfu/ml) (Farlow) also found positive result as a ovicidal activity against egg masses of *S. litura* (Anand and Tiwary, 2009).

For the management of *S. litura* it is necessary to test the bio-efficacy of insecticides and biopesticides *viz.*, Neem oil 1 %, *Sl*NPV (750 LE/ha), *M. anisopliae* (1×10^8 cfu/ml), *N. rileyi* (1×10^8 cfu/ml) *etc* on potato crop. The present research study was conducted with following objectives.

- To study the bio-efficacy of insecticides against *Spodoptera litura* (Fab.) on potato
- To study the phyto-toxicity of insecticides on potato
- To study the influence of insecticides on natural enemies

2. REVIEW OF LITERATURE

The present investigation being confined to the study on bio-efficacy of insecticides against *S. litura* on potato, phyto-toxicity of insecticides on potato and influence of insecticides on natural enemy like assassin bug, *Rhynocoris fusipes* (Fab.) under field condtion, the literature pertaining to these aspects is reviewed in this chapter and represented accordingly.

2.1. Bio-efficacy of insecticides against *Spodoptera litura* (Fab.) on potato

Abdullah *et al.* (2001) tested the efficacy of cypermethrin 10 EC, neem extract 0.1% and *Bacillus thuringiensis* var. kurstaki (53,000 SU/mg) against *S. litura* on soybean at 10 days interval. Cypermethrin was found significantly better among the treatments. neem extract moderately supressed the larval population while *Bt* showed less efficacy over untreated control.

Kumar *et al.* (2001) reported that cypermethrin was most effective insecticide against *S. litura* on chilli (*Capsicum* spp.).

Pokharkar *et al.* (2001) observed that spray of *Sl*NPV @ 750 LE/ha (4.5×10^{12} POBs/ha) found significantly effective against *S. litura* causing 91.68% larval mortality and 20.8 tones/ha yield of marketable potato.

Kulkarni and Lingappa (2002) studied the bio-efficacy of *N. rileyi*, *Sl*NPV and *Bacillus thuringiensis* (Berliner) against *S. litura* on potato. *Sl*NPV and *Bt* effective at higher concentration reducing larval number and foliar damage. Efficacy of *N. rileyi* increased with increase in dosage of fungus and all the doses of *N. rileyi* were significantly superior to untreated control in potato the crop.

Devi *et al.* (2003) tested the efficacy of *N. rileyi* against the larvae of *S. litura* on potato. The concentration of 2×10^8 conidia m^{-1} indicated that *N. rileyi* isolates of *S. litura* were the better mycosis and mortality observed in *S. litura* larvae. The cent per cent germination of conidia within 48 hr and 77-80% mortality in 7 days was observed in larvae.

Reddy *et al.* (2005) evaluated the efficacy of insecticides (spinosad, indoxacarb, lufenuron, neem and acephate), applied alone or in combination with *B. thuringiensis* against *S. litura* on sunflower. Indoxacarb + lufenuron and indoxacarb + *Bt* recorded the highest efficacy (69.9 and 68.1%) and yields (1656 and 1600 kg/ha).

Saini *et al.* (2005) concluded that thiodicarb 0.075% was the best insecticide (100% mortality) of *S. litura* followed by chlorpyriphos 0.06%, endosulfan 35 EC 0.11%, indoxacarb 0.03% and profenophos 0.15% giving 90.0, 76.7, 73.3 and 73.0% larval mortality, respectively within 72 hr when larvae feed on treated leaves.

Tomar *et al.* (2005) indicated that flubendiamide 20 WDG @ 25 a.i./ha was found to be highly effective in minimizing the lepidopteran pest and increasing the yield of seed cotton.

Venkateswarlu *et al.* (2005) evaluated indoxacarb and profenophos for the management of *S. litura* on cotton crops. Indoxacarb have higher relative toxicity to which, followed by profenophos which was more toxicant against *S. litura* on cotton crop.

Navi *et al.* (2006) evaluated the efficacy of *N. rileyi* (1011 conidia/ha), NSKE, 5% and quinalphos 0.05% in controlling the *S. litura* in groundnut. Due to which lowest foliar damage observed 12.95, 13.35 and 15.79% at 40, 55 and 70 days, respectively.

Dhawan *et al.* (2007) tested the susceptibility of 3rd instar larvae of *S. litura* aginst novel insecticides like emamectin 0.0010%, benzoate 0.0020%, novaluron 0.0037%, pyridalyl 0.0040%, flubendiamide 0.0044%, chlorantraniliprole 0.0390%, and thiodicarb 0.0410%. The relative toxicity of 390.0, 19.50, 10.54, 9.80, 8.80, 1.00 and 0.95 was observed, respectively. Emamectin benzoate was found to be most toxic insecticide to *S. litura* as compared to others.

Shivankar *et al.* (2008) reported the quinalphos 25 EC @ 0.05% as most effective insecticide showing 97.20% larval mortality of *Spodoptera* with 75.5 t/ha yield of sugarbeet.

Hole *et al.* (2009) observed that cypermethrin was the significantly superior for controlling the population of *S. litura* in soyabean and reduced foliar damage up to 6.5%. whereas all other insecticides *viz.*, dichlorvos, quinalphos were superior over untreated control.

Prasad and Sirisha (2009) evaluated the efficacy of certain insecticides and biopesticides for the management of *S. exigua* in onion. Thiodicarb @ 562 g a.i/ha was found superior result and followed by chlorpyriphos @ 312 g a.i/ha, quinalphos @ 250 g a.i/ha and biopesticides, *Bt* formulation 1 kg/ha and NSKE 5% recorded lower larval incidence and shoot damage. Thiodicarb registered highest mean yield of 12.25 t/ha which was on par with chloryriphos and quinalphos.

Shankarappa and Bhushan (2009) revealed that lufenuron 10 % EC @ 2 ml/lit was found to be best treatment with lowest incidence (20.99%) of *S. litura*, followed by acephate 75 WP @ 1 g/lit (22.26%), endosulfan 35 EC @ 2 ml/lit (23.83%) and carbaryl 50 WDP @ 3 g/lit (26.52%) on potato crop.

Shankarganesh *et al.* (2009) determined the relative susceptibility of insecticides to larvae of *S. litura* on tobacco. The relative toxicity of indoxacarb, followed by emamectin benzoate, profenophos, lambda cyhalothrin insecticides were 7.20, 2.87, 2.45 and 1.21 fold toxic to *S. litura*, respectively.

Shankarganesh *et al.* (2009) evaluated the toxicity of insecticides against 2nd and 3rd instar larvae of *S. litura* on soybean. Based on the LC_{50} obtained, the 2nd instar larvae was of 8.0, 2.1, 4.4 and 11.2 times susceptible than that of 3rd instar larvae to cypermethrin, fenvalerate, lambda cyhalothrin and profenophos, respectively.

Tatagar *et al.* (2009) indicated that flubendiamide 20 WG @ 60 g a. i./ha recorded highest yield of 7.48 q/ha with lowest fruit damage (3.45%) due to *S. litura* on chilli.

Bhushan *et al.* (2010) conducted an experiment to evaluate the efficacy of novaluron 10 EC, chlorfenapyr 10 SC and lufenuron 10 EC against *S. litura* on potato. The treatment lufenuron 10 EC was found superior for controlling the incidence (18.50%) of *S. litura* on potato followed by novaluron 10 EC (20.99%) and chlorfenapyr 10 SC (22.26%), respectively.

Hanumantharaya *et al.* (2010) studied the bio-efficacy of insecticides against leaf eating caterpillars and *S. exigua* in safflower crop. Indoxacarb 15 EC @ 0.3 ml/litre and spinosad 48 SC @ 0.15 ml/litre were effective and reduced larval population and also significantly higher seed yield of 1168.00 and 1162.00 kg/ha, respectively.

Malarvannan *et al.* (2010) studied the effect of *B. bassiana* against *S. litura* on tobacco crop. The least pupation (43.33%) was observed in tobacco with the highest spore concentration ($2.4x10^7$) of *B. bassiana*, while the fecundity was completely arrested due to *B. bassiana*.

Shashibhushan *et al.* (2010) studied the efficacy of insecticides against *S. litura* on potato. The incidence levels of *S. litura* before treatment varied from 31.53 to 34.33% among treatments. The incidence levels after post treatments (60 DAP) varied from 20.99 to 40.56%. Lufenuron 10% EC @ 0.75 ml/lit the best treatment with lowest incidence of 20.99%. The treatment of NSKE 5% (28.20%) also lower down pest population.

Taggar *et al.* (2011) tested the bio-efficacy of seven insecticides *viz.*, quinalphos 25 EC, carbaryl 50 WP, indoxacarb 14.5 SC, acephate 75 SP, endosulfan 35 EC, chlorpyrifos 20 EC and dichlorvos 76 EC against *S. litura* infesting soybean. Indoxacarb 14.5 SC @ 500 ml/ha proved most effective in controlling the pest at 3 and 7 days after spray (4.84 and 2.14 larvae/m^2, respectively), followed by acephate 75 SP @ 2.0 kg/ha (7.36 and 3.69 larvae/m^2, respectively). The highest mean grain yield was also recorded in the treatment indoxacarb 14.5 SC (1356 kg/ha), followed by acephate 75 SP (1299 kg/ha).

Murthy *et al.* (2012) evaluted *Sl*NPV @ 250 LE/ha in combination with different plant extracts against *S. litura* on cabbage. The maximum percentage of larval population was reduced due to the *Sl*NPV + NSKE 5% (81.66%) followed by *Sl*NPV + neem oil 0.1% (73.33%). The other botanicals like mustard oil 0.2%, chilli garlic extract 2.5%, Calatropis leaf extract 2% and Pongamia leaf extract 2% along with *Sl*NPV recorded 62.78, 60.26, 55.38 and 53.75 per cent larval reduction, respectively over control. Least per cent larval reduction was observed in sole treatment of *Sl*NPV (45.60%).

Asi *et al.* (2013) studied the susceptibility of different stages of *S. litura* to various strains of entomopathogenic fungi under laboratory conditions. Eggs and larvae were comparatively more susceptible to entomopathogenic fungi. The LC_{50} values for eggs were 1.13×10^6, 4.82×10^6 and 2.45×10^7conidia ml^{-1} in *M. anisopliae*, *I. fumosorosea* and *B. bassiana*, respectively.

Ghosal *et al.* (2013) observed the efficacy of insecticides (spinosad, rynaxypyr, indoxacarb, flubendiamide) for the management of *S. litura* on tomato. Results showed that rynaxypyr 18.5% SC @ 40 g a.i./ha were found to be superior over other treatments against *Spodoptera.* The lowest fruit infestation (2.40%) protection over control and highest marketable fruit yield (34.74 q/ha) after two applications.

Shiwani *et al.* (2013) found that indoxacarb was 66.32 times more toxic than cartap hydrochloride against *S litura* on tobacco. The relative toxicity in order of indoxacarb > flubendiamide > cartap hydrochloride was reported against *S. litura* on tobacco crop.

Gupta and Kumar (2014) tested the bio-efficacy of *B. bassiana* against 3rd instar larvae of *S. litura.* The fungal preparation @ $0.2x10^8$ spore/ ml caused 80% mortality of *S. litura* followed $0.125x10^8$ spore/ml (73.3%) and $0.1x10^8$ spore/ml (46.6%). Thus, the number of spore of *B. bassiana* increased, per cent mortality of *S. litura* also increased.

Sharma and Pathania (2014) studied the susceptibility of 4th instar larvae of *S. litura* to insecticides *viz.*, alphamethrin, endosulphan, flubendiamide, indoxacarb and novaluron and biopesticides like emamectin benzoate and spinosad. *S. litura* larvae were highly susceptible to emamectin benzoate, flubendiamide and indoxacarb when they were sprayed as foliar spray.

Tukaram *et al.* (2014) carried out bioassay of flubendiamide 39.5% SC against tobacco caterpillar (*S. litura*) populations collected from different host crops like castor, ground nut, chilli, sunflower, soybean, cabbage and onion *etc.* The result revealed that the population collected from castor recorded minimum LC_{50} value of (2.66 ppm) and it was followed by sunflower (2.81 ppm), groundnut (2.82 ppm), onion (2.86 ppm), cabbage (2.90 ppm) and soybean (2.94 ppm). Highest LC_{50} value of 3.29 ppm was found in population collected from chilli ecosystem indicating that these populations showed less susceptibility than the population collected from other ecosystem.

2.2. Phyto-toxicity of insecticides on potato

Daniela *et al.* (2000) tested the phytotoxic potential of *Beauveria brongniartii* (Saccardo) against seed potatoes. *B. brongniartii* not showed any phtotoxicity on potato.

Gaskin *et al.* (2000) sprayed two novel organosilicone adjuvant blends, Du-Wett and Bond Xtra on potato crop and both were showed no any risk of phytotoxicity.

Begona *et al.* (2006) studied effect of insecticides *viz.*, imidacloprid, pirimicarb or mineral oil on *Myzus persicae* (Sulzer) on potato crop. When these insecticides were sprayed on potato plants highest mortality of aphids (over 80%) was observed without symptoms of phytotoxicity on the potato plants and yield was not reduced.

Kharbade (2011) reported that entomopathogenic fungus *viz.*, *M. anisopliae*, *B. bassiana*, *V. lecanii*, botanicals *viz.*, *dashparni* extract, neem based insecticides and thiamethoxam 25 WG were not phytotoxic on the *Bt* cotton crop.

No phytotoxicity was observed with organic pesticides *viz.*, Hinganbet @ 5%, Ritha fruit extract @ 5% and NSKE @ 5% on cotton crop (Anonymous, 2013).

Wrighta *et al.* (2014) reported that wettable sulphur was not showed any phytotoxicity symptoms on tomato and potato.

2.3. Influence of insecticides on natural enemies

Ghelani *et al.* (2000) evaluated toxicity of various synthetic (quinalphos 0.05%, monocrotophos 0.04%, endosulfan 0.07%, methyl-o-demeton 0.025%, phosphamidon 0.03%, chlorpyriphos 0.04% and dimethoate 0.03%) and botanical (nicotine 0.5%) insecticides. The synthetic insecticides were more toxic than botanical, among the synthetic insecticides, quinalphos was highly toxic to bug, while botanicals were safe to assassin bug.

Ravichandran *et al.* (2003) tested cypermethrin on the functional response of predatory and mating behaviour of assassin bug (*Acanthaspis pedestris* Stal.). The intensity of abnormal behaviour increased as the concentration of cypermethrin was increased. Cypermethrin also reduced the predatory efficiency and prolonged the mating events in *A. pedestris*.

Paul *et al.* (2004) evaluated eleven insecticides (Carbaryl, esfenvalerate, deltamethrin, monocrotophos, chlorpyrifos, methomyl, cypermethrin, methidathion, malathion, dimethoate and endosulfan) in cotton, to test the compatibility with natural enemies *viz.*, assassin bug

(*Pristhesancus plagipennis* Walker) and it was proved that these insecticides are toxic to assassin bugs.

Grundy (2007) used indoxacarb, pyriproxifen, buprofezin, spinosad and fipronil for control of *Helicoverpa armigera*, and *Creontiades spp*. in cotton. However, these insecticides were reported to be toxic to assassin bug, (*P. plagipennis*).

Pathan *et al*. (2008) studied the toxicity of pyrethroid classes and organophosphate against different *Chrysoperla carnea* (Stephens). The LC_{50} values for chlorpyrifos and profenofos were in the range of 59.3-1,023 and 180.02-1,118 respectively. The LC_{50} values of lambda-cyhalthrin, alphamethrin and deltamethrin were 359.08-2,677, 112.9-923.5, and 47.81-407.03, respectively.

Arno and Gabarra (2011) studied the side effects of selected insecticides on the *Tuta absoluta* (Tomato leafminer) predators *Macrolophus pygmaeus* (Predatory bug) and *Nesidiocoris tenuis*, predatory mirid bug (Hemiptera: Miridae). Seven days after applying the insecticides the mortality produced by indoxacarb ranged from 28% for nymphs of *M. pygmaeus* to 77% for females of *N. tenuis* and were significantly higher than those produced by azadirachtin, spinosad and the control (<13%). Spinosad significantly reduced the offspring of *M. pygmaeus* and azadirachtin significantly reduced the offspring of *N. tenuis* females.

Muhammad *et al.* (2012) conducted experiment to develop IPM package for green peach aphid, *Myzus persicae*

(Sulzer) on potato crop. The population means of ladybird beetles per 10 plants showed significant effect ($P<0.05$) for potato varieties, foliar insecticides (2.9 on Actara and 3.8 on Provado), and foliar insecticide doses (0.9 on labeled dose, 2.7 on reduced dose and 6.5 on zero dose). Both the insecticides at either dosage significantly reduced the ladybird beetle population as compared to zero dose (6.53). However, plants treated with Provado reduced dose had significantly higher population of ladybird beetles (3.63) as compared to Actara reduced dose (1.67).

Imura (2013) studied the insecticidal effects on the twenty eight spotted lady bird and *Orius* spp. brinjal. Fenpyroxymate buprofezin, indoxacarb, pyrifluquinazon, and permethrin was reducd the population of these natural enemies.

Mukesh *et al.* (2013) evaluated effect of insecticides on the population of *C. carnea* in green gram. The treatments of dimethoate 0.03%, profenophos 0.05%, abamectin at 0.01% and diafenthiuron at 0.05% were highly toxic. The treatment of imidacloprid 0.005%, thiamethoxam 0.025% and acephate 0.037% were moderately toxic against the predator. The treatment of karanj extract 5 ml/l, azadirachtin 5 ml/l, *M. anisopliae* $1x10^8$ spores/l and *B. bassiana* $1x10^8$ spores/l were least toxic to *C. carnea.*

3. MATERIALS AND METHODS

The present experiment "Management of *Spodoptera litura* (Fab.) on potato" was conducted to study the bio-efficacy of insecticides against *S. litura* on potato, phyto-toxicity of insecticides on potato crop and the influence of insecticides on natural enemies.

The experiment was carried out at AICRP Potato, NARP, Pune in *Kharif* season during 2014-15.

The materials and methods employed to study above aspects was described in this chapter.

3.1. Materials

3.1.1. Potato tuber seed

The potato tuber seed "*Kufri Ashoka*" variety was procured from CPRS, Modipuram through AICRP Potato, NARP, Ganeshkhind, Pune.

3.1.2. Insecticides and Appliances

Chemical insecticides required for the spraying were purchased from the local market while bio-pesticides required for the experiment were made available from Bio-control laboratory, Agricultural Entomology section, College of Agriculture, Pune. The details of insecticides and biopesticides used for the experiment with their name, dose/ liter of water and source of product are given in Table 1.

The Hand operated knapsack sprayer, manufactured by M/s American Spring and Pressing Company, Malad, Mumbai was used for the application of insecticides and biopesticides.

Table 1. Details of insecticides used for spraying

Tr. No.	Treatment	Trade name	Dose /ha (Kg or lit)	Source / Manufacturer
T_1	*Nomuraea rileyi* (Farlow) (1×10^8 cfu/ml)	Phule *Nomuraea*	2.00 Kg	Biological Control Laboratory, Department of Agril. Entomology, College of Agriculture, Pune.
T_2	*Metarhizium anisopliae* (Metchnikoff) Sorokin (1×10^8 cfu/ml)	Phule *Metarhizim*	2.00 Kg	Biological Control Laboratory, Department of Agril. Entomology, College of Agriculture, Pune.
T_3	*Spodoptera litura* (Fabricius)NPV (750 LE/ha)	Phule Magic	0.50 lit.	M.P.K.V. Rahuri.
T_4	Neem oil 1 %	Nimbin	1.00 lit.	Multimol Micro Fertilizer Industries Sinnar, Nasik.
T_5	Lambda-cyhalothrin 5 SC	Karate	0.50 lit.	Syngenta Co. Ltd.
T_6	Flubendiamide 39.35 SC	Fame	0.50 lit.	Bayer Crops Science Pvt Ltd.
T_7	Indoxacarb 15.8 EC	Avaunt EC	0.50 lit.	E. I. Dupont Co.
T_8	Profenophos 44 EC	Polytrin-C	1.00 lit.	Syngenta Co. Ltd.
T_9	Untreated control	Water Spray	-	-

3.2. Methods for field experiment

3.2.1. Experimental Details

Design of experiment	:	Randomized Block Design
Crop	:	Potato
Cultivar	:	*Kufri Ashoka*
Number of replications	:	Three
Number of treatments	:	Nine
Plot size	:	3.00 m. x 2.00 m.
Spacing	:	60 cm. x 25 cm.
Season	:	*Kharif* 2014
Date of planting	:	21th July 2014
Date of first spraying	:	5th August 2014
Date of second spraying	:	19th August 2014
Date of harvesting	:	2nd November 2014
Location	:	AICRP Potato, NARP, Pune.

3.2.2. Layout of experiment

RI	RII	RIII
T_9	T_1	T_5
T_6	T_4	T_8
T_1	T_7	T_3
T_3	T_9	T_6
T_5	T_2	T_4
T_8	T_6	T_1
T_7	T_3	T_7
T_2	T_5	T_2
T_4	T_8	T_9

N

3.3. Insecticidal application

The quantity of spray required was estimated each time by spraying water on control plots. The quantity of insecticides required for preparing solution was calculated for each insecticidal treatment. At the time of preparing spray fluid, the measured quantity of insecticide was mixed with required quantity of water and then the solution was poured in knapsack sprayer and used for spraying.

3.4. Method of application of insecticidal spray

The insecticidal sprays were applied on each plot of irrespective treatments of all three replications at a time. The first sparying of insecticidal was given immediately after observing uniform larval population of *S. litura* on all plots and second spary was applied 14th days after first spraying. Both spary was given as a foliar spary in morning hours or in eveving with the help of hand operated high volume knapsack sprayer. Avoid the drifts of spray fluid on neighboring plots. Care had taken to wash thoroughly the spray pump with water before using for other insecticides.

3.5. Method of recording observations

3.5.1 Bio-efficacy of insecticides against *S. litura* on potato

3.5.1.1. Egg masses

The no. of egg masses of *S. litura* on plant/meter row length considered for recording the egg masses population during the study. The egg masses were recorded early in the morning on potato crop.

The egg masses population recorded one day before spraying was considered as a pre-count while 3rd day after 1st and 2nd spray was considered as a post-count.

3.5.1.2. Larval population

The no. of live larvae of *S. litura*/meter row length on plants as well as in soil considered for recording the population of during the study. The larval population was recorded early in the morning when most of the larvae were found to feed on foliage of potato crop.

The larval population recorded one day before spraying was considered as a pre-count while survival population recorded on 3rd, 7th and 14th day after spraying were considered as post-count.

3.5.1.3. Per cent foliar damage

For screening against per cent foliar damage, five plants were selected randomly and per cent plant damage and leaf damage were estimated. The data (leaf damage) recorded was analyzed statistically following analysis of variance technique for randomized block design and interpreted at five per cent level of significance (Shankarappa and Shashibhushan, 2009).

3.5.2. Per cent tuber damage

For recording the per cent tuber damage due to *S. litura*, the healthy tubers and damaged tubers were seprated and counted from each plot at the time of harvesting and per cent tuber damage was calculated (Shankarappa and Shashibhushan, 2009).

3.5.3. Tuber yield

Tuber yield was recorded at the time of harvesting from each plot. The weight of tuber was recorded per plot in kg and then converted to tonnes per hectare.

3.5.4. Influence of insecticides on natural enemies

The population of natural enemy of *S. litura* i.e. assassin bug (*Rhynocoris fusipes* Fab.) was recorded before spraying as a pre-count and after 14 DAS of second spray as a post-count.

3.5.5. Phyto-toxicity of insecticides on potato

Observation of phytotoxicity symptoms on potato was recorded on 3rd, 7th and 14th days after insecticidal treatments for the phytotoxic symptoms *viz.*, injury to leaf tips, leaf surface, wilting, necrosis, epinasty and hyponasty on plants were taken in to consideration. The total number of leaves and those showing phytotoxicity if any were counted. The data collected was converted into percentage. The extent of phytotoxicity was recorded based on phytotoxicity scale 0 to 10 (Table 2).

Table 2.

Score	**Phytotoxicity (%)**
0	No Phytotoxicity
1	0-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-90
10	91-100

The per cent leaf injury was calculated by using following formula.

$$\text{Per cent leaf injury} = \frac{\text{Total grade point}}{\text{Maximum grade x No. of leaves observed}} \times 100$$

3.6. Analysis of data

The data on average population of *S. litura* larvae and egg mass were transformed into square root values by Poisson formula $\sqrt{x + 0.5}$ while Per cent foliar damage and per cent tuber damage were analysed by arc sin transformation table values, as given by C. I. Bliss (Panse and Sukhatme, 1967).

4. RESULTS AND DISCUSSION

The experiment was carried out to study the bio-efficacy of insecticides against *Spodoptera litura* (Fab.) on potato, study the phyto-toxicity of insecticides on potato and influence of insecticides on natural enemies in *Kharif* season of 2014-2015. The results obtained were discussed in this chapter.

4.1. Bio-efficacy of insecticides against *S. litura* on potato

4.1.1. Bio-efficacy of insecticides against egg masses of *S. litura* on potato

The bio-efficacy of the treatments were assessed on the basis of number of egg masses per meter row length before spray and 3rd day each after 1st and 2nd spray.

The data presented in Table 3 and depicted in Fig. 1 indicated the bio-efficacy of insecticides against egg masses of *S. litura* on potato. The pre-count data were statistically non-significant and pre-count ranged from 1.22 to 1.54 egg masses/meter row length in experimental field.

4.1.1.1. After first spray

Three days after first spraying, the data indicated that, the treatment with flubendiamide 39.35 SC was found to be most effective which recorded lowest egg masses population of 0.52 egg masses/meter row length and was on par with profenophos 44 EC in which 0.56 egg masses/meter row length was observed. The next best treatment in order of bio-efficacy was indoxacarb 15.8 EC which recorded 0.62

Table 3: Bio-efficacy of insecticides against egg masses of *S. litura* on potato

Number of egg masses/meter row length						
Treat. No.	**Treatments**	**Dose/ha**	**Pre-count**	**Ist spray 3 DAS**	**IInd spray 3 DAS**	**Mean**
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	1.33 (1.35)	0.93 (1.20)	0.54 (1.02)	0.74 (1.11)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	1.52 (1.42)	1.08 (1.26)	0.85 (1.16)	0.96 (1.21)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	1.41 (1.38)	0.86 (1.17)	0.49 (1.00)	0.68 (1.08)
T_4	Neem oil 1%	1.00 lit.	1.30 (1.34)	0.97 (1.21)	0.67 (1.08)	0.82 (1.15)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	1.54 (1.43)	0.77 (1.13)	0.38 (0.93)	0.58 (1.04)
T_6	Flubendiamide 39.35 SC	0.50 lit.	1.30 (1.33)	0.52 (1.01)	0.18 (0.82)	0.35 (0.92)
T_7	Indoxacarb 15.8 EC	0.50 lit.	1.50 (1.41)	0.62 (1.06)	0.29 (0.89)	0.46 (0.98)
T_8	Profenophos 44 EC	1.00 lit.	1.22 (1.31)	0.56 (1.03)	0.21 (0.84)	0.39 (0.94)
T_9	Untreated control	Water spray	1.38 (1.37)	1.61 (1.45)	1.53 (1.42)	1.57 (1.44)
SEm ±			0.05	0.02	0.05	0.03
C. D. at 5 %			NS	0.06	0.15	0.08

Mean of three replications, DAS- days after spraying
Figures in the parenthesis are means of $\sqrt{x+0.5}$ transformed values

egg masses/meter row length. This was followed by lambda-cyhalothrin 5 SC, *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) which chronicled 0.77, 0.86, 0.93 and 0.97, 1.08 egg masses/meter row length, respectively. The highest egg masses population of 1.61 egg masses/meter row length was observed in untreated control.

4.1.1.2. After second spray

The data on the bio-efficacy of treatments at varied intervals after second spray were furnished in Table 3 and in Fig. 1.

On 3rd days after second spraying the treatment with flubendiamide 39.35 SC was superior by recorded 0.18 egg masses/meter row length and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.21 and 0.29 egg masses/meter row length were observed. The next best treatments were lambda-cyhalothrin 5 SC (0.38 egg masses), *Sl*NPV (750 LE /ha) (0.49 egg masses), *N. rileyi* (1×10^8 cfu/ml) (0.54 egg masses), neem oil 1% (0.67 egg masses) and *M. anisopliae* (1×10^8 cfu/ml) (0.85 egg masses) were observed. The highest egg masses population of 1.53 egg masses/meter row length was observed in untreated control after second spray.

Overall results of first and second spray revealed that flubendiamide 39.35 SC was observed to be most promising by recording lowest of 0.35 egg masses/meter row length which was on par with profenophos 44 EC in which 0.39 egg masses/meter row length was observed. The next best treatments in descending order of efficacy were indoxacarb 15.8 EC, lambda-cyhalothrin 5 SC, *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.46, 0.58, 0.68, 0.74, 0.82 and 0.96 egg masses/meter row length were recorded. The untreated control recorded highest of 1.57 egg masses/meter row length.

Trends of the bio-efficacy of insecticides against egg masses of *S. litura* on potato in the order of statistical performance were depicted below.

Trends: Flubendiamide 39.35 SC and Profenophos 44 EC > Indoxacarb 15.8 EC > Lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) and *N. rileyi* (1×10^8 cfu/ml) > Neem oil 1% > *M. anisopliae* (1×10^8 cfu/ml).

Hanan *et al.* (2014) reported that flubendiamide and profenophos exhibited high inhibitory activity in suppressing the number of egg masses of *S. litura* which is in accordance with present results.

Zidan *et al.* (2000) proved that profenophos was most effective having ovicidal action against egg masses of *S. litura* which are corroborated with present findings.

Anand and Tiwary (2009) found that the positive results of ovicidal activity of biopesticides *viz.*, *N. rileyi*, *M. anisopliae* which are in agreement with present results.

4.1.2. Bio-efficacy of insecticides against larval population of *S. litura* on potato

The bio-efficacy of insecticides against *S. litura* on potato were assessed on the basis of number of larvae per/meter row length before spray and 3rd, 7th and 14th days after first and second spraying.

4.1.2.1. After first spray

Performance of each treatment was judged on the basis of survival larval population of *S. litura*.

A perusal of data from Table 4 and depicted in Fig. 2 indicated that there was no significant difference in pre-count of larval population in field experimental plots showing uniform pest distribution all over the field. The larval population before spray ranged from 4.88 to 6.12 larvae/meter row length.

Three days after first spraying, all the treatments were significantly superior over untreated control in reducing larval population. Among the insecticides, the treatment with flubendiamide 39.35 SC was found to be most promising by recording lowest larval population of 1.80 larvae per/meter row length and was on par with profenophos 44 EC, indoxacarb 15.8 EC and lambda-cyhalothrin 5 SC in which 1.94, 2.00 and 2.20 larvae/meter row length were observed. The next best treatment in order of their bio-efficacy was *Sl*NPV (750 LE/ha) which had recorded 3.82 larvae/meter row length. This was followed by *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 4.58, 4.94 and 4.98 larvae/meter

Table 4: Bio-efficacy of insecticides against *S. litura* larvae on potato after first spray

Population of live larvae/meter row length							
Treat. No.	**Treatments**	**Dose/ha**	**Pre-count**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	5.70 (2.49)	4.58 (2.25)	3.10 (1.90)	2.40 (1.70)	3.36 (1.96)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	5.17 (2.38)	4.98 (2.34)	3.22 (1.93)	2.88 (1.84)	3.69 (2.05)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	4.88 (2.32)	3.82 (2.08)	2.88 (1.84)	2.00 (1.58)	2.90 (1.84)
T_4	Neem oil 1%	1.00 lit.	5.10 (2.36)	4.94 (2.33)	3.20 (1.92)	2.56 (1.75)	3.56 (2.01)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	5.22 (2.39)	2.20 (1.63)	1.98 (1.57)	1.50 (1.41)	1.89 (1.54)
T_6	Flubendiamide 39.35 SC	0.50 lit.	4.94 (2.33)	1.80 (1.52)	1.12 (1.27)	0.93 (1.20)	1.28 (1.33)
T_7	Indoxacarb 15.8 EC	0.50 lit.	5.47 (2.44)	2.00 (1.58)	1.46 (1.40)	1.07 (1.25)	1.51 (1.41)
T_8	Profenophos 44 EC	1.00 lit.	6.12 (2.57)	1.94 (1.56)	1.20 (1.30)	1.00 (1.22)	1.38 (1.37)
T_9	Untreated control	Water spray	5.88 (2.52)	7.80 (2.88)	9.10 (3.10)	10.40 (3.30)	9.10 (3.10)
SEm ±			0.06	0.14	0.12	0.08	0.06
C. D. at 5 %			NS	0.41	0.35	0.23	0.17

Mean of three replications, DAS- days after spraying
Figures in the parenthesis are means of $\sqrt{x+0.5}$ transformed values

row length were noticed, respectively. The highest larval population of 7.80 larvae/meter row length was observed in untreated control.

At 7th days after spraying, the flubendiamide 39.35 SC recorded lowest larval count of 1.12 larvae/meter row length and was found on par with profenophos 44 EC (1.20 larvae) and indoxacarb 15.8 EC (1.46 larvae). The next insecticidal treatment was lambda-cyhalothrin 5 SC in which 1.98 larvae/meter row length was observed. However, it was followed by *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1%, and *M. anisopliae* (1×10^8 cfu/ml) in which 2.88, 3.10, 3.20 and 3.22 larvae/meter row length were observed, respectively. The highest larval population of 9.10 larvae/meter row length was observed in untreated control.

At 14th days after first spraying, the significant variation in larval population was observed in different insecticidal treatments. The insecticide treatment, flubendiamide 39.35 SC has maintained its superiority over rest of the treatments by recording 0.93 larvae/meter row length which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 1.00 and 1.07 larvae/meter row length were noticed, respectively. The next best treatment in order of bio-efficacy was lambda-cyhalothrin 5 SC which was recorded 1.50 larvae/meter row length was followed by *Sl*NPV (750 LE/ha) in which 2.00 larvae/meter row length was observed. This was followed by *N. rileyi* (1×10^8 cfu/ml), neem oil 1%, and *M. anisopliae* (1×10^8 cfu/ml), 2.40, 2.56 and 2.88 larvae per/meter row length were noticed, respectively. In untreated control 10.40 larvae/meter row length was observed.

Overall results of the first spray revealed that all the insecticidal treatments were found to be effective against *S. litura* over untreated control. The treatment with flubendiamide 39.35 SC was observed to be most promising by recording larval population 1.28 larvae/meter row length which was on par with profenophos 44 EC in which 1.38 larvae/meter row length was observed. The next best treatments in descending order of their bio-efficacy were indoxacarb 15.8 EC (1.51 larvae) > lambda-cyhalothrin 5 SC (1.89 larvae) > *Sl*NPV (750 LE/ha) (2.90 larvae) > *N. rileyi* (1×10^8 cfu/ml) (3.36 larvae) > neem oil 1% (3.56 larvae) and *M. anisopliae* (1×10^8 cfu/ml) (3.69 larvae). In untreated control larval population was found to be 9.10 larvae/meter row length was observed after first spraying.

4.1.2.2. After second spray

The data on the bio-efficacy of treatments at varied intervals after second spray are furnished in Table 5 and in Fig. 3.

All the treatments were found significantly superior over untreated control after 3 DAS of second spraying, in controlling the larval population. The treatment with flubendiamide 39.35 SC was found to be the most effective which recorded lowest larval population of 0.73 larvae/meter row length and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.87 and 0.93 larvae/meter row length were observed, respectively. The

Table 5: Bio-efficacy of insecticides against *S. litura* larvae on potato after second spray

Population of live larvae/meter row length						
Treat. No.	**Treatments**	**Dose/ha**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	1.80 (1.52)	1.20 (1.30)	0.87 (1.17)	1.29 (1.33)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	2.53 (1.74)	2.13 (1.62)	1.47 (1.40)	2.04 (1.59)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	1.67 (1.47)	1.13 (1.28)	0.60 (1.05)	1.13 (1.28)
T_4	Neem oil 1%	1.00 lit.	2.00 (1.58)	1.93 (1.56)	1.33 (1.35)	1.75 (1.50)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	1.20 (1.30)	1.07 (1.25)	0.53 (1.02)	0.93 (1.20)
T_6	Flubendiamide 39.35 SC	0.50 lit.	0.73 (1.11)	0.53 (1.02)	0.20 (0.84)	0.49 (0.99)
T_7	Indoxacarb 15.8 EC	0.50 lit.	0.93 (1.20)	0.73 (1.11)	0.40 (0.95)	0.69 (1.09)
T_8	Profenophos 44 EC	1.00 lit.	0.87 (1.17)	0.67 (1.08)	0.33 (0.91)	0.62 (1.06)
T_9	Untreated control	Water spray	10.13 (3.26)	9.27 (3.13)	10.53 (3.32)	9.98 (3.24)
SEm ±			0.07	0.07	0.07	0.03
C. D. at 5 %			0.21	0.20	0.21	0.09

Mean of three replications, DAS- days after spraying
Figures in the parenthesis are means of $\sqrt{x+0.5}$ transformed values

next best treatment in order of their bio-efficacy was lambda-cyhalothrin 5 SC which recorded 1.20 larvae/meter row length. This was followed by *Sl*NPV (750 LE/ha) (1.67 larvae) and *N. rileyi* (1×10^8 cfu/ml) (1.80 larvae) followed by neem oil 1% (2.00 larvae) followed by *M. anisopliae* (1×10^8 cfu/ml) (2.53 larvae). The higher larval population of 10.13 larvae/meter row length was observed in untreated control.

At 7th days after spraying, the flubendiamide 39.35 SC recorded lowest 0.53 larvae/meter row length and was on par with profenophos 44 EC (0.67 larvae) and indoxacarb 15.8 EC (0.73 larvae). The next best insecticidal treatment was lambda-cyhalothrin 5 SC in which 1.07 larvae/meter row length was observed and was at par with *Sl*NPV (750 LE/ha) and *N. rileyi* (1×10^8 cfu/ml) in which 1.13 and 1.20 larvae/meter row length was recorded, respectively. This was followed by neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 1.93 and 2.13 larvae/meter row length were observed, respectively. The higher larval population of 9.27 larvae/meter row length was observed in untreated control.

On 14th days after second spraying, all the treatments bared significant discrepancy in larvae/meter row length. The treatment with flubendiamide 39.35 SC was recorded lowest of 0.20 larvae/meter row length and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.33 and 0.40 larvae/meter row length were observed. The next best treatment was lambda-cyhalothrin 5 SC which recorded 0.53 larvae/meter row length and at par with

*Sl*NPV (750 LE/ha) in which 0.60 larvae/meter row length was observed. This was followed by *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) which chronicled 0.87, 1.33 and 1.47 larvae/meter row length, respectively. In untreated control larval population was increased up to 10.53 larvae/meter row length after second spray.

Overall results of the second spray revealed that all the insecticidal treatments were found to be effective against *S. litura* over untreated control. The treatment with flubendiamide 39.35 SC was observed to be most promising by recording larval population of 0.49 larvae/meter row length which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.62 and 0.69 larvae/meter row length was observed. The next best treatments in descending order of their bio-efficacy were lambda-cyhalothrin 5 SC followed by *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.93, 1.13, 1.29, 1.75 and 2.04 larvae/meter row length were recorded.

Trends of the bio-efficacy of insecticides against *S. litura* on potato in the order of statistical performance were depicted below.

Trends: Flubendiamide 39.35 SC > Profenophos 44 EC and indoxacarb 15.8 EC > Lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > Neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml).

The results obtained in the present study are in agreement with Tomar *et al.* (2005) who indicated that flubendiamide 20 WDG @ 25 a.i./ha was effective on reducing larval population of *S. litura* on cotton. Tatagar *et al.* (2009) also indicated that flubendiamide 20 WG @ 60 a.i./ha recorded lowest fruit damage (3.45%) due to *S. litura* in chilli.

Reddy *et al.* (2005) reported that indoxacarb reduced the larval population of *S. litura* on sunflower. Venkateswarlu *et al.* (2005) studied that indoxacarb and profenophos have higher relative toxicity for the management of *S. litura* on cotton crop.

The present findings are in accordance with Kulkarni and Lingappa (2002) who reported significantly superior results of *N. rileyi*, NPV against *S. litura* on potato. Bio-efficacy of *Sl*NPV (750 LE/ha) found to be significantly promising against *S. litura* causing 91.68% larval mortality on potato reported by Pokharkar *et al.* (2001) which is close in agreement with present results.

4.1.3. Per cent foliar damage due to *S. litura* on potato

The per cent foliar damage due to *S. litura* on potato were assessed on the basis of per cent foliar damage per plant before spray and 3rd, 7th and 14th days after first and second spraying.

4.1.3.1. After first spray

Performance of each treatment was judged on the basis of per cent foliar damage due to *S. litura*.

A perusal of data from Table 6 and depicted in Fig. 4 indicated that there was no significant difference in pre-count of per cent foliar damage in field experimental plots showing even distribution of pest causing homogenous damage. The per cent foliar damage before spray ranged from 34.40 to 37.60 per cent/plant.

Three days after first spraying, all the treatments were significantly superior over untreated control in reducing per cent foliar damage. Among the insecticides, the treatment with flubendiamide 39.35 SC was found to be most promising by recording lowest per cent foliar damage of 26.93 per cent/plant and was on par with profenophos 44 EC, indoxacarb 15.8 EC and lambda-cyhalothrin 5 SC in which 28.20, 28.40 and 28.80 per cent foliar damage/plant were observed, respectively. The next best treatment in order of efficacy was *Sl*NPV (750 LE/ha) which recorded 31.07 per cent foliar damage/plant this was followed by *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 31.27, 31.53 and 32.73 per cent foliar damage/plant were noticed, respectively. The highest per cent foliar damage was observed in untreated control (35.13 per cent/plant).

At 7th days after spraying, the flubendiamide 39.35 SC exhibited lowest of 22.93 per cent foliar damage per plant and was on par with profenophos 44 EC, indoxacarb 15.8 EC and lambda-cyhalothrin 5 SC in which 24.40, 25.93 and 26.07 per cent foliar damage observed, respectively. This was followed by *Sl*NPV (750 LE/ha) and *N. rileyi*

Table 6: Per cent foliar damage due to *S. litura* on potato after first spray

Per cent foliar damage/plant							
Treat. No.	**Treatments**	**Dose/ha**	**Pre-count**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	37.60 (37.81)	31.27 (34.00)	29.00 (32.58)	26.87 (31.22)	29.97 (33.15)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	35.20 (36.38)	32.73 (34.90)	31.93 (34.40)	28.47 (32.24)	31.04 (33.83)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	35.27 (36.42)	31.07 (33.87)	27.07 (31.32)	25.93 (30.61)	28.02 (31.95)
T_4	Neem oil 1%	1.00 lit.	37.00 (37.44)	31.53 (34.15)	30.80 (33.70)	27.60 (31.68)	28.73 (32.41)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	36.13 (36.93)	28.80 (32.44)	26.07 (30.67)	23.47 (28.95)	26.11 (30.72)
T_6	Flubendiamide 39.35 SC	0.50 lit.	36.20 (36.97)	26.93 (31.25)	22.93 (28.54)	20.20 (26.69)	23.36 (28.86)
T_7	Indoxacarb 15.8 EC	0.50 lit.	35.87 (36.78)	28.40 (32.19)	25.93 (30.56)	22.27 (28.12)	25.53 (30.33)
T_8	Profenophos 44 EC	1.00 lit.	36.00 (36.86)	28.20 (32.05)	24.40 (29.54)	21.13 (27.30)	24.57 (29.67)
T_9	Untreated control	Water spray	34.40 (35.88)	35.13 (36.35)	35.53 (36.58)	37.20 (37.58)	35.96 (36.81)
SEm ±			1.26	0.79	1.19	0.95	0.88
C. D. at 5 %			NS	2.37	3.56	2.85	2.64

Mean of three replications, DAS- days after spraying
Figures in the parenthesis are means of arc sin transformation values

(1×10^8 cfu/ml) in which 27.07 and 29.00 per cent/plant were observed. This was followed by neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 30.80 and 31.93 per cent foliar damage per plant were observed, respectively. In untreated control highest foliar damage was observed (35.53 per cent/plant).

At 14th days after first spraying, the significant variation in per cent foliar damage was observed in insecticidal treatments. The insecticide treatment, flubendiamide 39.35 SC had maintained its superiority over rest of the treatments by recording 20.20 per cent foliar damage/plant which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 21.13 and 22.27 per cent foliar damage/plant were noticed, respectively. The next best treatment in order of lambda-cyhalothrin 5 SC which was recorded 23.47 per cent/plant and followed by *Sl*NPV (750 LE/ha) (25.93 per cent/plant) followed by *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 26.87, 27.60 and 28.47 per cent foliar damage per/plant were reported, respectively. In untreated control per cent foliar damage was increased up to 37.20 per cent/plant.

Overall results of the first spray revealed that all the insecticidal treatments were found to be effective against *S. litura* over untreated control. The treatment with flubendiamide 39.35 SC was observed to be most promising by recording 23.36 per cent foliar damage/plant which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 24.57 and 25.53 per cent foliar damage/plant was exhibited, respectively. The next best treatments in descending order lambda-cyhalothrin 5 SC (26.11 per cent/plant) and was at par with *Sl*NPV (750 LE/ha) (28.02 per cent/plant). This was followed by *N. rileyi* (1×10^8 cfu/ml) (29.04 per cent/plant), neem oil 1% (29.97 per cent/plant) and *M. anisopliae* (1×10^8 cfu/ml) (31.04 per cent/plant) foliar damage was recorded after first spraying. In untreated control per cent foliar damage was observed 35.96 per cent/plant.

4.1.3.2. After second spray

The data on the per cent foliar damage varied intervals after second spray were furnished in Table 7 and in Fig. 5.

Three days after second spraying, all the treatments were significantly superior over untreated control in reducing per cent foliar damage. Among the insecticides, the treatment with flubendiamide 39.35 SC was found to be most effective which was recorded 14.60 per cent foliar damage/plant and found on par with profenophos 44 EC in which 15.67 per cent/plant foliar damage was observed. The next best treatment was indoxacarb 15.8 EC which was recorded 15.93 per cent foliar damage/plant. This was followed by lambda-cyhalothrin 5 SC (17.60 per cent/plant), *Sl*NPV (750 LE/ha) (18.27 per cent/plant), *N. rileyi* (1×10^8 cfu/ml) (19.33 per cent/plant), neem oil 1% (21.07 per cent/plant) and *M. anisopliae* (1×10^8cfu/ml) (21.73 per cent/plant) foliar damage were observed after second spraying.

Table 7: Per cent foliar damage due to *S. litura* on potato after second spray

Per cent foliar damage/plant						
Treat. No.	**Treatments**	**Dose/ha**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	19.33 (26.08)	16.13 (23.67)	12.07 (20.32)	15.84 (23.42)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	21.73 (27.79)	18.40 (25.40)	14.11 (22.05)	18.08 (25.13)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	18.27 (25.30)	14.53 (25.08)	10.85 (19.22)	14.55 (22.38)
T_4	Neem oil 1%	1.00 lit.	21.07 (27.32)	17.60 (24.80)	12.87 (21.01)	17.18 (24.45)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	17.60 (24.80)	12.73 (26.55)	8.40 (16.84)	12.91 (21.02)
T_6	Flubendiamide 39.35 SC	0.50 lit.	14.60 (22.46)	10.13 (18.55)	5.80 (13.93)	10.18 (18.56)
T_7	Indoxacarb 15.8 EC	0.50 lit.	15.93 (23.52)	11.00 (26.31)	6.40 (14.65)	11.11 (19.43)
T_8	Profenophos 44 EC	1.00 lit.	15.57 (23.32)	10.53 (18.94)	6.00 (14.18)	10.70 (19.12)
T_9	Untreated control	Water spray	37.67 (37.86)	41.40 (40.05)	39.33 (38.84)	39.47 (37.72)
SEm ±			0.30	0.58	0.31	0.92
C. D. at 5 %			0.91	1.75	0.94	2.26

Mean of three replications, DAS- days after spraying
Figures in the parenthesis are means of arc sin transformation values

The highest per cent foliar damage was observed in untreated control 37.67 per cent/plant.

At 7th days after spraying, the flubendiamide 39.35 SC recorded lowest of 10.13 per cent foliar damage/plant and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 10.53 and 11.00 per cent foliar damage/plant were observed. The next best treatment was lambda-cyhalothrin 5 SC in which 12.73 per cent/plant was observed. This was followed by *Sl*NPV (750 LE/ha) (14.53 per cent/plant) and *N. rileyi* (1×10^8 cfu/ml) (16.13 per cent/plant), neem oil 1% (17.60 per cent/plant) and *M. anisopliae* (1×10^8 cfu/ml) (18.40 per cent/plant) were observed, respectively. In untreated control per cent foliar damage was increased up to 41.40 per cent/plant.

On 14th days after second spraying, all the treatments bared significant discrepancy in per cent foliar damage/plant. The treatment with flubendiamide 39.35 SC was recorded lowest 5.80 per cent foliar damage/plant and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 6.00 and 6.40 per cent foliar damage/plant were observed. The next best treatment was lambda-cyhalothrin 5 SC recorded 8.40 per cent/plant. This was followed by *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) which chronicled 10.85, 12.07 and 12.87, 14.11 per cent foliar damage/plant, respectively. In untreated control foliar damage was observed 39.33 per cent/plant.

Overall results of second spray revealed that all the insecticidal treatments maintained their effectiveness against *S. litura* over untreated control. The treatment with flubendiamide 39.35 SC was perceived to be superior was recorded lowest 10.18 per cent foliar damage/plant and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 10.70 and 11.11 per cent/plant were observed. The next best treatment was lambda-cyhalothrin 5 SC in which 12.91 per cent/plant was observed and was at par with *Sl*NPV (750 LE/ha) in which 14.55 per cent/plant was noticed. This was followed by *N. rileyi* (1×10^8 cfu/ml) (15.84 per cent/plant) and neem oil 1% (17.18 per cent/plant) followed by *M. anisopliae* (1×10^8 cfu/ml) (18.08 per cent/plant) were observed, respectively. In untreated control 39.47 per cent foliar damage/plant was observed after second spray.

Trends of the bio-efficacy of insecticides against per cent foliar damage due to *S. litura* on potato in the order of statistical performance were depicted below.

Trends: Flubendiamide 39.35 SC > Profenophos 44 EC and Indoxacarb 15.8 EC > Lambda-cyhalothrin 5 SC and *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > Neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml).

The results are in confirmation with those of Shankarappa and Bhushan (2009) who reported that lufenuron 10% EC @ 2ml/lit was found to be best treatment with lowest foliar damage due to *S. litura* followed by acephate 75 WP @ 1 g/lit on potato crop.

Hole *et al.* (2009) reported that profenophos 0.1% gave maximum protection after application and reported 6.5 % foliar damage in soybean which is in accordance with present results.

Goshal *et al.* (2013) reported that rynaxyper and indoxacarb were most effective insecticide against foliar damage of *S. litura* on tomato which are corroborated with present findings.

Prasad and Sirisha (2009) tested the thiodicarb @ 562 g a.i/ha and chlorpyriphos @ 312 g a.i/ha were recorded lower larval incidence and shoot damage due to *S. litura* on onion crop which are in agreement with present findings.

4.2. Per cent tuber damage due to *S. litura* on potato

A result of per cent tuber damage due to *S. litura* recorded at the time of harvesting was described in Table 8 and in Fig. 6.

The per cent tuber damage was observed at the range of 8.02-20.03 per cent at the time of harvesting. Flubendiamide 39.35 SC was superior over all treatment causing minimum tuber damage (8.02 per cent/plot) and was on par with profenophos 44 EC (9.68 per cent/plot) and indoxacarb 15.8 EC (10.00 per cent/plot). The next best treatment was lambda-cyhalothrin 5 SC which was recorded 12.30 per cent tuber damage/plot. This was followed by *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 13.85, 14.53, 15.45 and 15.89 per cent tuber damage was observed, respectively. In untreated control per cent tuber damage

Table 8: Per cent tuber damage due to *S. litura* at harvesting

Per cent tuber damage at harvesting						
Treat. No.	**Treatments**		**Replication**			
		Dose /ha	**R I**	**R II**	**R III**	**Mean**
T_1	*Nomuraea rileyi* ((1×10^8 cfu/ml))	2.00 kg	11.36 (19.64)	16.30 (23.81)	15.92 (23.50)	14.53 (22.32)
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	14.20 (22.14)	19.26 (25.99)	14.22 (22.14)	15.89 (23.42)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	13.00 (21.13)	13.96 (21.89)	14.52 (22.38)	13.83 (21.80)
T_4	Neem oil 1 %	1.00 lit.	15.42 (23.11)	15.46 (23.11)	15.48 (23.11)	15.45 (23.11)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	13.00 (21.13)	10.68 (19.00)	13.22 (21.30)	12.30 (20.48)
T_6	Flubendiamide 39.35 SC	0.50 lit.	8.33 (16.74)	8.14 (16.54)	7.58 (15.89)	8.02 (16.39)
T_7	Indoxacarb 15.8 EC	0.50 lit.	9.40 (17.85)	8.80 (17.26)	11.80 (20.09)	10.00 (18.40)
T_8	Profenophos 44 EC	1.00 lit.	9.56 (17.95)	9.24 (17.66)	10.24 (18.63)	9.68 (18.08)
T_9	Untreated control	Water spray	20.36 (26.78)	21.34 (27.49)	18.40 (25.40)	20.03 (26.56)
SEm ±			0.78			
C. D. at 5 %			2.35			

Figures in the parenthesis are means of arc sin transformation values

was found higher as compared to all treatments (20.03%).

Trends of the bio-efficacy of insecticides against per cent tuber damage due to *S. litura* on potato in the order of statistical performance were depicted below.

Trends: Flubendiamide 39.35 SC > Profenophos 44 EC and Indoxacarb 15.8 EC > Lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) and *N. rileyi* (1×10^8 cfu/ml) > Neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml).

The studies carried out by Shankarappa and Bhushan (2009) are in agreement with the present investigations, who reported that carbaryl poison bait and lufenuron 10% EC which was lowest tuber damage 4.61 and 7.37 per cent on potato crop.

4.3. Effect of insecticidal treatments on yield of marketable potato

The yield of marketable potato obtained from insecticide treatments and presented in Table 9 and Fig. 7. Among the treatments, flubendiamide 39.35 SC was found to be most promising by recording highest yield of potato 21.80 tonnes/ha and was at par with profenophos 44 EC and indoxacarb 15.8 EC in which 21.55 and 21.35 tonnes/ha yield observed, respectively.

The next best treatment in order of merit was lambda-cyhalothrin 5 SC which recorded 17.21 tonnes/ha of marketable potato. This was followed by *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 16.65, 16.50, 16.00 and 15.21 tonnes/ha potato yield were recorded, respectively. The

Table 9: Effect of insecticidal treatments on yield of marketable potato

Treat. No.	Treatments	Dose/ha	Yield (ton/ha)
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	16.50
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	15.21
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	16.65
T_4	Neem oil 1%	1.00 lit.	16.00
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	17.21
T_6	Flubendiamide 39.35 SC	0.50 lit.	21.80
T_7	Indoxacarb 15.8 EC	0.50 lit.	21.35
T_8	Profenophos 44 EC	1.00 lit.	21.55
T_9	Untreated control	Water spray	12.50
SEm ±		-	0.14
CD at 5 %		-	0.45

lowest potato yield was recorded in untreated control i.e. 12.50 tonnes/ha.

Trends of the bio-efficacy of insecticides against yield of potato in the order of statistical performance were depicted below.

Trends: Flubendiamide 39.35 SC > Profenophos 44 EC and Indoxacarb 15.8 EC > Lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) and *N. rileyi* (1×10^8 cfu/ml) > Neem oil 1% > *M. anisopliae* (1×10^8 cfu/ml).

The results obtained in the present study are in agreement with Pokharkar *et al.* (2001) who reported that spray of *Sl*NPV (750 LE/ha) was significantly promising against *S. litura* and 20.8 tonnes/ha yield of marketable potato.

4.4. Influence of insecticides on natural enemies

The influence of insecticidal treatments on the assassin bug (*Rhynocoris fusipes*, Fab.) was recorded and data obtained presented in Table 10.

The pre-count population of predatory assassin bug before first spray ranged from 0.33-0.67/meter^2.

After the second spray of insecticides, flubendiamide 39.35 SC declined the assassin bug population from (0.60 to 0.07), followed by profenophos 44 EC (0.67 to 0.13), indoxacarb 15.8 EC (0.67 to 0.20) and lambda-cyhalothrin 5 SC (0.33 to 0.20) per meter^2.

Bio-pesticides had no any adverse effects on assassin bug population. The treatment of *Sl*NPV (750 LE/ha) bug population was increased from 0.40 to 0.47/meter^2 followed

Table 10: Influence of insecticides on natural enemy (Assassin bug, *Rhynocoris fusipes* Fabricius)

Treat. No.	**Population of Assassin bug /meter²**			
	Treatments	**Dose /ha**	**(Before Ist spray) Pre-count**	**After IInd spray**
T_1	*Nomuraea rileyi* (1×10⁸ cfu/ml)	2.00 kg	0.53 (1.05)	0.60 (1.14)
T_2	*Metarhizium anisopliae* (1×10⁸ cfu/ml)	2.00 kg	0.53 (1.02)	0.80 (1.08)
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	0.40 (0.95)	0.47 (1.05)
T_4	Neem oil 1%	1.00 lit.	0.40 (0.95)	0.67 (0.98)
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	0.33 (0.91)	0.20 (0.84)
T_6	Flubendiamide 39.35 SC	0.50 lit.	0.60 (1.05)	0.07 (0.75)
T_7	Indoxacarb 15.8 EC	0.50 lit.	0.67 (1.08)	0.20 (0.84)
T_8	Profenophos 44 EC	1.00 lit.	0.67 (1.08)	0.13 (0.80)
T_9	Untreated control	Water spray	0.60 (1.05)	1.07 (1.25)
SEm ±			0.07	0.06
C. D. at 5 %			NS	0.19

Mean of three replications
Figures in the parenthesis are means of $\sqrt{x+0.5}$ transformed values

by *N. rileyi* (1×10^8 cfu/ml) from 0.53 to 0.60/meter^2 followed by neem oil 1% from 0.40 to 0.67 per meter^2 and *M. anisopliae* (1×10^8 cfu/ml) from 0.53 to 0.80/meter^2, respectively. In untreated control bug population was increased from 0.60 to 1.07/meter^2.

Trends of influence of insecticides on natural enemies, assassin bug (*R. fusipes*) on potato in the order of statistical performance were depicted below.

Trends: *M. anisopliae* (1×10^8 cfu/ml) > Neem oil 1% and *N. rileyi* (1×10^8 cfu/ml) > *Sl*NPV (750 LE/ha) > Lambda-cyhalothrin 5 SC > Indoxacarb 15.8 EC > Profenophos 44 EC and Flubendiamide 39.35 SC.

Ghelani *et al.* (2000) proved that the mortality of eggs and nymphs of assassin bug revealed that all the synthetic insecticides were more toxic than botanical insecticides which are corroborated with present findings.

The results are in confirmation with that Ravichandran *et al.* (2003) also reported the intensity of behaviour and the predatory efficiency of assassin bug was affected as the concentration of cypermethrin was increased.

Paul *et al.* (2004) tested eleven insecticides (Carbaryl, esfenvalerate, deltamethrin, chlorpyrifos, methomyl, monocrotophos, cypermethrin, methidathion, malathion, dimethoate and endosulfan) in cotton. According to observations it was proved that these insecticides are toxic to assassin bugs. Grundy (2007) used indoxacarb, pyriproxifen, buprofezin, spinosad and fipronil for control of

Helicoverpa armigera in cotton. But it was proved that these insecticides were toxic to assassin bug, (*Pristhesancus plagipennis* Walker) which are in agreement with present findings.

4.5. Phyto-toxicity of insecticides on potato

The data recorded on phyto-toxicity of insecticides on potato was presented in Table 11.

It was obvious from the experiment that *M. anisopliae* (1×10^8 cfu/ml), *N. rileyi* (1×10^8 cfu/ml), *Sl*NPV (750 LE/ha), neem oil 1%, lambda-cyhalothrin 5 SC, flubendiamide 39.35 SC, indoxacarb 15.8 EC and profenophos 44 EC did not exhibit any phy-toxicity effect on potato.

In all two spray applications of four chemical insecticides and four bio-pesticides were undertaken along with untreated control. The results indicated that test insecticides did not exhibit any phytotoxicity symptoms such as injury to leaf tip and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty on potato variety *Kufri Ashoka.*

The results obtained in the present study are in agreement with Begona *et al.* (2006) reported that imidacloprid, pirimicarb or mineral oil were no any phytotoxicity symptoms observed on potato crops.

Daniela *et al. (*2000) studied that not any phtotoxicity on potato due to *Beauveria brongniartii* (Saccardo.) which is in accordance with present results.

Kharbade (2011) reported that entomopathogenic fungus *viz., M. anisopliae, B. bassiana, V. lecanii,* botanicals *viz.*, *dashparni* extract, neem based insecticides and thiamethoxam 25 WG were not phytotoxic effect on *Bt* cotton crop which is corroborated with present results.

Table 11: Phyto-toxicity of insecticides on potato

Treat. No.	Treatments	Dose/ ha	Phyto-toxicity symptoms observed				
			Injury to leaf tip and leaf surface	Wilting	Vein clearing	Necrosis	Epinasty and Hyponasty
T_1	*Nomuraea rileyi* (1×10^8 cfu/ml)	2.00 kg	0	0	0	0	0
T_2	*Metarhizium anisopliae* (1×10^8 cfu/ml)	2.00 kg	0	0	0	0	0
T_3	*Sl*NPV (750 LE/ha)	0.50 lit.	0	0	0	0	0
T_4	Neem oil 1%	1.00 lit.	0	0	0	0	0
T_5	Lambda-cyhalothrin 5 SC	0.50 lit.	0	0	0	0	0
T_6	Flubendiamide 39.35 SC	0.50 lit.	0	0	0	0	0
T_7	Indoxacarb 15.8 EC	0.50 lit.	0	0	0	0	0
T_8	Profenophos 44 EC	1.00 lit.	0	0	0	0	0
T_9	Untreated control	Water spray	0	0	0	0	0

Observed on 3rd, 7th and 14th DAS and Mean of first and second spray

5. SUMMARY AND CONCLUSIONS

5.1. Summary

Potato (*Solanum tuberosum* L.) is economically important vegetable crop. It is mostly grown in open field condition in most parts of India, including Maharashtra. The crop, however, is attacked by a number of pests, among which *Spodoptera litura* (Fab.) is most important one. *S. litura* causes 25.8 to 100 per cent losses in potato at crop stage in field. Insecticidal control mostly relies up on conventionally recommended flubendiamide that is reported to be effective against *S. litura* on potato. Selective insecticides were efficient in actions against target pest. Therefore present investigations were carried out to find out bio-efficacy of insecticides against *S. litura* with their phyto-toxic effect on potato crop. The influence of insecticides on natural enemies was also studied. The results of the research experiment are summarized here under.

5.1.1. Bio-efficacy of insecticides against *S. litura* on potato

5.1.1.1. Egg masses

Overall results revealed that all the insecticidal treatments maintained their effectiveness against egg masses of *S. litura* over untreated control. The treatment with flubendiamide 39.35 SC was observed to be most promising by recording lowest of 0.35 egg masses/meter row length which was on par with profenophos 44 EC in which 0.39 egg masses/meter row length was observed. The next best treatments in descending order of efficacy were indoxacarb 15.8 EC > lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.46, 0.58, 0.68, 0.74, 0.82 and 0.96 egg masses/meter row length were recorded, respectively.

5.1.1.2. Larval population

Among the insecticides, the treatment with flubendiamide 39.35 SC was observed to be most promising by recording lowest larval population of 0.49 larvae/meter row length which was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 0.62 and 0.69 larvae/meter row length was observed. The next best treatments in descending order of their bio-efficacy were lambda-cyhalothrin 5 SC > *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 0.93, 1.13, 1.29, 1.75 and 2.04 larvae/meter row length were observed, respectively.

5.1.1.3. Per cent foliar damage

The treatment with flubendiamide 39.35 SC was perceived to be superior was recorded lowest of 10.18 per cent foliar damage/plant and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 10.70 and 11.11 per cent/plant foliar damage were observed. The next best treatment was lambda-cyhalothrin 5 SC in which foliar damage of 12.91 per cent/plant was observed and was at par with *Sl*NPV (750 LE/ha) (14.55 per cent/plant). This was followed by *N. rileyi* (1×10^8 cfu/ml) (15.84 per cent/plant) > neem oil 1% (17.18 per cent/plant) > *M. anisopliae* (1×10^8 cfu/ml) (18.08 per cent/plant).

5.1.2. Per cent tuber damage due to *S. litura* on potato

Flubendiamide 39.35 SC was observed to be superior over all treatment causing lowest tuber damage (8.02 per cent/plot) and was on par with profenophos 44 EC (9.68 per cent/plot) and indoxacarb 15.8 EC (10.00 per cent/plot). The next best treatment was lambda-cyhalothrin 5 SC which recorded 12.30 per cent tuber damage. This was followed by *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) in which 13.85, 14.53, 15.45 and 15.89 per cent tuber damage was observed, respectively.

5.1.3. Effect of insecticidal treatments on yield of marketable potato

Among the treatments, flubendiamide 39.35 SC was found to be most promising by recording highest yield of marketable potato 21.80 tonnes/ha and was on par with profenophos 44 EC and indoxacarb 15.8 EC in which 21.55 and 21.35 tonnes/ha yield observed, respectively. The next best treatment in order of merit was lambda-cyhalothrin 5 SC which recorded 17.21 tonnes/ha yield of marketable potato. This was followed by *Sl*NPV (750 LE/ha) > *N. rileyi* (1×10^8 cfu/ml) > neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) which recorded 16.65, 16.50, 16.00 and 15.21 tonnes/ha yield of marketable potato.

5.1.4. Influence of insecticides on natural enemies

Bio-pesticide have found no any adverse effects on assassin bug population. In treatments of *M. anisopliae* (1×10^8 cfu/ml), *N. rileyi* (1×10^8 cfu/ml), *Sl*NPV (750 LE/ha) and neem oil 1% were safer to assassin bug. The insecticides *viz.*, lambda-cyhalothrin 5 SC, indoxacarb 15.8 EC, profenophos 44 EC and flubendiamide 39.35 SC were moderately safe to assassin bug.

5.1.5. Phyto-toxicity of insecticides on potato

The insecticide treatments *viz.*, *M. anisopliae* (1×10^8 cfu/ml), *N. rileyi* (1×10^8 cfu/ml), *Sl*NPV (750 LE/ha), neem oil 1%, lambda-cyhalothrin 5 SC, flubendiamide 39.35 SC, indoxacarb 15.8 EC and profenophos 44 EC at the evaluated doses did not exhibit any phytotoxic effect on foliage of potato.

5.2. Conclusions

- ❖ Among the insecticide treatments, flubendiamide 39.35 SC, profenphos 44 EC and indoxacarb 15.8 EC were significantly superior in suppressing the larval population of *S. litura*. Lambda-cyhalothrin 5 SC and *Sl*NPV (750 LE/ha) was also effective succeeding treatment in controlling larval population. The treatment with *N. rileyi* (1×10^8 cfu/ml), neem oil 1% and *M. anisopliae* (1×10^8 cfu/ml) were also found effective against *S. litura* larvae over untreated control. All the insecticide treatments also recorded lower no. of egg masses over untreated control.

- Insecticidal treatments, flubendiamide 39.35 SC, profenphos 44 EC and indoxacarb 15.8 EC were proved to be the most promising treatment as realized by lower per cent of foliar and tuber damage and recorded higher yield of marketable potato. *Sl*NPV (750 LE/ha), *N. rileyi* (1×10^8 cfu/ml), neem oil 1%, and *M. anisopliae* (1×10^8 cfu/ml) were also showed positive results over untreated control.
- All the evaluated insecticide molecules did not exhibit any phyto-toxicity symptoms on potato; moreover exhibiting relative safetyness to the predatory assassin bug.
- The results of present investigations are indicative for selective and precise use of promising insecticide which is necessary in developing an ecologically sound Integrated Pest Management programme for *S. litura* on potato.

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7. APPENDIX

Weekly Weather Data 2014

Weekly averages of meteorological parameters during the year 2014.

Met. Week	T_{max} (°C)	T_{min} (°C)	R H I (%)	R H II (%)	RAIN (mm)	R.D (d)	B S S (hr)
1	32.0	15.1	93	27	0.0	0.0	8.9
2	30.1	10.4	95	32	0.0	0.0	8.6
3	31.3	11.5	93	32	0.0	0.0	8.0
4	31.1	11.4	94	27	0.0	0.0	8.5
5	31.7	14.7	82	33	0.0	0.0	7.0
6	31.4	14.7	90	36	0.0	0.0	8.0
7	32.9	15.1	90	26	0.0	0.0	7.9
8	33.5	12.6	85	22	0.0	0.0	9.9
9	34.2	12.4	81	16	0.0	0.0	9.7
10	35.2	14.0	71	19	0.0	0.0	9.5
11	35.6	16.7	73	19	0.4	0.0	8.5
12	35.7	16.1	63	17	0.0	0.0	9.4
13	36.2	17.3	62	19	0.0	0.0	8.5
14	36.8	16.6	58	14	0.0	0.0	9.9
15	38.7	20.1	50	15	0.0	0.0	9.5
16	35.5	19.1	68	22	0.0	0.0	10.8
17	38.4	22.6	55	20	0.0	0.0	10.1
18	39.4	23.8	48	20	0.0	0.0	10.1
19	38.2	23.2	57	22	0.0	0.0	10.1
20	36.7	24.7	66	30	0.0	0.0	8.1
21	36.5	24.9	67	37	0.0	0.0	8.7
22	35.7	24.3	69	40	0.1	0.0	9.0
23	33.1	22.7	84	55	15.6	0.6	4.3
24	28.6	22.8	85	74	15.9	0.6	1.4
25	29.2	22.7	83	69	4.0	0.1	4.5
26	27.8	22.3	88	78	5.2	0.6	1.3
27	28.1	22.3	89	76	2.8	0.3	2.7
28	26.9	21.9	87	79	6.5	0.4	1.6
29	26.2	21.8	91	88	6.5	0.7	0.1

30	25.7	21.7	92	88	11.7	1.0	0.4
31	26.2	21.4	89	86	6.9	0.7	2.4
32	27.7	21.4	86	72	0.6	0.0	3.4
33	28.4	22.0	88	70	0.3	0.0	4.6
34	28.2	21.7	84	67	0.5	0.0	4.0
35	29.1	20.1	87	59	0.1	0.0	5.1
36	29.9	20.4	87	62	2.0	0.3	6.2
37	30.8	21.4	94	62	17.2	0.9	4.3
38	28.8	21.4	88	69	13.8	0.3	3.6
39	28.3	21.1	85	67	1.0	0.1	3.5
40	30.4	21.3	88	60	2.0	0.3	7.2
41	30.0	20.3	86	58	0.0	0.0	7.5
42	32.2	20.2	89	46	2.5	0.1	7.1
43	31.8	19.9	88	49	0.4	0.1	7.5
44	31.8	18.1	87	43	0.0	0.0	8.5
45	30.2	15.3	89	40	0.0	0.0	7.9
46	29.2	12.5	92	36	0.0	0.0	9.0
47	31.2	14.0	92	37	0.0	0.0	9.0
48	29.8	18.5	94	53	2.1	0.1	6.3
49	29.1	13.1	94	36	0.5	0.1	7.8
50	29.3	7.3	94	26	0.0	0.0	9.5
51	29.5	8.5	94	31	0.0	0.0	9.3
52	28.7	12.9	97	42	0.0	0.0	7.5

8. VITA

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MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

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Fig. 1: Bio-efficacy of insecticides against egg masses of *S. litura* on potato

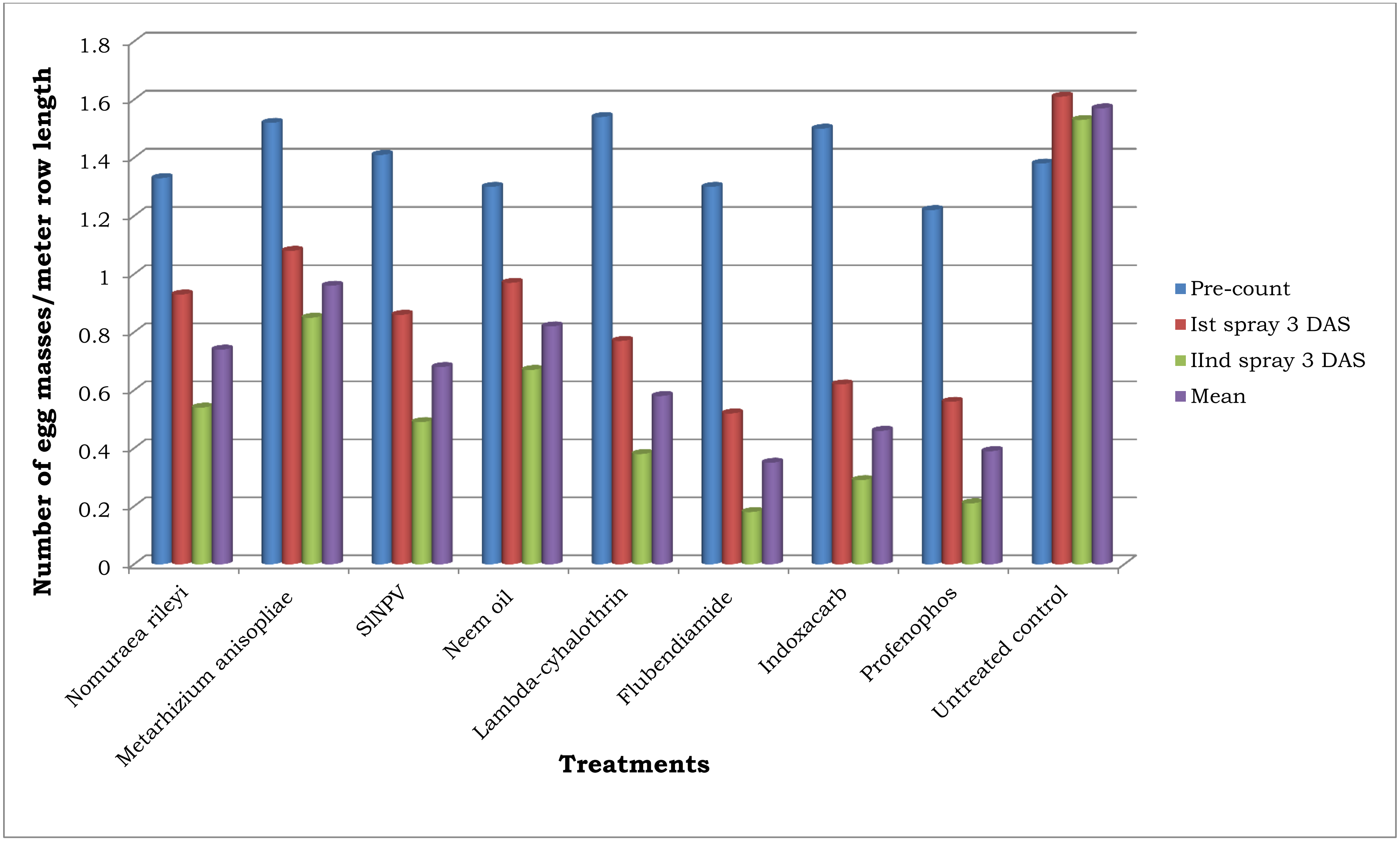


Fig. 2: Bio-efficacy of insecticides against *S. litura* larvae on potato after first spray

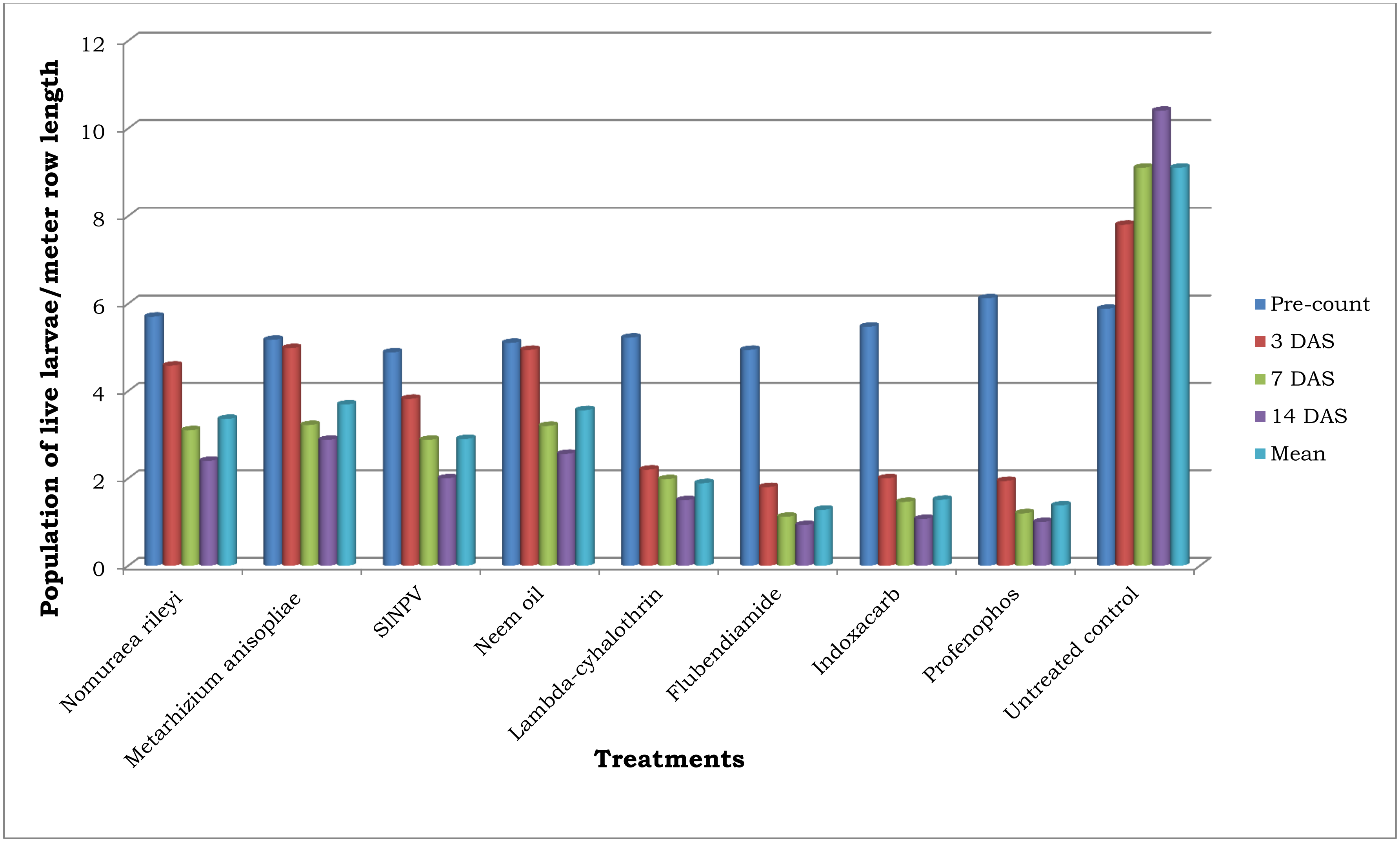


Fig. 3: Bio-efficacy of insecticides against *S. litura* larvae on potato after second spray

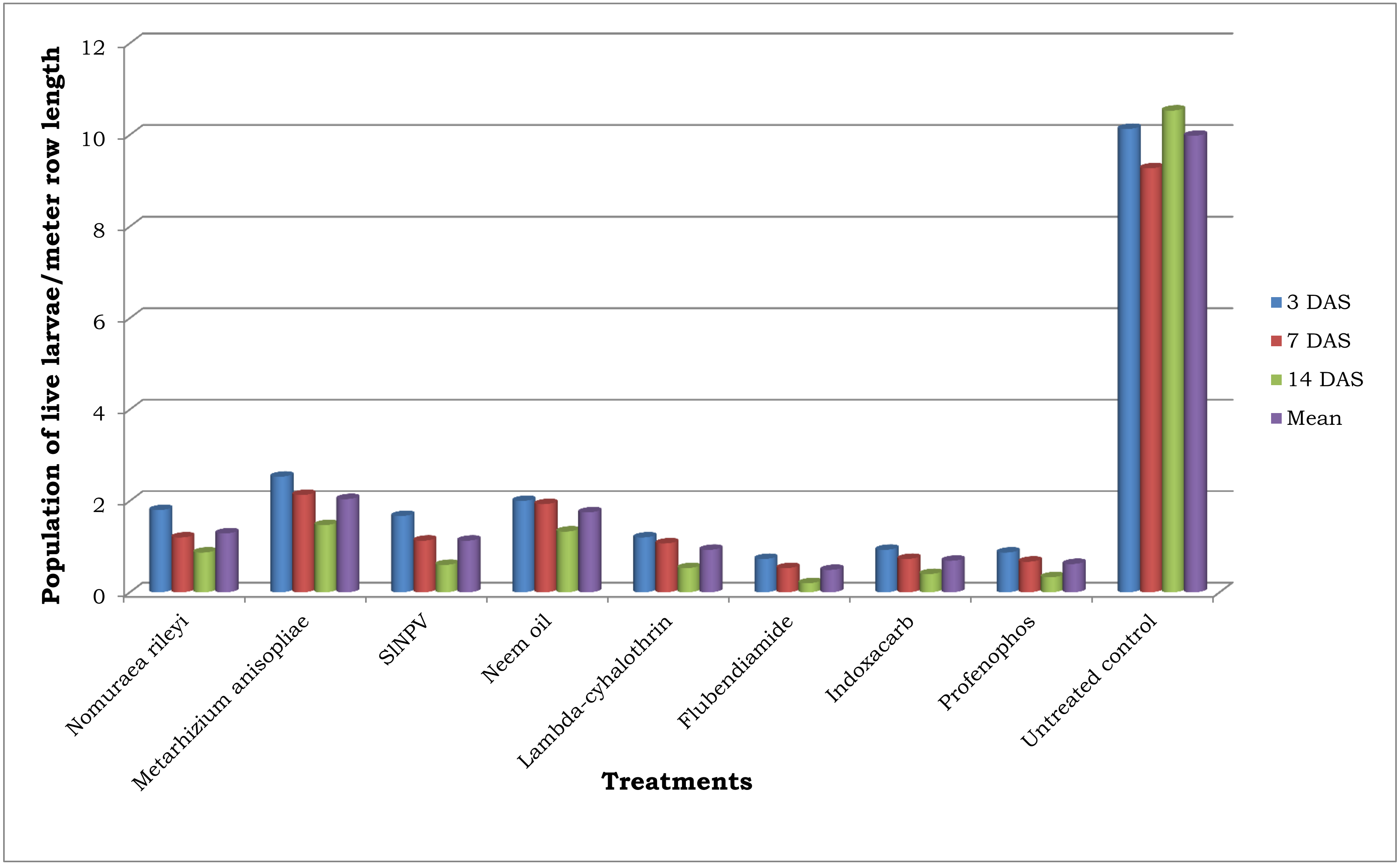


Fig. 4: Per cent foliar damage due to *S. litura* on potato after first spray

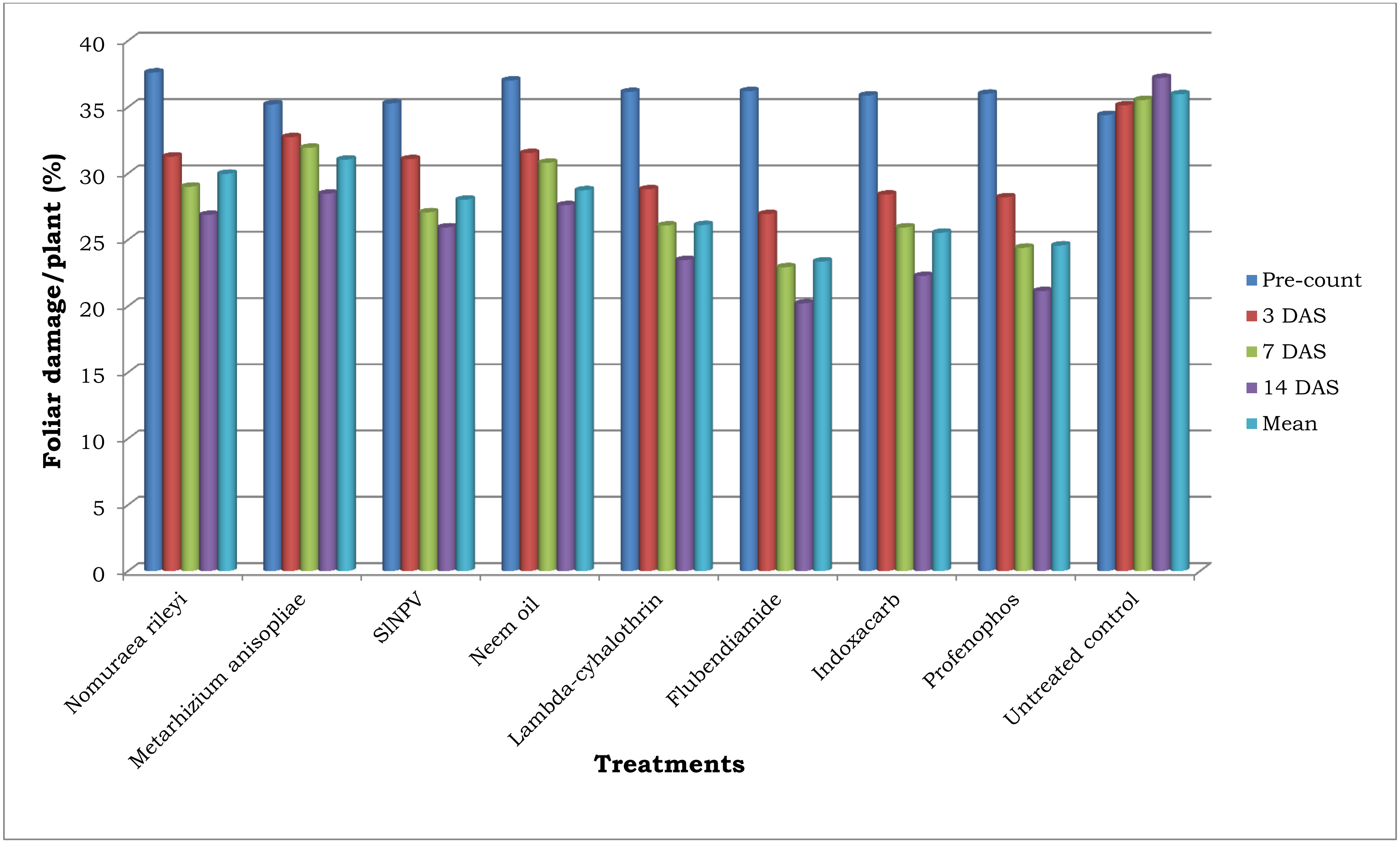


Fig. 5: Per cent foliar damage due to *S. litura* on potato after second spray

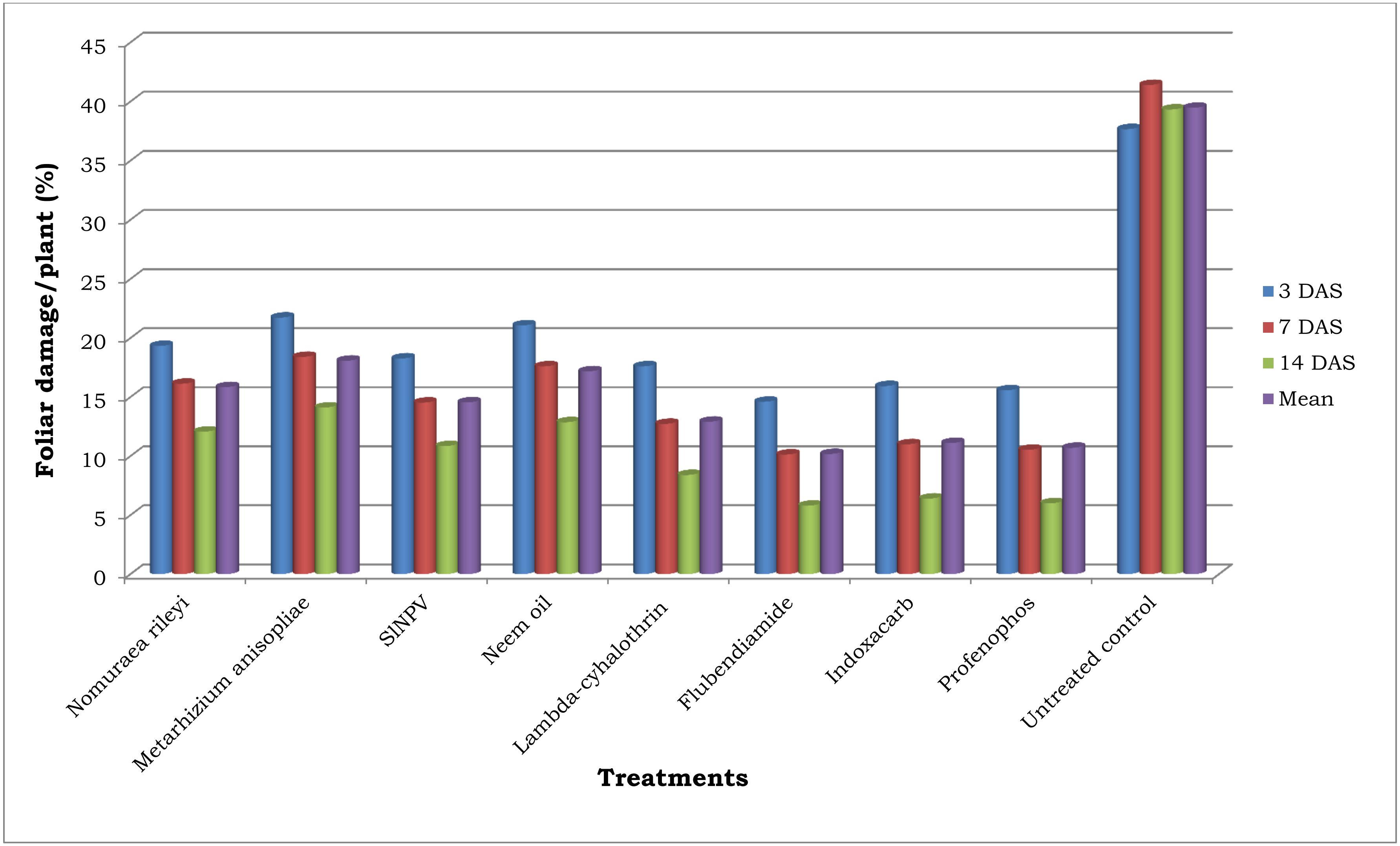


Fig. 6: Per cent tuber damage due to *S. litura* at harvesting

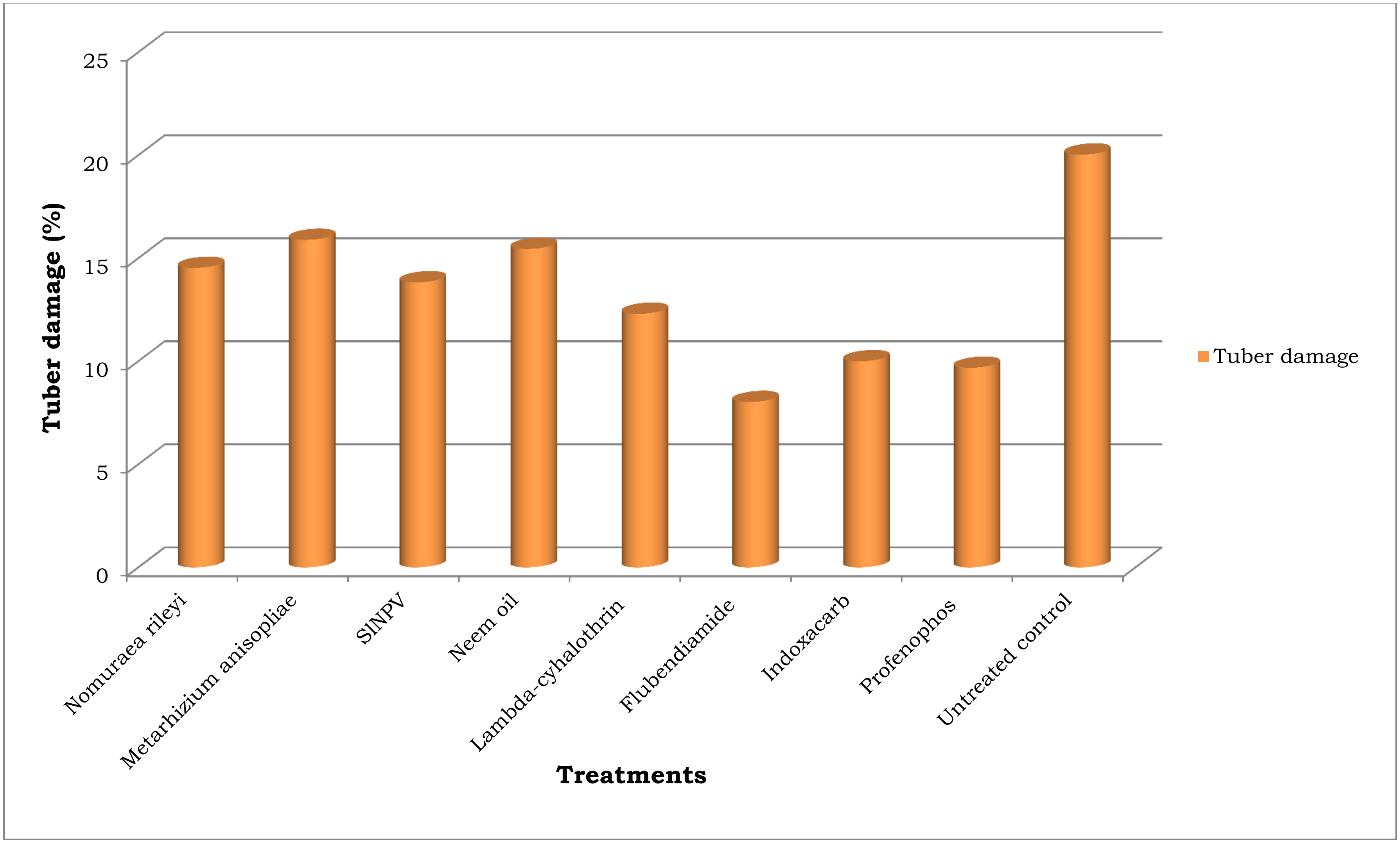
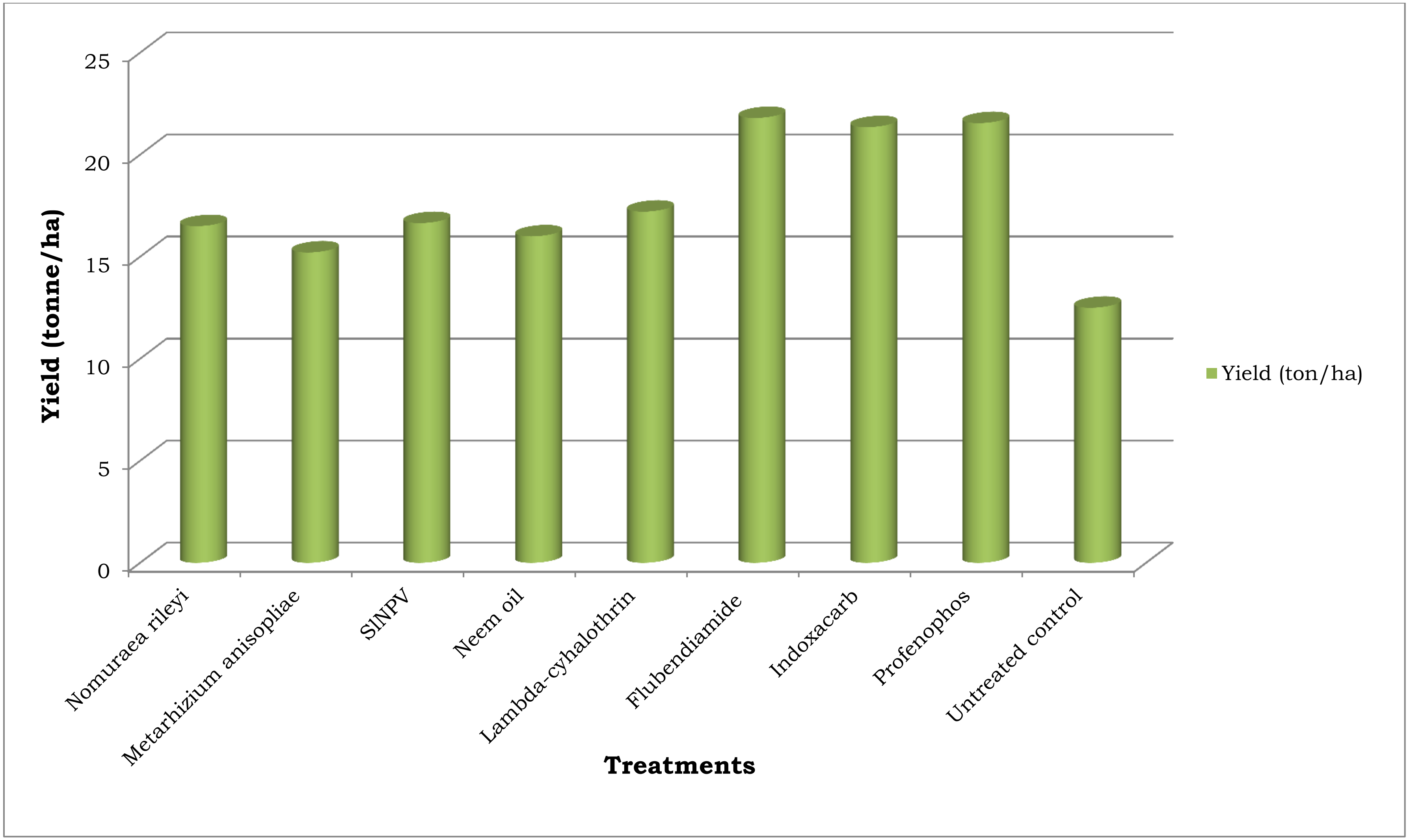


Fig. 7: Effect of insecticidal treatments on yield of marketable potato



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LIST OF ABBREVIATIONS

a.i.	:	Active ingredient
AICRP	:	All India Co-ordinated Research Project
Av.	:	Average
B.S.S.	:	Bright sunshine hours
C.D.	:	Critical Difference
cfu	:	Colony forming unit
cm	:	Centimeter (s)
DAS	:	Days after spraying
e.g.	:	Exampli gratia (for example)
EC	:	Emulsifiable Concentrate
et al.	:	Et alli (and others)
etc.	:	Et cetera (and others)
Fig.	:	Figure
g	:	Gram(s)
ha	:	Hectare
hrs.	:	Hours
i.e.	:	Id est (That is)
kg	:	Kilogram
LE	:	Larval equivalent
lit.	:	Litre
mg	:	Milligram
mha	:	Million hectare
ml	:	Millilitre
mm	:	Millimeter
M.P.K.V.	:	Mahatma Phule Krishi Vidyapeeth

MT	:	Metric tonne
MW	:	Meteorological week
NARP	:	National Agricultural Research Project
N.S.	:	Non-significant
N.S.K.E.	:	Neem seed kernel extract
POBs	:	Polyhydral occlusion bodies
ppm	:	Parts per million
q	:	Quintal
R H I	:	Relative humidity morning
R H II	:	Relative humidity evening
R D	:	Rainy day
SEm	:	Standard error of mean
SC	:	Soluble Concentrate
Spp.	:	Species
T_{max}.	:	Temperature maximum
T_{min}.	:	Temperature minimum
t	:	Tonnes or ton
Var.	:	Variety
Viz.	:	Videlicet (namely)
WG	:	Wettable granule
WP	:	Wettable powder

Plate I: Experimental plot/Field

Plate V: Damaged tubers due to *S. litura*

Plate II: Larvae of *S. litura* on potato leaves

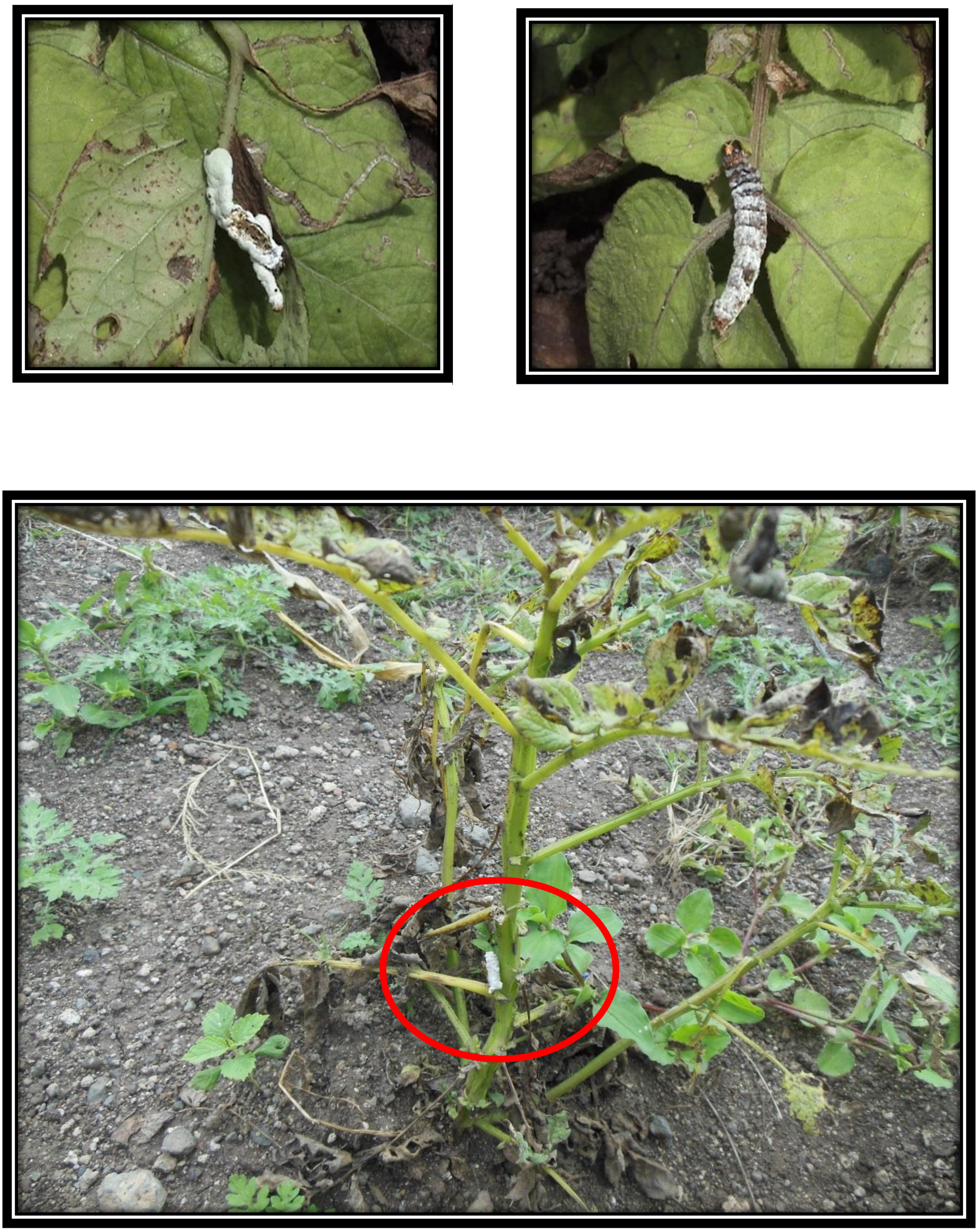

Plate IV: Death of *S. litura* larvae due to *Nomuraea rileyi*

Plate VI: Harvested Potato tubers

Plate III: Foliar damage due to *S. litura* larvae