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Research article

Influence of Plant Based Pesticidal Application on Life Stages of *Euproctis lunatus* - A Hidden Factor for Reduced Yield of Castor

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Abstract

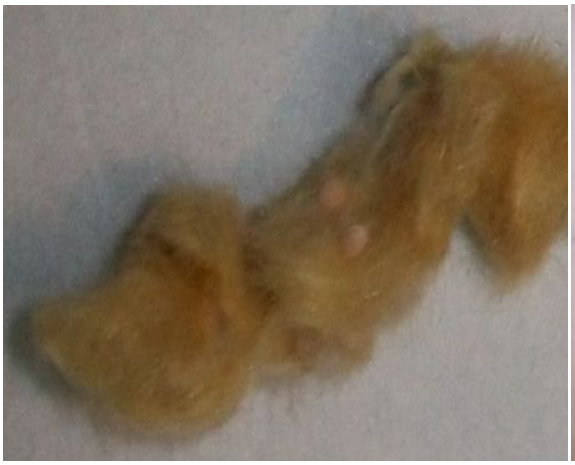
Castor is an important crop grown in tropical and sub-tropical regions of the world. The world castor seed production has fluctuated from a low of 937,000 tones to a high of 1,488,000 tones. India is the world's largest producer and dominates the international trade. It contributes about 62% of the world production and ranks first. A pest is an animal whose population often increases above a certain level of economic injury and its existence conflicts with human welfare, convenience and profits. The seriousness of the attack is decided by its feeding efficiency, host-plant relationship, nature of the injuries conflicted and the susceptibility of the plant to attack. The chemical groups, conventionally in use today are synthetic pyrethroids, organophosphates and carbamates. The impact of synthetic pesticides on beneficial arthropods and the human health risks by exposure to these chemicals are issues of growing concerns. In perspective of the damage caused by such insects, the objectives of the present research were to assess the efficacy of two insecticides (deltamethrin and Spinosad) belonging to two different categories (conventional and non-conventional) on mortality, malformation, longevity, pre-oviposition, oviposition, post-oviposition, fecundity and fertility of the lepidopterous polyphagous pest *Euproctis lunata*. Topical application of sublethal concentrations of spinosad affects the mortality, moulting and longevity, fecundity and fertility, pre-oviposition, oviposition and post-oviposition period. The recommended concentrations may be

regarded as safe for spray operator because the application of high concentrations put the spray operator at greater risk, lead to residue hazards or prove uneconomic.

Key words: Agriculture, castor, insect, larvae, pesticide, productivity, yield

INTRODUCTION

In recent years there is a significant lowering in the losses caused by insects because of the awareness of farmers and increase in scientific knowledge. To control any pest it is essential to have a correct idea of the insect pest identification, its biology, distribution, food range, damaging stage, mode of damage and the nutritional ecology. The method chosen must be economical and free from creating any other problem immediately or in future, it should not harm the natural enemies of the pest and should be easy to operate and be readily available to an ordinary cultivator. India is an agricultural land having different climatic conditions due to which, it is possible to grow every crop and attends an outstanding position in the world with respect to several agricultural products. The speedy development of agriculture is vital in the progress of our country. Today, India has a large and diverse agriculture and is one of the world's leading producers of castor as well as a major consumer with an expanding population to feed. Insects are regarded as the most successful group within the animal kingdom, over 80% of all living beings are insects. The unceasing struggle between man and his insect enemies started even before the dawn of civilization. In spite of the numerous advance made by man in evolving newer and deadlier weapons to fight the war against insects, he has not succeeded in controlling the thousands of serious pests which damages his food and other agricultural products, destroy his possessions and even attack himself and transmit diseases and also injure his domestic animals (Von Keyserlin *et al.,* 1985; Safiuddin *et al.,* 2012; Mazid and Mohammad, 2012).



(A) Eggs

(B) Newly hatched larvae

The need to protect economically important crops from the ravage of phytophagus insects by ecologically acceptable methods has led to the development of alternate strategies for insect control using an array of targets (Van Beek *et al.,* 1994). The chemical method is practically layman's weapon for quick and easy use because small amount of chemicals are sufficient for the control of large number of insects. About 80,000 tones of pesticides are used in agriculture in India annually (Srinivasan, 1997; Khan *et al.,* 2011a & b). Although the use of insecticides is very effective but it is ecologically unsound and has many serious limitations, resulted in ecological hazards and it will be highly damageable or danger for environmental pollution, ecosystem and chances are brighter to develop resistance in insects. Pesticide resistance in agriculture was first notified in India in 1963 when a number of serious pests were reported to become resistant to D.D.T and H.C.H (two of the most commonly using pesticides during the 1960's and 1970's). Resistance in insect has mainly been caused by excessive, indiscriminate and injudicious use of pesticides (Jayaraj, 1989; Quddusi *et al.,* 2014; Mazid *et al.,* 2009 a &b). The widely used method for the control of a pest is through different insecticides or through bio-pesticides. The problems caused by synthetic pesticides and their residues have increased the need for effective, bio-degradable insecticides with greater selectivity. It is clear that the excessive use of insecticides in agriculture is a serious cause of concern, therefore, use of bio-pesticides considered as safer substitute.

(C) Mature larvae

(D) Adult larvae

Castor (*Ricinus communis L.*) is an important crop grown in tropical and sub-tropical regions of the world. Castor cake is used in agriculture as organic manure due to its high nitrogen content. The world castor seed production has fluctuated from a low of 937,000 tones to a high of 1,488,000 tones. India is the world's largest producer of castor seed and dominates the international castor oil trade. It contributes about 62% of the world production and ranks first (Annon, 1995; Khan *et al.,* 2014a). The top producer of castor seed in India is Gujrat, with 86 percent share, followed by Rajasthan and Andhra Pradesh. Among the several factors that contribute to low productivity of castor, the insect pests constitute the major factor. Crop suffers heavily due to attack of various

pests, which reduces their yield. Castor hairy or tussock caterpillar, *Euproctis lunata* (Walk.) is a very destructive pest of castor belonging to order lepidoptera, family lymantridae.

Oriental leafworm moth *Euproctis lunata* is a Noctuid moth which is considered as a serious but sporadic agricultural insect pest causes economic losses of crops from 25.8-100% (Ateyyat *et al*., 2009) based on crop stage and its infestation level in the field. It is also known as the Cluster caterpillar, Cotton leafworm, Tobacco cutworm, and Tropical armyworm. It is one of the most economically important insect pests in many countries including India, Japan, China, and other countries of Southeast Asia. It is also established on most Polynesian islands where it occurs in a variety of island forms. It infests a wide range of cultivated food plants numbering around 112, belonging to 44 families of which 40 species are known from India (Banerji *et al.,* 1985; Mazid *et al.,* 2012). It has a large host range of more than 150 host plants from over 40 mostly dicotyledonous plant families including crops, vegetables, weeds and ornamental plants (Dhingra *et al.,* 2005; Mazid *et al.,* 2014 a & b).

(E) Malformed adult (F) Incomplete ecdysis

It feeds gregariously on leaves leaving midrib veins only. It is a major pest of many crops. Common cutworm, *Euproctis lunata* is ubiquitous, multivoltine pest that underwent the holometabolous type of development. The life cycle is completed in about 6-8 weeks. After emergence between 2 and 5 days, female lays 1000-2000 eggs on the lower surface of host plant. The egg is round and dirty white. Eggs hatched between 4-5 days. The newly emerged larva is whitish and then turns yellow green an hour after with a pattern of red, yellow, and green lines from the head to the anal region. As the larva grew bigger, the body turns brown with 3 thin yellow lines down the back. The body of the newly emerged larva is cylindrical, head size is wider. In perspective of the damage caused by such insects, the objectives of the present research were to assess the efficacy of two insecticides (deltamethrin and spinosad) belonging to two different categories on mortality, malformation, longevity, pre-oviposition, oviposition, post-oviposition, fecundity and fertility of one lepidopterous polyphagous pest *Euproctis lunata*.

MATERIALS AND METHODS

The adults of *Euproctis lunata* were collected from agricultural fields of Aligarh. Culture was maintained in B.O.D at 27±1°C temperature and 75-80% relative humidity in the laboratory. The larvae were kept in rearing jars of size 20×15 cm. The top of jar was covered by muslin cloth and tightened with rubber band. They were fed on thoroughly washed castor leaves to avoid microbial infection at regular intervals. When larvae pupate to adults, they were transferred to fresh jar provided with 10% sucrose solution. The egg laying was done either along the sides of glass jars on the inner surface of muslin cloth. Before collecting the eggs the adults were transferred to another jar. The eggs so, collected were placed in a petridish and kept in another jar and the jar covered with muslin cloth. The newly hatched larvae were put on new jars with new fresh leaves. Fresh leaves were provided daily and regular cleaning of faecal matter was done. Not more than 20 larvae were kept in a jar to avoid overcrowding.

Sampling of Experiment

In thepresent study 24 hrs old 5^{th} instar larvae were used for the experiments. The samples of newly moulted 4^{th} instar larvae *Euproctis lunata* between 10:00am and 12:00 noon each day were isolated and maintained age-wise. Subsequently, fresh moulted 5^{th} instar larvae were treated with different concentrations of spinosad and deltamethrin. Likewise, the 4^{th} instar larvae of *Euproctis lunata* were also sorted out from the random culture and maintained in separate rearing jars. As soon as they moulted to 5^{th} instar which can be visually ascertained by the size, head capsule and exuviae they were treated with varying concentrations of the mentioned insecticides.

Preparation of different Concentrations of Insecticides used

Dilution and application of insecticides

The following formula was used to make the stock solution

X = A×B/C

Where,

X = Volume of solution in hand to be diluted to the describe volume.

A= Concentration desired.

B = Volume of solution desired.

C= Concentration of solution in hand.

The stock solutions of each insecticides were further diluted to sub-lethal level on the basis of LD 50 value as:

Spinosad: 0.0009%, 0.0007%, 0.0005% and 0.0001%

Deltamethrin: 0.0001%, 0.00008%, 0.00006%, 0.00004%

Experimental Procedure

These sublethal concentrations of each insecticide were used for topical application on the 5^{th} instar larvae of both *Euproctis lunata.* The effect of these chemicals were observed on mortality, malformation, fecundity, fertility and longevity by using four sublethal concentrations of each insecticide at the above said controlled conditions. For each concentration of diluted insecticide only 1µl was applied topically on the thoracic pleuron of individual 5^{th} instar larvae of both insects by 26-guage needle attached to a tuberculin syringe fitted into a manually operated micro applicator. At the time of application the age of the experimental insect was one day. For each concentration

100 individual larvae were used. Two sets of control consisting of same number of larvae of same age were also maintained parallel with each set of experiment at the same controlled conditions to compare the results. One set were treated with 1µl acetone solution and regarded as control-I, whereas the second set also having the same number of untreated larvae of same age was regarded as control-II, to compare the acetone treated larvae. When females subsequently emerged from the survived treated larvae they were paired with the males emerged from the untreated larvae of corresponding age from control-II (Magdum *et al.,* 2001; Mazid *et al.,* 2013 c & d). The number of eggs laid by each females and fertility were recorded. The unhatched eggs were also counted. Similar observations were also made in controls consisting of the males and females emerged from acetone-treated as well as untreated larvae.

Interpretation of Data

The data on mortality, malformation, longevity, hatching of *Euproctis lunata* affected by different concentration of spinosad and deltamethrin were recorded for each replicates and mean value of three such replicates of each treatment was calculated. The determination of any change was not only ascertained arithmetically but appreciated by statistical analysis also.

Statistical Analysis

The experiments were replicated and data subjected to statistical analysis. The data obtained was statistically analyzed by the application of the following method and formulae:

The standard deviation (S.D.) was calculated by the following formula:

$$S.D.=\sqrt{\frac{\sum D^2}{n-1}}$$

Where, S.D. = Standard deviation,

D = sum of square of the difference of mean value,

n = number of observations

On the basis of standard deviation (S.D.) standard error (S.E.) was calculated by the following formula:

$$S.E=\frac{S.D}{\sqrt{n}}$$

where, S.E. = standard error,

S.D. = standard deviation,

n = number of observations.

It was also necessary to appreciate the difference between mean values of different sets of samples. Arithmetically it was uncertain; therefore, we tested the mean values statistically. For this purpose, the statistical technique of variation significance (t-test) was applied by using the formula:

$$t = \sqrt{\frac{m_1 - m_2}{\frac{S.D_1}{n_1} + \frac{S.D_2}{n_2}}}$$

where, t = significant value,

m_1 = Mean value of first set of observations

m_2 = Mean value of second set of observations

$S.D_1$. = Standard deviation of first set of observations

$S.D_2$ = Standard deviation of second set of observations

n_1 = Number of observations of first set

n_2 = Number of observations of second set

The calculated‘t’ was compared with the tabulated‘t’ at 5% level. If the calculated value remained higher than the tabulated‘t’ value, the data are significant, otherwise insignificant. Further, to measure the intensity of association between fecundity/fertility and concentrations of insecticides, a regression line was fitted to the data, followed by correlation analysis (Fang *et al.,* 2002) using the formula:

$$Y = A + Bx$$

RESULTS

The first set, which consisting of 25 larvae of 24 hrs old 5th instar, was topically treated with 1µl of acetone solution only, the average initial mortality within 24 hrs was 8.00%, followed by 04% in the next ensuing instar 01% during pupal-adult emergence. Thus the total loss up to adult emergence was 13.00% which was 05.67% more than the untreated larvae (control-II). The larvae that survived after the treatment were quite active, healthy, showing normal feeding and moulted to adult successfully, however, 11.33% adults showed malformation either in wings or legs (Plate-I, Fig.E). In the second set, the topical application of the lowest selected sublethal concentration of spinosad (0.0001%) on 5th instar larvae cause 14.66% mortality within the same instar, whereas, 07% died during the next 6th instar, 2.5% during larval-pupal transformation and 3.84% during pupal-adult emergence resulting in average total loss of 28% which was 15% more as compared to control-1 (Plate-I, Fig. F). Out of the adult emerged from the survived treated larvae, 16% had malformed legs and wings (Plate-I, Fig. E). The average longevity of the surviving treated 5th instar larvae was 04 days which was 4.25% more as compared to control, whereas the average survival duration of affected 6th instar larvae was 25% more as that of control-I. The average longevity of the affected adult males and females was increased by 42.45 and 34.11% respectively than the control.

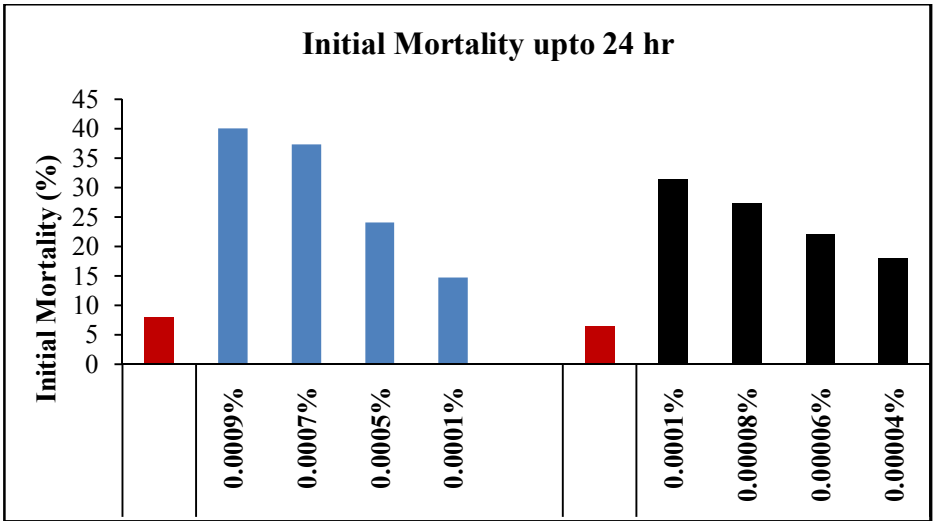


Fig. 1. Mortality (upto 24 hr) of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

In the third set, the topical application of 0.0005% spinosad resulted 24% mortality within the same instar, whereas 8.3% larvae died during the next larval stage, 4.7% died due to incomplete larval-pupal transformation and 5.26% during pupal-adult emergence leading to the average total loss of 42.66% up to adult emergence which was 22.66% more than the control-I. The adults which emerged from the survived treated larvae, 20.66% had malformed wings or legs (Plate-I, Fig. E). The longevity of the treated 5th instar larvae was enhanced by 17.81% as compared to control, whereas, longevity of next ensuing instar was 33.33% more as compared to control-I. The longevity of the adult males which emerged from the survived larvae was increased by 20.87% and the survival duration of the affected females was 18.18% more than the control-I. In the fourth set of 25 larvae treated with 0.0007% concentration of spinosad, 37.33% larvae could not survived the treatment and died within the same instar, whereas, 7.2% lost their lives during the next ensuing instar, 1.9% died during larval-pupal transformation and 3.57% died due to incomplete pupal-adult emergence. Out of adults which emerged from the survived larvae, 24% had malformed wings. The total loss of life up to adult emergence was 50% which was 37% more than that of the control-I. The average larval duration of the treated 5th instar larvae was 30.36% more as compared to control-I, whereas, the larval duration of the next ensuing instar was increased by 51.29% as compared to control-I.

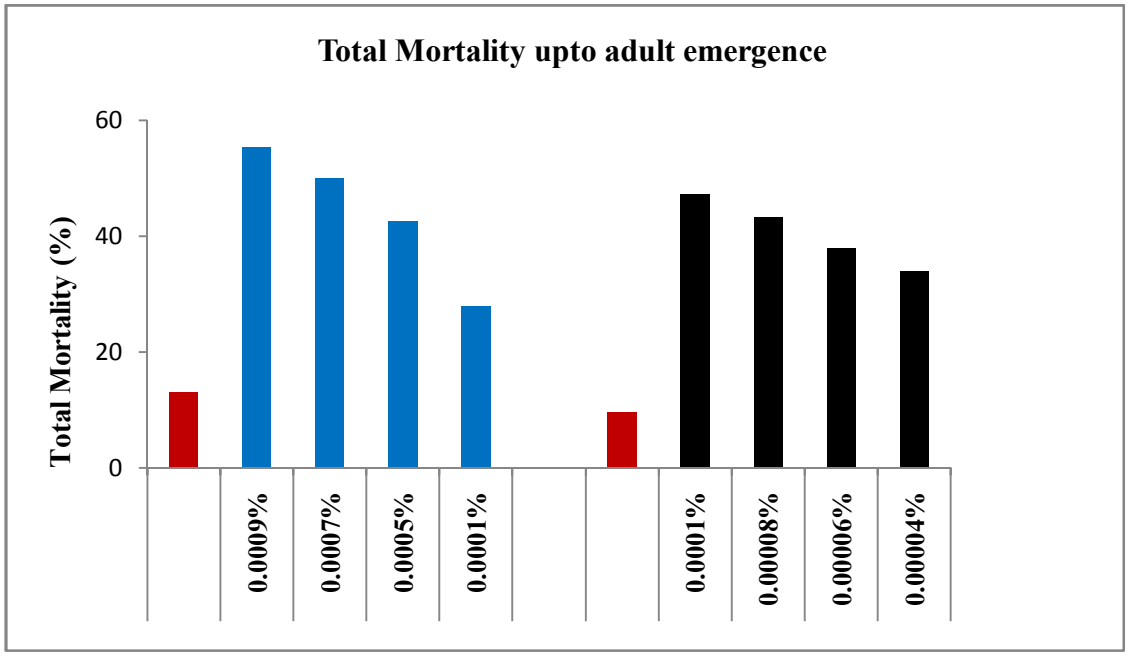


Fig. 2. Mortality (upto adult emergence) of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

The average survival duration of the adult males which emerged from the survived treated larvae was increased by 11.59%, whereas, the average survival duration of the adult females that emerged from the survived treated larvae was enhanced by 6.83% than control (Fig. 3). In the final fifth set of experiment when 25 larvae (5th instar) were treated topically with 0.0009% of spinosad, 40% larvae died during the same instar, whereas 05% larvae succumbed at next instar. Further, 03% larvae died during the larval-pupal transformation and 7.33% died during the process of pupal-adult emergence. Thus, the total larval mortality up to adult emergence was 55.33%, which was 42.33% more than the control-I. Among the adults which emerged from the survived larvae, 35.33% had malformed wings or legs (Plate-I, Fig. E). The mean longevity of 5th and 6th instar larvae was prolonged by 41.08 and 59.07% respectively as compared to the control-I. Whereas, the mean longevity of those adult males and females which emerged from the survived treated larvae, decreased by 22.67 and 17.49% respectively than the control-I. The adults which emerged from the survived treated larvae had no effect on their behavior and were as competitive as those of controls. The newly emerged affected males were paired with females of same age of the same set to observe fecundity and fertility.

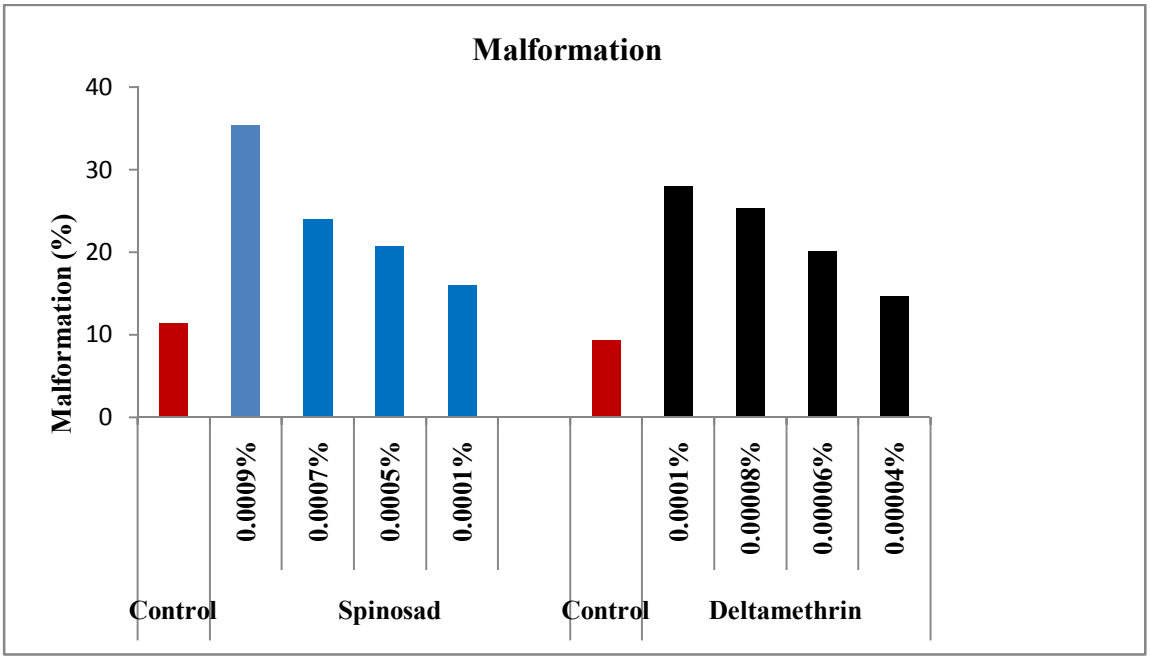


Fig. 3. Malformation of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

Following the topical application of 0.0009, 0.0007, 0.0005, and 0.0001%, concentrations of Spinosad on 5th larval instar of *Euproctis lunata,* the pre-oviposition period of the females emerged from the survived treated larvae was significantly increased by 53.00, 60.06, 68.02 and 62% respectively as compared to control-I. Likewise the post oviposition of the affected females emerged from the survived treated following the topical application of the lower selected sub-lethal concentrations viz., 0.0001, 0.0005 and 0.0007% of spinosad was also enhanced by 71.43, 63.64, 50.00% respectively as compared to control-I. On the other hand, the exposure of the highest selected sub-lethal concentration of spinosad (i.e. 0.0009%) reduced the post-oviposition period of the affected females by 50% as compared to control-I (Table-02). Similarly, the oviposition period of the mated mature female following the exposure of 0.0009, 0.0007, 0.0005 and 0.0001%, concentrations of spinosad was also dropped by 34.64, 42.26, 65.36 and 84.76% respectively as compared to control-I.

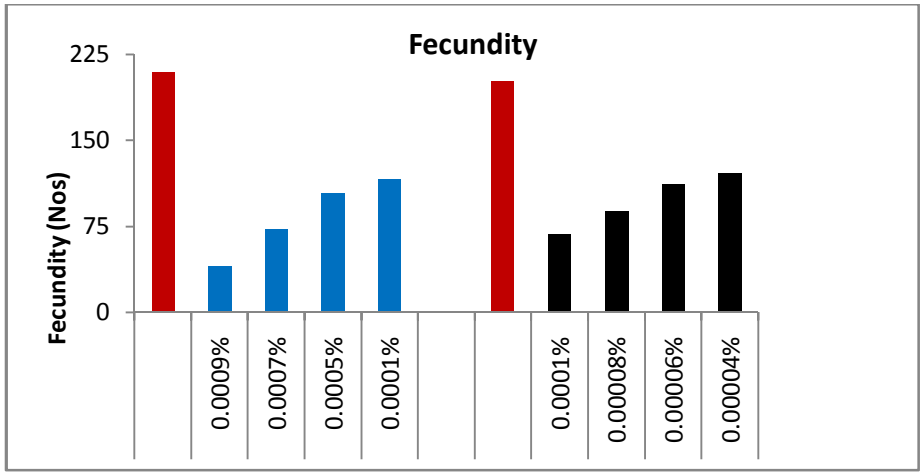


Fig. 4. Fecundity of female emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

Discussion

Insecticides are often the only effective remedy for quickly and inexpensively reducing the pest population below the economic injury levels. If in anyway crop is being damaged by pest attack, we must have to prevent it from damage by using the appropriate methods. The use of toxic chemicals and bio-pesticides for the control of pest increases tremendously during the last few decades. The toxicity of insecticides to humans and wildlife has caused much public concern and prompted the use of more target-specific chemicals. This approach has led to the development of botanical such as citrus oil, derivatives, neem-azadirachtinetc, soaps and oils, microbial insecticides such as *Beauveria*, *Bacillus thruingensis*, pheromones, natural products like spinosads, nitenpyram, imidaclopridetc, which are able to efficiently control agricultural pest species with minimum effects of natural enemies. Spinosad is a mixture of spinosyn A and D which are tetracyclic-macrolide secondary metabolites produced by anactinomycete, *Saccharopolysporas pinosa* (Thompson *et al.*, 1997; Khan *et al.,* 2014b). This compound has two unique modes of action, acting primarily on the insect nervous system at the nicotinic acetylcholine receptor and exhibiting activity at GABA receptor (Watson, 2001). It is a broad spectrum natural bio-insecticide offered a new mode of action and relatively safe on natural enemies (Temerak, 2003). Sarfraz *et al.* (2005) reported that currently there are only a few cases of insect resistance to spinosad and it is not known to share cross-resistance mechanisms with any existing class of insecticide. On the basis of simple reciprocal crosses and backcrosses, resistance appears to be inherited as a co-dominant trait controlled by a single locus.

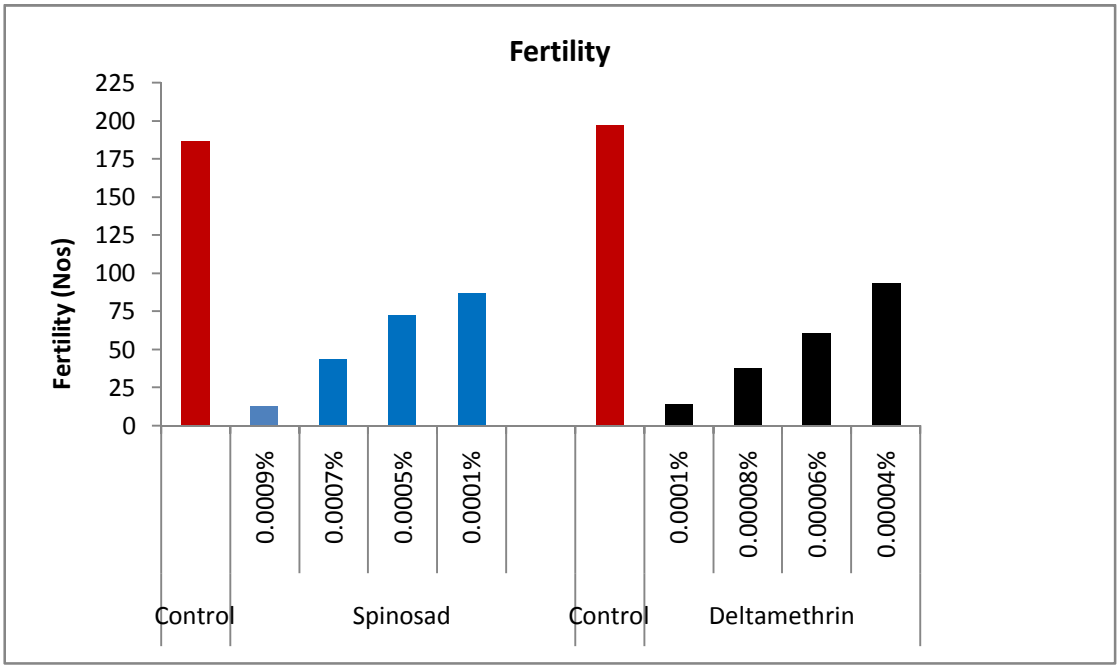


Fig. 5. Fertility of female emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

Furthermore, they concluded that in general, spinosad has larger margins of safety for parasitoids and predators but its higher concentrations may prove lethal to certain beneficial arthropods. The efficacy of spinosad can be conserved if it is judiciously rotated with other suitable insecticides in a spray program and the maximum number of applications is restricted. Thus, it becomes inevitable to find out the most effective chemicals against particular species of insect pest which do not adversely affect the environment and are also bio-degradable. In the present investigation the efficacy of deltamethrin and spinosad belonging to two different categories on two lepidopterous polyphagous pests *Euproctis lunata* was studied and the results wererecorded on mortality, metamorphosis, longevity, pre-oviposition period, oviposition period, post-oviposition-period, fecundity as well as fertility of the adults. The topical application of four selected sublethal concentrations of spinosad viz., 0.0009, 0.0007, 0.0005 and 0.0001% on 24 hrs old 5th instar larvae of *Euproctis lunata* gave varied mortality and increased with increasing sublethal concentrations of spinosad viz., 0.0009, 0.0007, 0.0005 and 0.0001% on 24 hrs old 5th instar larvae of *Euproctis lunata* gave varied mortality and increased with increasing sublethal concentrations. The effect of the above said concentrations either on initial mortality with in 24 hour or up to adult emergence was more pronounced when the application was made on 5th instar larvae of *Euproctis lunata*. The initial mortality following the topical application of the highest selected sublethal concentration (i.e. 0.0009%) of spinosad in case of *E. lunata* was 20.67% more whereas, the lowest selected concentration (i.e. 0.0001%) showed 11.33% more larval death in case of *E. lunata*as.

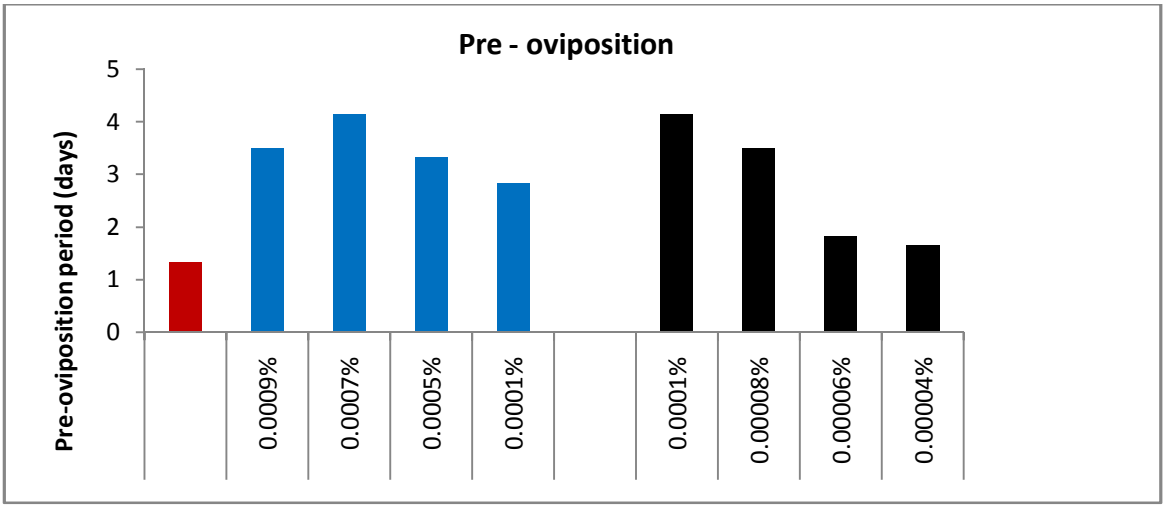


Fig. 6. Pre–oviposition period *Euproctis lunata following* topical application of Spinosad and Deltamethrin.

Likewise the total mortality of larvae up to adult emergence following the exposure of highest (0.0009%) and lowest (0.0001%) selected concentrations of spinosad to 5th instar larvae of *E. lunata* was respectively 23.33% and 19%. Likewise the topical application of four different selected sublethal concentrations of deltamethrin viz., 0.00004, 0.00006, 0.00008 and 0.0001% on 24 hrs old 5th instars larvae of *Euproctis lunata* also gave varied mortality and increased with increasing sublethal concentrations. The effect of the above said deltamethrin concentrations either on initial mortality with in 24 hour or up to adult emergence was more pronounced when the application was made on 5th instar larvae of *Euproctis lunata*. The initial knockdown effect within 24 hrs as well as the residual toxic effect up to adult emergence in case of *E. lunata* following the topical application of the highest selected sublethal concentration (i.e. 0.0001%) deltamethrin was respectively 3.33% and 9.33%. However, if we compare the overall toxicity of both the insecticides (i.e. spinosad and deltamethrin) against the individual insect than spinosad proves to be good for *E. lunata*. The total larval mortality up to adult emergence was due to partly by direct toxicity and partly by moulting failure or malformations at the intermediate stage. The results are similar to those reported by earlier workers like Elliott *et al.* (2007) who conducted laboratory experiment to evaluate the contact and oral toxicity of commercial formulations of spinosad and deltamethrin to adults of the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze) and showed that method of exposure had a significant effect on flea beetle mortality and feeding damage to canola seedlings

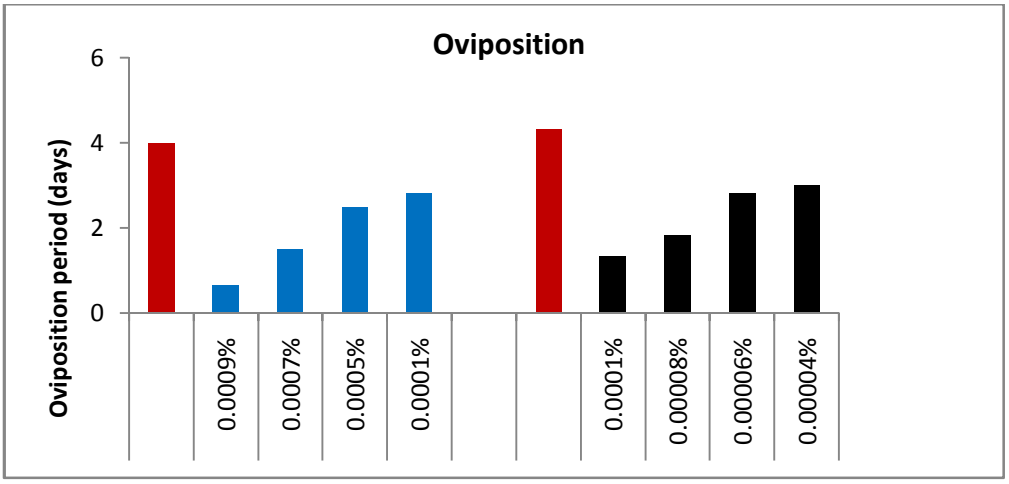


Fig. 7. Oviposition period of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

Topical treatment of flea beetles with deltamethrin or different concentrations of spinosad resulted in significantly lower mortality and higher feeding damage than exposure to treated canola cotyledons. Furthermore they reported that spinosad was more toxic by ingestion than by topical contact. Mortality from treated cotyledons was significantly higher with 60 ppm deltamethrin than with 80 or 120 ppm spinosad after 24 h exposure but not after 120 h exposure. Delayed mortality in the spinosad treatments did not result in high feeding damage; damage after 120 h was not significantly different in the spinosad and deltamethrin treatments. Low concentrations of spinosad (40 ppm) strongly inhibited feeding activity within 24 h after exposure. Mortality from spinosad was higher after beetles were exposed to treated cotyledons for 120 h than for 24 h. Mortality from spinosad, but not deltamethrin, was significantly higher at 25 °C than at 15 °C. An ionic surfactant, polyethylenimine, increased the toxicity of 40 ppm spinosad. On the basis of the results they suggest that spinosad has potential for use as an insecticide against crucifer flea beetles on canola. The exposure of spinosad and deltamethrin to the 5th instar larvae of *E. lunata* resulted in the emergence of malformed adults. This percentage of malformation increased with increasing sublethal concentrations.

The pre-oviposition period as well as the post-oviposition period of the affected females of *E. lunata* which survived the exposure of various sublethal concentrations of deltamethrin enhanced significantly, whereas, the oviposition period of the affected females declined significantly as compared to control. Likewise, the exposure of various sublethal concentrations of spinosad to the 5th instar larvae of *E. lunata* resulted in significant reduction in oviposition period of the affected females, however, the pre-oviposition period of the affected females was enhanced significantly as compared to control. The maximum increase in post-oviposition period was recorded following the application of lowest selected sublethal concentrations of spinosad and this increase decent down gradually with increasing sublethal concentration and ultimately decreases significantly following the application of the highest selected sublethal concentration to the 5th instar larvae of *E. lunata*.

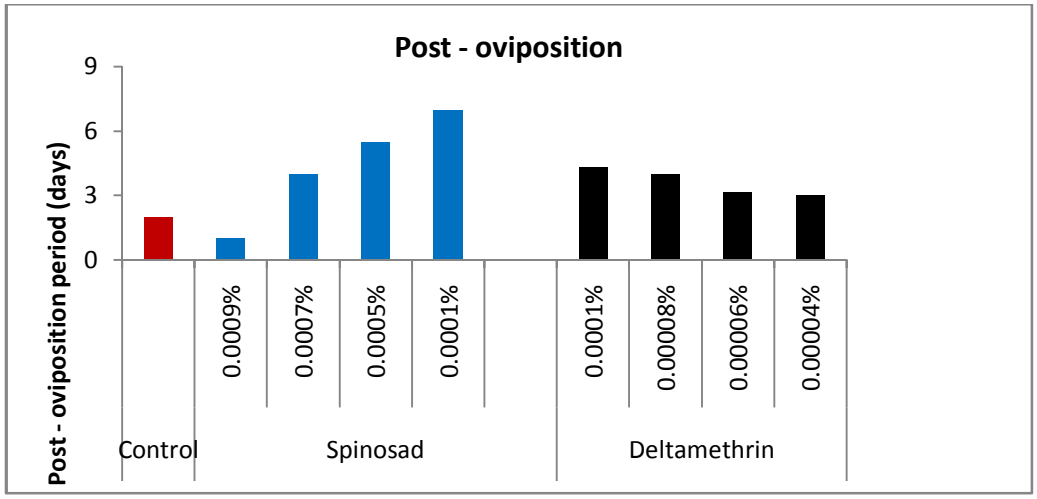


Fig. 8. Post-oviposition period of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

James and Price (2002) also observe on two spotted mites exposure to imidacloprid by ingestion causes increased female longevity. Pre-oviposition period increases with increasing concentration of insecticides. James and Price (2002) reported that prolonged in the immature stage and the survival rate of *Plutellaxy lostella* was lower in the LC_{25} and LC_{50} for spinosad. They also showed that spinosad at sublethal concentration extended the development time of survivor larvae and reduced larval weight of *Helicoverpa armigera*. Post exposure effects were indicated by decreased pupation ratio and pupal weight, by prolonged prepupal and pupal period and by decreasing emergence ratio, fecundity and longevity of adults. Knutson (1955) reported larval development of *Crysoperla carnea* when treated with spinosad was concentration dependent. The longevity of adult *D. cingulatus* emerged from the IVth instar treated nymphs with 0.008 µg cythion (malathion) was 38.9% more when compared with control. Acording to Streets (1976) insecticides inhibited hydroxylation process of some steroids to slow down the production of moulting hormone, thereby prolonging the larval period. Also, Katiyar and Lemonde (1972) observed monocrotophos, gardona and aldicarb to act as antiacetylcholinestrase agents resulting in greater prolongation of the larval period of *T. confusum.*

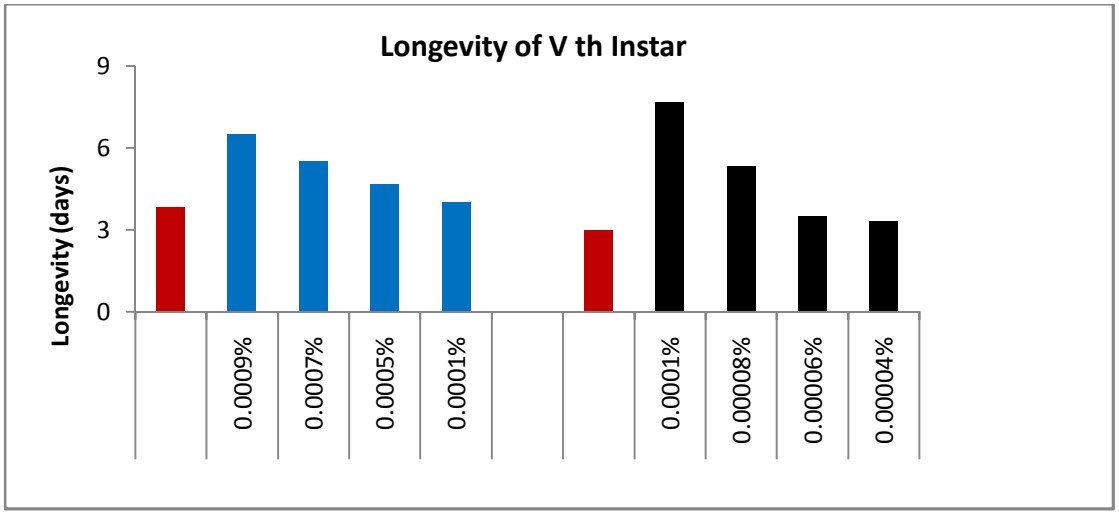


Fig. 9. Longevity of 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

The fecundity and fertility of the affected females of *E. lunata* emerged from the 5th instar nymphs treated with various selected sublethal concentrations of both insecticides i.e. spinosad and deltamethrin decreased linearly with increasing concentrations. If we compare the efficacy of both the insecticides against *E. lunata* then spinosad proved to be good in causing the maximum reduction in egg production, whereas, deltamethrin caused the maximum reduction in fertility of the eggs. But when we compare the efficacy of the above said insecticides against *Euproctis lunata* than deltamethrin showed the maximum reduction of egg production and egg hatching and proves to be good as compared to spinosad. Similarly, a significant reduction of fecundity was observed when *Ceratitis capitata* (Diptera; tephritidae) adults ingested 0.1mg/literspinosad (Richards and Davies, 1977; Mazid *et al.,* 2013a & b; Temerak, 2007). Similarly Yin *et al.* (2008) recorded that the adult longevity, population growth and fecundity of *Plutellaxy lostella* was strongly reduced when the larvae were treated with spinosad. Amer (2004) recorded that spinosad caused reduction in adult longevity, fecundity and fertility of *P. gossypiella*. Also, Liu and Trumble (2005) and Zaliznaik and Nugegod (2006) reported that spinosad high affected on fertility and fecundity of *Bactericerca cockerelli*. Egg fertility was reduced in *Helicoverpazea* (Boddie) when females were fed with concentrations≤1 mg (AI)/liter and then paired with untreated males (Lopez and Latheef, 1999).

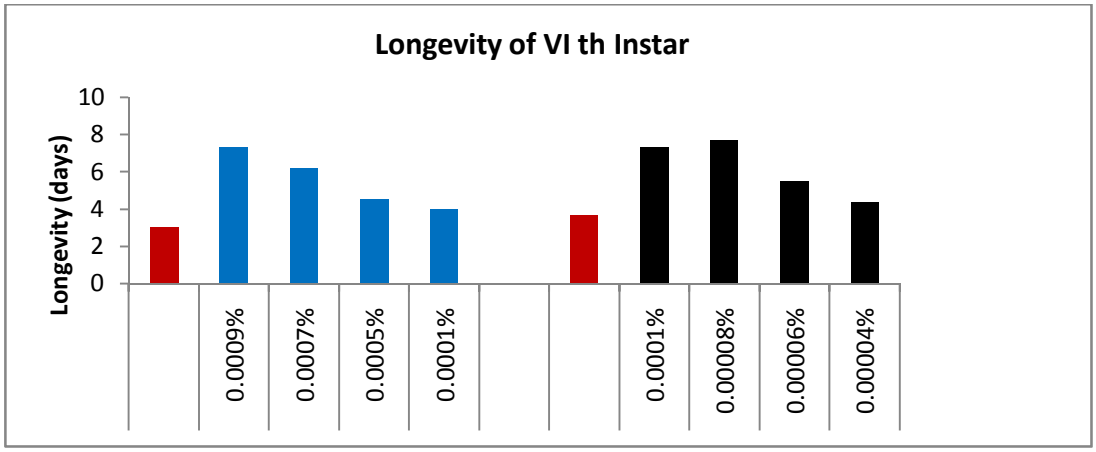


Fig. 10. Longevity of 6th instar larvae emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

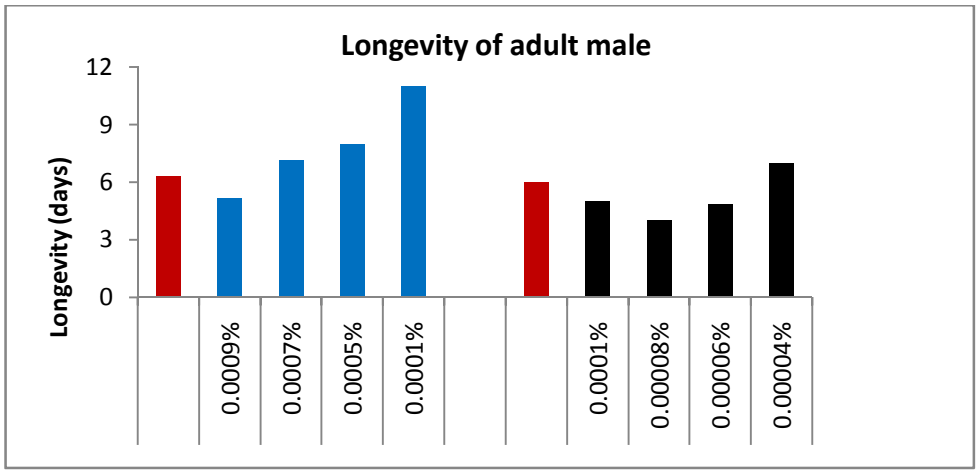


Fig. 11. Longevity of adult male emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

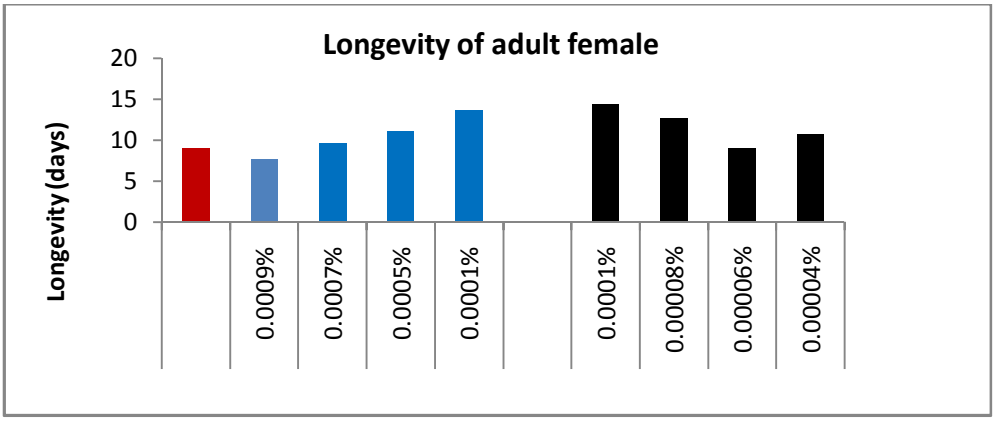


Fig. 12. Longevity of adult female emerged from 5th instar larvae treated of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

Conclusion

On the basis of the present finding on *Euproctis lunata* it is concluded that the topical application of both the insecticides i.e. spinosad and deltamethrin in its sublethal concentrations causes not only heavy mortality but also developed infecundity and infertility in the affected females, thus keep the pest population at the minimum. Therefore, spinosad and deltamethrin can be recommended for the control of *Euproctis lunata.* The recommended concentrations may be regarded as safe for spray operator because the application of high concentrations put the spray operator at greater risk, lead to residue hazards or prove uneconomic.

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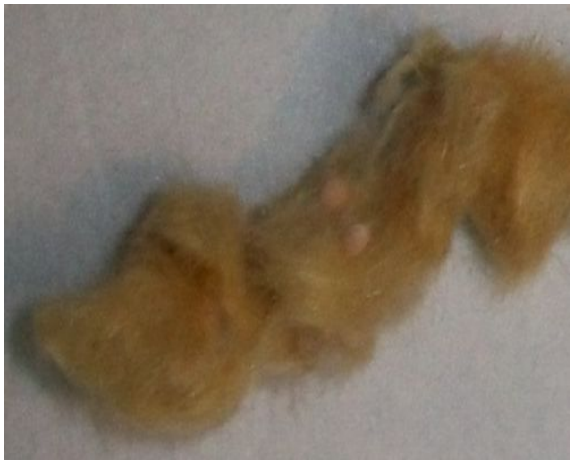
PLATE-I



(A) Eggs

(B) Newly hatched larvae

(C) Matured larvae

(D) Adult female

(E) Malformed Adult

(F) Incomplete ecdysis

Fig. 1. Mortality (upto 24 hr) of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

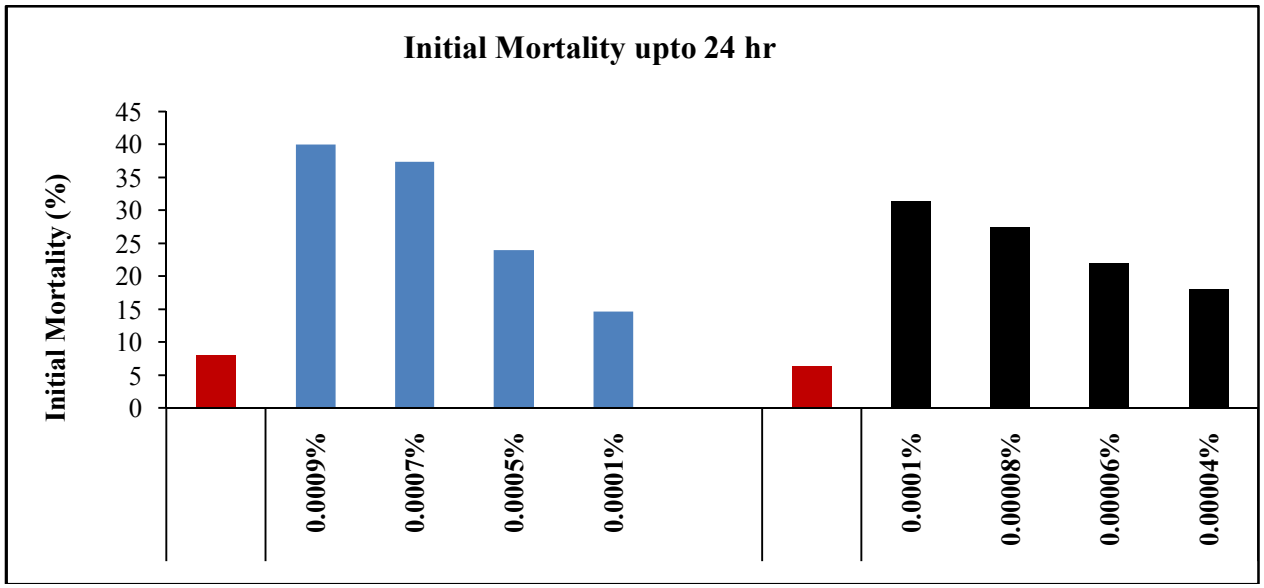


Fig. 2. Mortality (upto adult emergence) of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

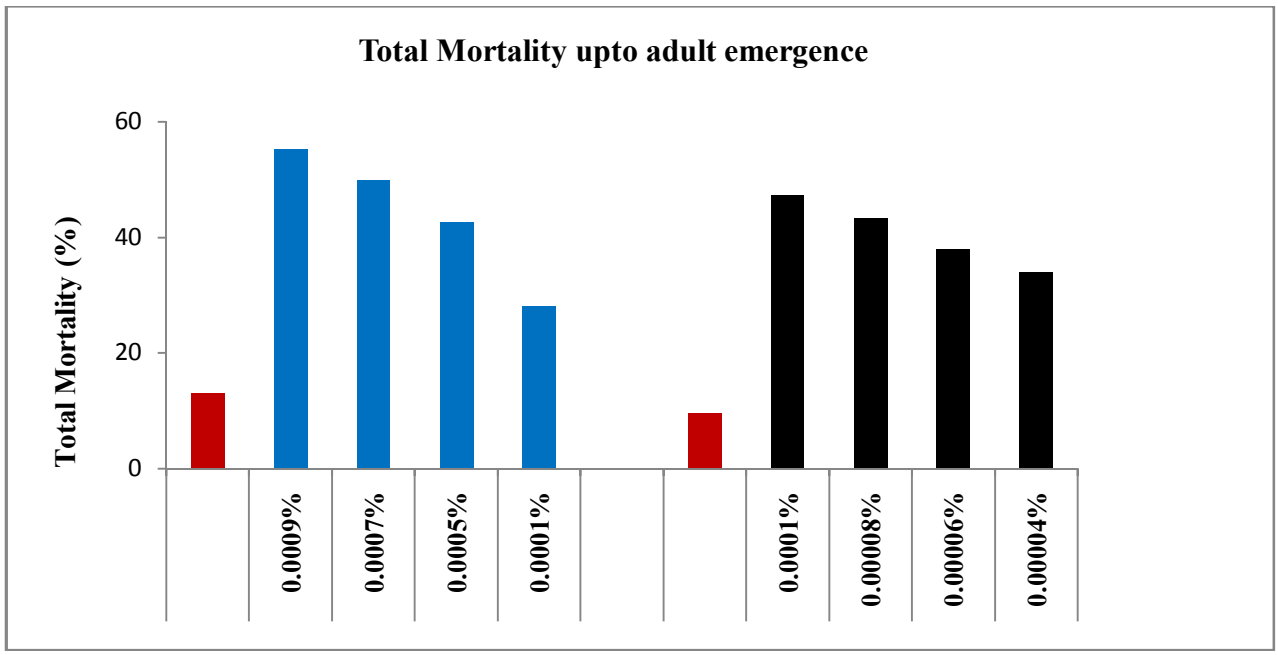


Fig. 3. Malformation of treated 5th instar larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

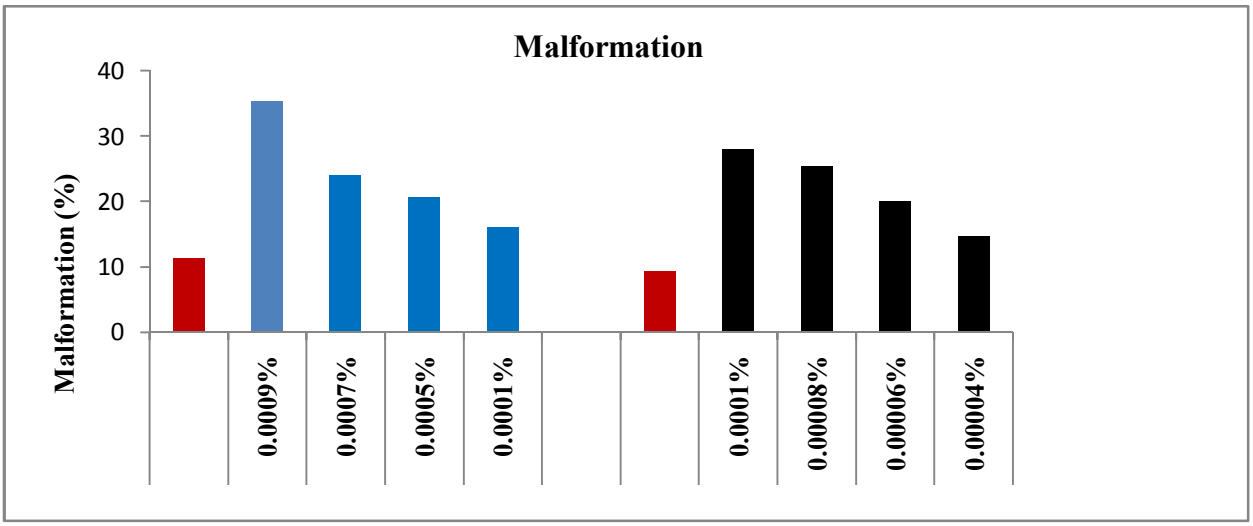


Fig. 4. Fecundity of female emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

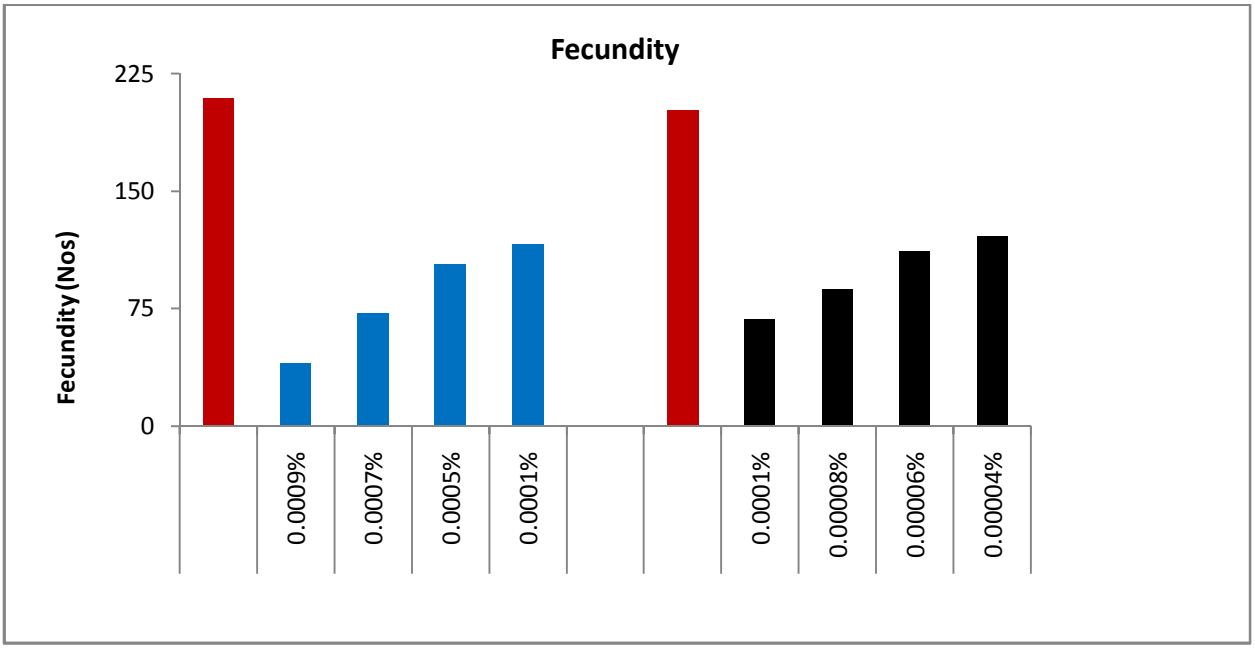


Fig. 5. Fertility of female emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

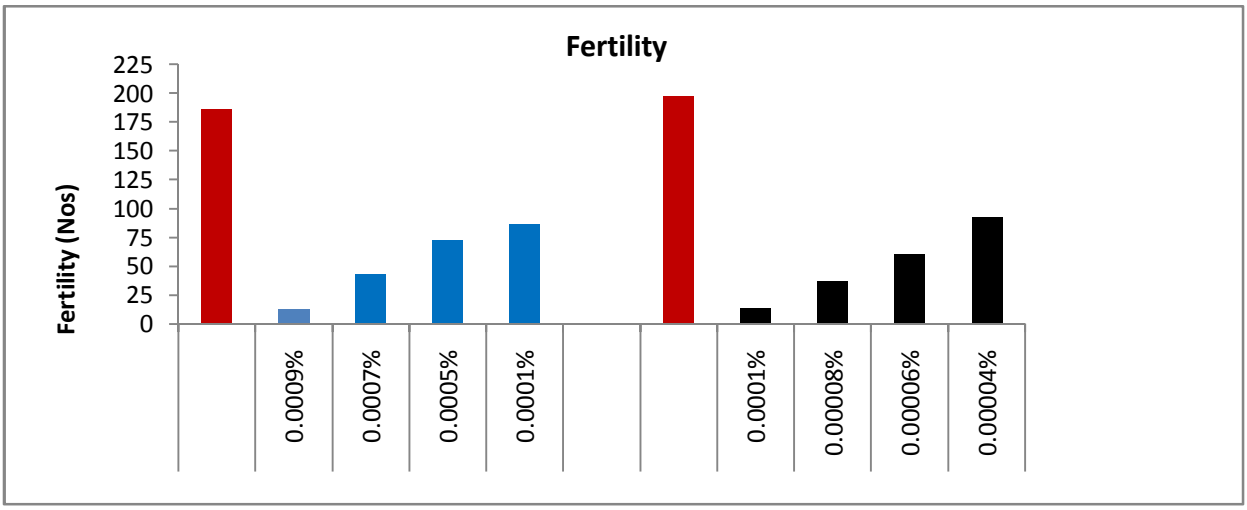


Fig. 6. Pre–oviposition period *Euproctis lunata following* topical application of Spinosad and Deltamethrin.

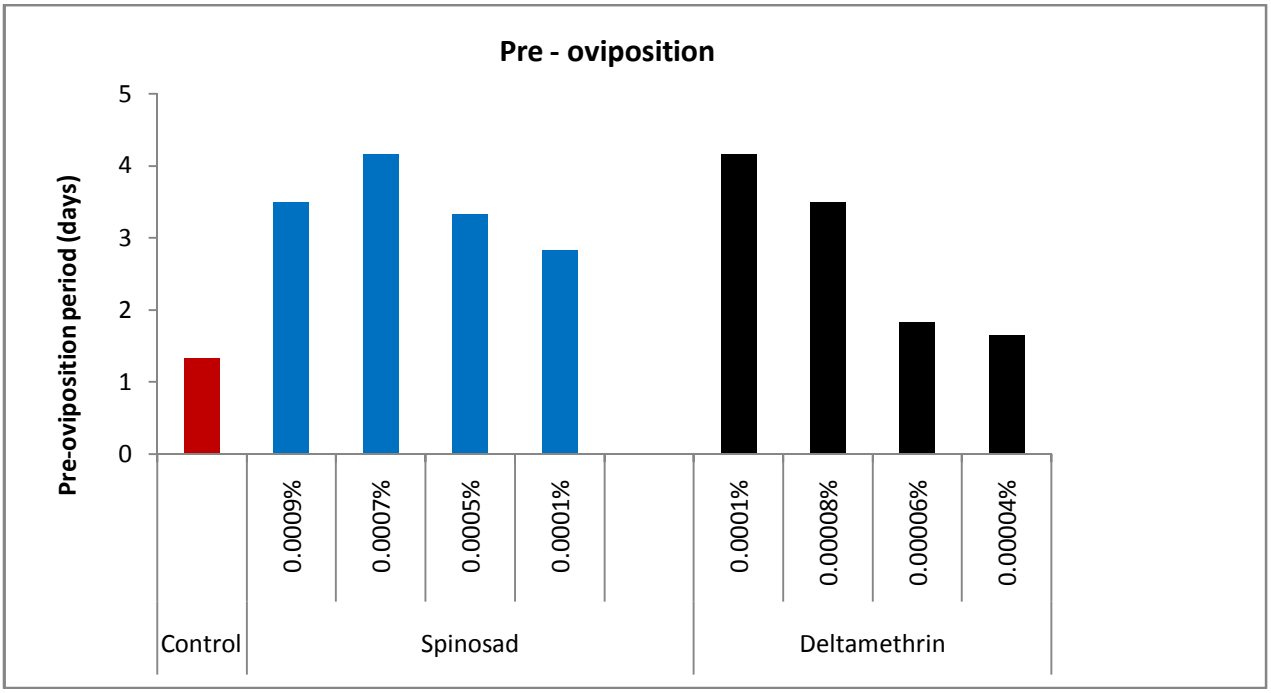


Fig. 7. Oviposition period of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

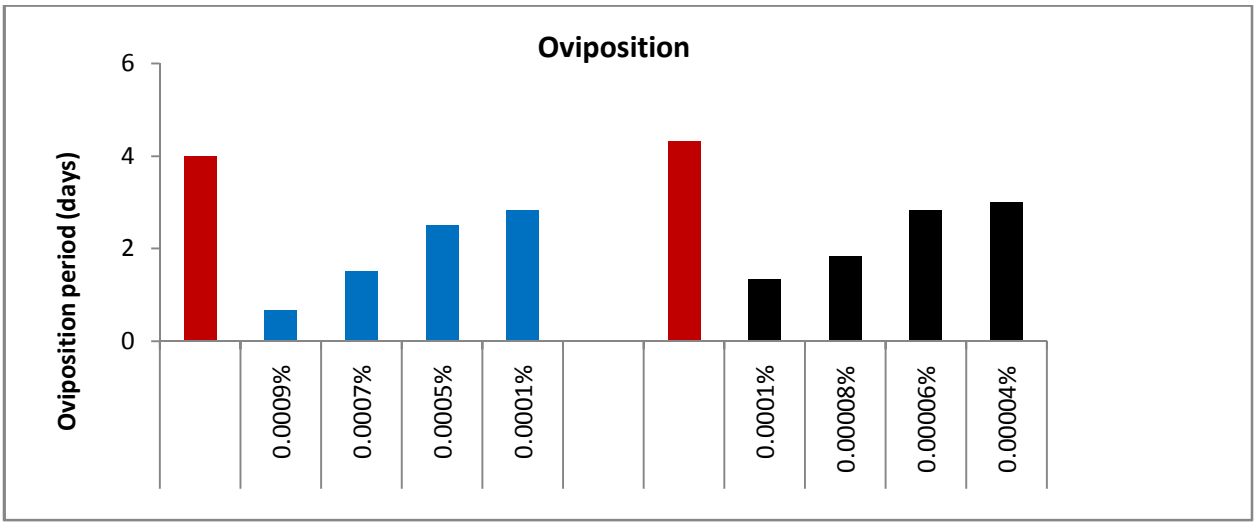


Fig. 8. Post-oviposition period of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

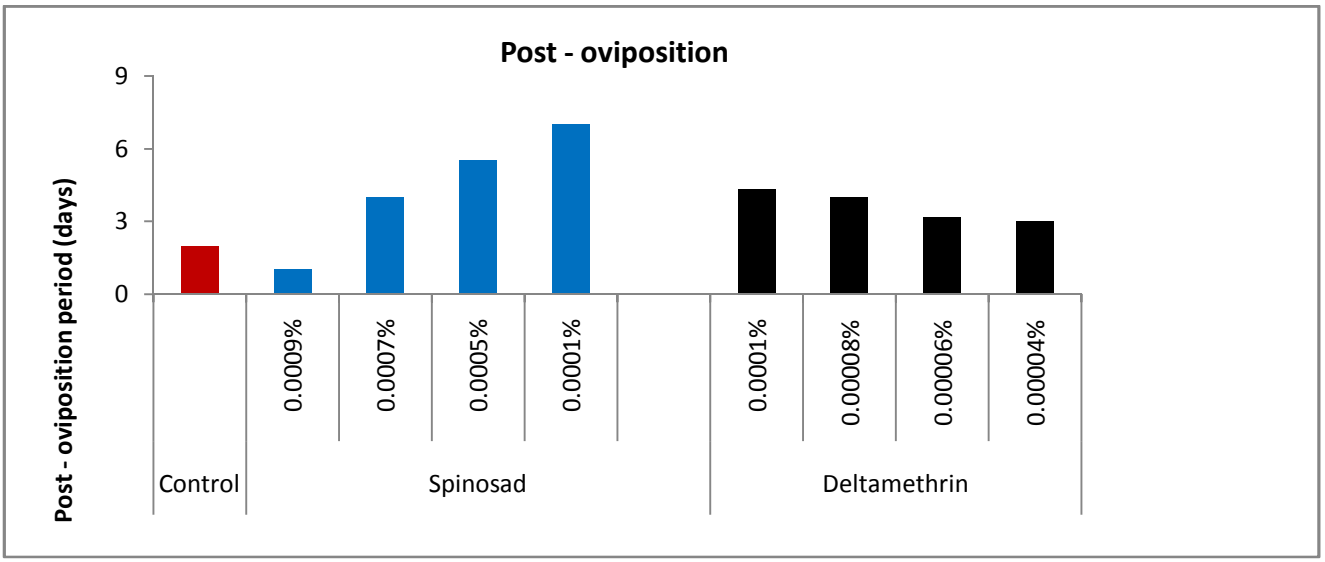


Fig. 9. Longevity of 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

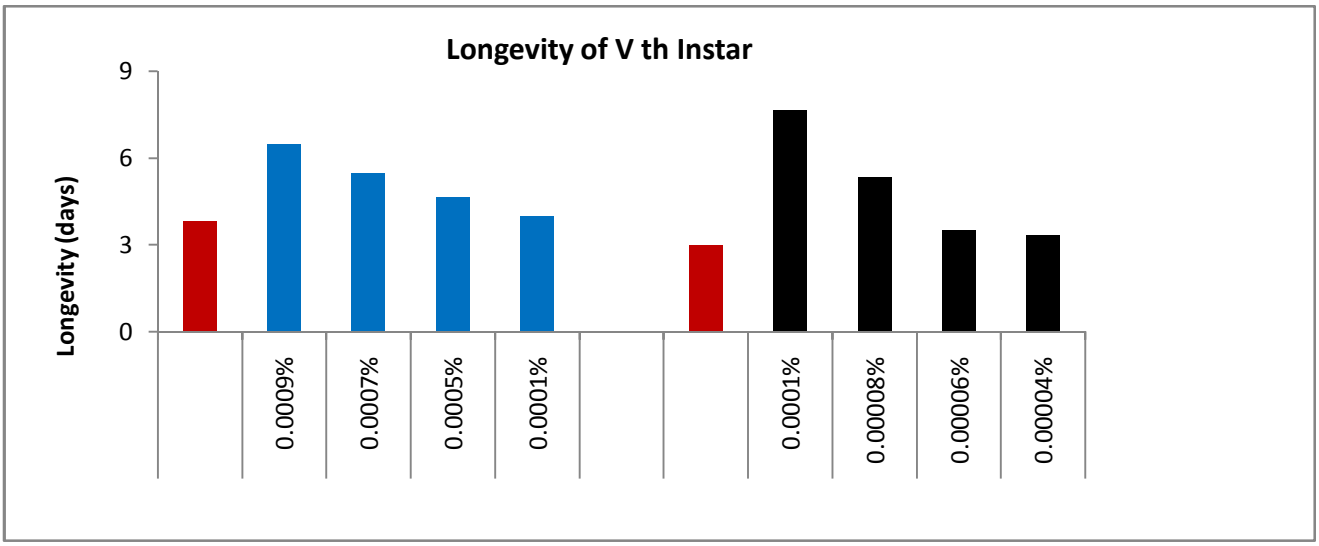


Fig. 10. Longevity of 6th instar larvae emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

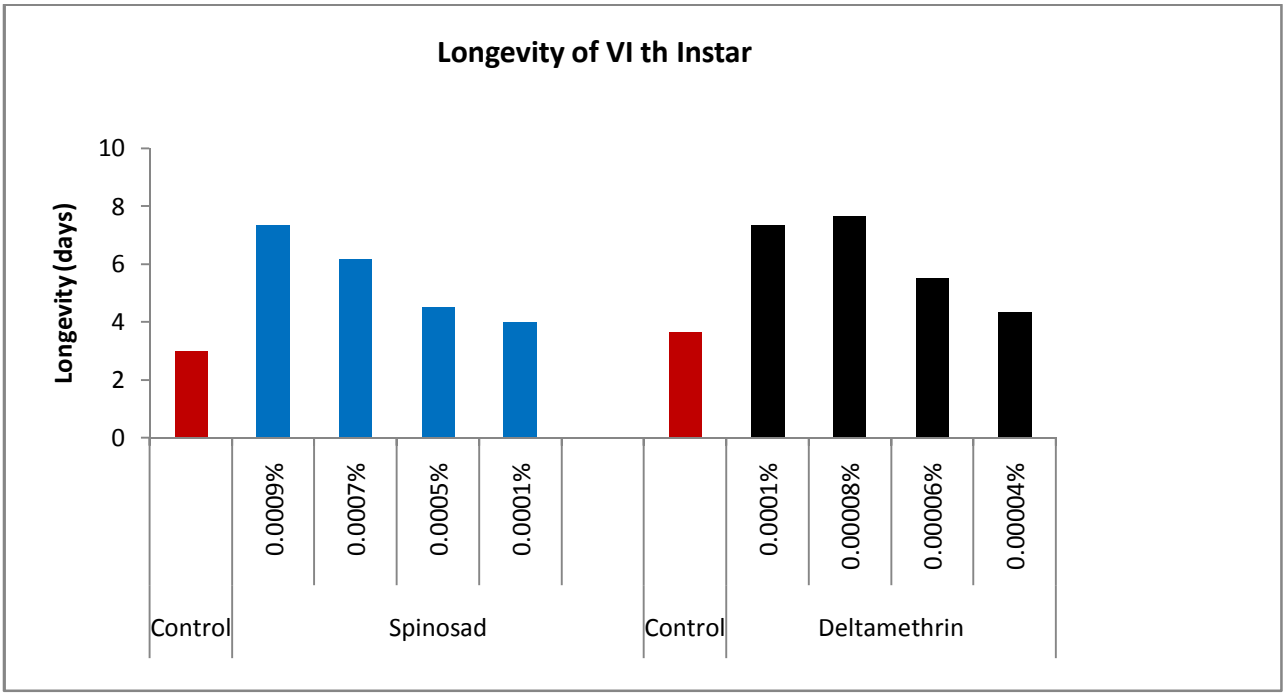


Fig. 11. Longevity of adult male emerged from 5th instar treated larvae of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.

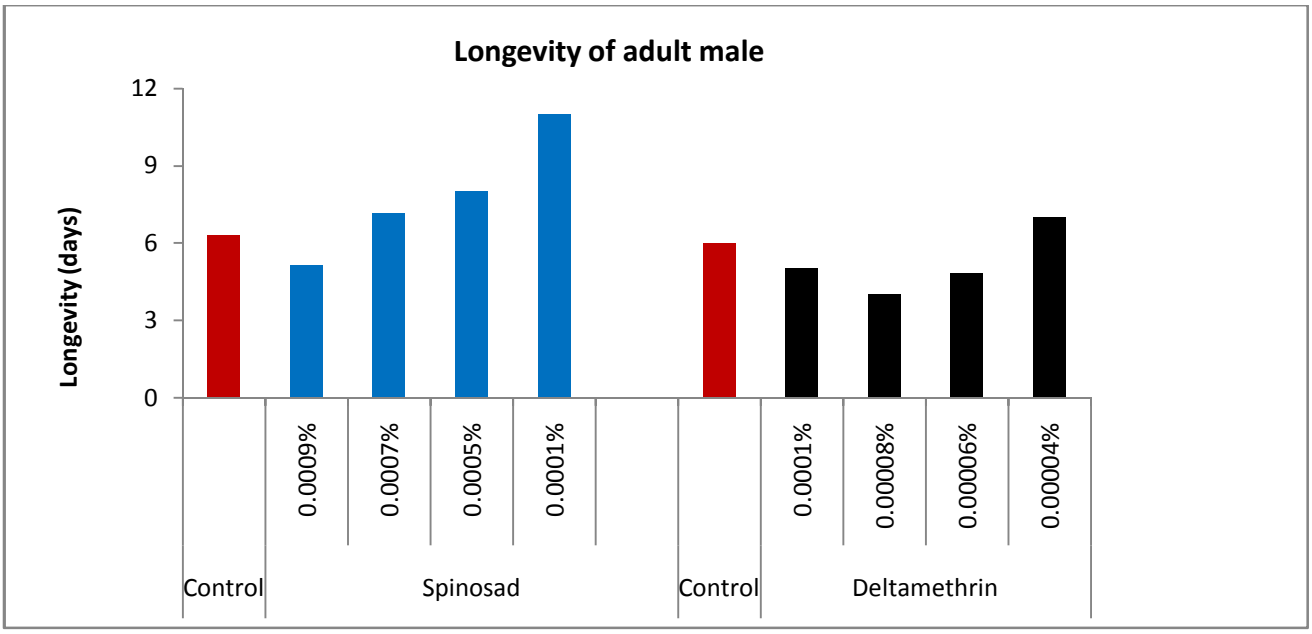


Fig. 12. Longevity of adult female emerged from 5th instar larvae treated of *Euproctis lunata* following topical application of Spinosad and Deltamethrin.