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Biology and Management of *Spodoptera litura* on Cabbage in Laboratory Conditions

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Spodoptera litura, commonly known as the tobacco cutworm, is a significant polyphagous pest of cabbage and other cruciferous crops. This study investigated the biology and evaluated the efficacy of different management strategies against *Spodoptera litura* on cabbage under laboratory conditions. Observations on the life cycle parameters, including incubation period (3.0±0.0 days), larval duration (29.60 days), pupal duration (8.80±1.48 days), and adult longevity (8.20±0.92 days, female, and 5.90±1.10 days, male), were recorded. Different management strategies, such as neem kernel extract (NSKE) containing 0.15% azadirachtin, *Beauveria bassiana* (Green Beauveria @ 1 × 10^8 CFU/ml and Multiplex Baba 2 × 10^8 CFU/ml), and newer insecticides (Novaluron, 10% EC, and Spinosad, 2.5% SC), were evaluated for their efficacy in controlling larval populations. Spinosad (0.025 %) and novaluron (0.01 %) when treated on I, II, III and IV instar larva resulted in 100% mortality in only 3 DAT while Green Beauveria (2% and 4%) was able to kill only 43.33% of I and II instar larvae in 3 DAT and Multiplex Baba (4%) 10% and 16.67% on III and IV instar larvae, respectively. The application of NSKE (0.2%) was only effective on I and III instar larvae with a

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mortality rate of 33.33 and 11.11% respectively. Thus, the results revealed that chemical insecticides were highly effective than *Beauveria bassiana* and NSKE. This information can be utilized to develop sustainable and eco-friendly pest management programs for *Spodoptera litura* on cabbage in field conditions.

Keywords: Cabbage; Spodoptera litura; biology; pest management; Beauveria bassiana.

1. INTRODUCTION

Cabbage is an important cole crop. It is used as salad, boiled vegetables and dehydrated vegetables as well as in cooked curries and pickles. It possesses both antioxidant and anticarcinogenic properties (Cohen et al., 2000). It is now grown almost throughout the year. West Bengal, Orissa, Assam, Bihar, Gujarat, Jharkhand, Madhya Pradesh, Chhattisgarh, Haryana, Uttar Pradesh are major cabbage growing states. Although cabbage is attacked by a number of insect pests of which tobacco caterpillar (*Spodoptera litura,* Fab.) is a serious pest of cabbage. This pest can be found all throughout the globe, from tropical to subtropical to temperate zones (Shah et al., 2019). Pest infestation normally leads to reduction in market value and may result in total crop failure in case of heavy infestation. It has also been reported as pest of cabbage, cauliflower, castor, cotton, groundnut, tobacco, maize, green gram, potatoes, soybean, rice, sunflower, tomato etc. more than 60 plant cultivated species reported in India (Garad et al., 1984). Many different management measures were implemented by farmers on a national and international scale to control this harmful pest, both in the field and in controlled laboratory settings (Ramzan et al., 2020).

Although the biology of this pest has been worked out by several researchers, in the era of climate change it is pertinent to study the biology of the insect pests concerning the phenology of the host plants as the pest's biology is affected by biotic and abiotic factors. Temperature is the most important factor affecting the biology of insects in various ways. Information on biotic aspects of biology is essentially required to find out the changes brought about if any due to climate change to get ready to cope with the situation of pest status and to devise the management practices and formulate the IPM program accordingly for sustainable agricultural production.

*Spodoptera litur*a was the first lepidopteran to develop insecticide resistance in India (Srivastava and Joshi, 1965). By 1965, resistance to Benzene Hexa Chloride (BHC) was reported in field populations from Rajasthan (Srivastava and Joshi, 1965) and West Bengal (Mukherjee and Srivastava, 1970). High level of resistance to different groups of synthetic pyrethroids has also been detected in the field strains of *Spodoptera litura* (Mayuravalli et al*.,* 1985). *Spodoptera litura* has been reported to develop resistance to insecticides belonging to organophosphates and pyrethroid groups (Armes et al*.,* 1997; Kranthi et al*.,* 2002).

As a result, managing *Spodoptera litura* has grown more challenging globally, and the most widely used insecticides are not working to control it. The development of resistance is a result of the selection pressure exerted on sprayed populations, increasing the frequency of resistant individuals (Torres-Vila et al*.,* 2002). Hence in this study, we have used a biopesticide (*Beauveria bassiana*), botanical insecticide (Neem seed kernel extract) and some newer insecticides like Spinosad and Novaluron for the management of *S. litura*.

2. MATERIALS AND METHODS

2.1 Biology of *Spodoptera litura* on Cabbage under Laboratory Conditions

The details of the materials used and techniques adapted are as follows:

2.1.1 Cultivation of cabbage

Cabbage (var. Cabbage Savitri) was grown in Rabi season on 21 September 2017 in the horticulture field of the Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India. All the recommended agronomic practices were followed to raise the crop, except plant protection measures.

2.1.2 Preparation of field

The land was prepared by giving two ploughings. Farmyard manure @ 8 tonnes/acre was incorporated during land preparation.

2.1.3 Sowing of seeds

For raising nursery, seeds @ 500 g/ha were sown in nursery beds one month prior to transplanting.

2.1.4 Transplanting

Seedlings (4-week-old) were transplanted to main field. A day before uprooting, seed beds were irrigated for easy uprooting and to minimize the root damage. Transplanting of seedlings was done in the afternoon for better establishment. The planting was done at a distance of 60 × 45 cm.

2.1.5 Irrigation and intercultural operations

The crop was irrigated at every 10-15 days to fulfill the water requirement and to maintain enough moisture in the field. Shallow frequent cultivation was given in the cabbage field by hoe to kill young weeds.

2.1.6 Maintenance of the culture of test insect

Laboratory culture of the pest was started with the larvae collected from cabbage fields of *Jawan*, Aligarh, (U.P). Moths thus reared were caged in glass jars (20cm×15cm), covered on top with muslin cloth and provided with stripes of folded crepe paper for oviposition. The adults were fed on 10 per cent honey solution soaked in cotton wool. The eggs were collected every day and kept separately in a petri plate for hatching. The first stage larva of *S. litura* was transferred to fresh tender leaves of cabbage in a plastic vial. Later instars were kept separately. The full-grown larvae were released in a glass jar provided with a layer of about 10 cm sterilized moist soil at the bottom for pupation. The adults emerging from the pupae were reared through a second generation to ensure the continuous supply of larvae of different stages. The culture was maintained at 27±1 °C temperature and 70±5 relative humidity in Biological Oxygen Demand incubator.

2.1.7 Biology of *Spodoptera litura*

Twenty eggs from egg mass were examined under microscope to study their color and shape. Freshly laid eggs were observed and counted daily. Hatching percentage was calculated from the number of eggs hatched out of total number of eggs kept under observation.

To determine the number and duration of different larval instars and total larval period, the newly emerged larvae (1st instars) were placed individually in plastic vials (4.5×12cm^2) with the help of fine camel hair brush. Tender and fresh cabbage leaves were kept inside the vials as the food and replaced daily with fresh leaves. The number of larval instars, duration of larval instars was observed daily. The number of larval instars were determined on the basis of moults observed at each moulting.

Pupal period was considered from the date of pupa formation to the date of adult emergence. The newly emerged male and female adults were used to study the longevity of adults separately. To study the pre-oviposition, oviposition and post-oviposition periods, the freshly emerged male and female adults were paired and confined in jars separately for egg laying. The eggs laid by each female on paper stripes, and muslin cloth were removed daily with the help of a fine camel hair brush and total number of eggs laid by each female was recorded separately. A time gap between mating and the commencement of egg laying was considered as the pre-oviposition period. The period between the starting and cessation of egg laying was recorded as the oviposition period, while, the period between the cessation of egg laying to the death of female was considered as post oviposition period.

The number of eggs laid by each female was recorded daily till the death of the female. The average fecundity of each female was worked out separately. The longevity of the female and male was calculated separately from the date of emergence to the survival of the adults. The total life period of *Spodoptera litura* was calculated by recording the number of days taken by the insect to complete different stages, *i.e*., from egg to adult.

2.1.8 Bioefficacy of some insecticides on different stages of *Spodoptera litura* in laboratory conditions

Laboratory trials were conducted to test and compare the efficacy of *Beauveria bassiana*, neem based insecticide, spinosad and novaluron against *Spodoptera litura.* For evaluation of bioefficacy, solution of spinosad (2.5% SC) @ 0.025 per cent, novaluron (10% EC) @ 0.01 per cent, Neem Kernel Extract (containing 0.15% azadirachtin) @ 0.2 percent was prepared and commercial formulations of *Beauveria bassiana* viz., Multiplex Baba and Green Beauveria,

were taken. Conidial suspensions of these formulations @ 1 × 10^8 CFU / ml, 2 × 10^8 CFU / ml respectively, at 2 different concentrations, 2 and 4% were prepared in distilled water containing 0.01% Cween 80. This concentration was more or less near the minimum recommended concentration for use on cabbage crops. The five sets of boxes were maintained for each insecticide. The young cabbage leaves were dipped in insecticides for 30 seconds and after air-drying the food was transferred to the sterilized Petri plates lined with filter paper. Five 1st, 2nd, 3rd and 4th instar larvae were introduced in separate sterilized Petri plates. A control set was also run simultaneously which contained the larvae and food sprayed with only 0.01% aqueous Cween 80. Five such replications were maintained for each treatment including that of control.

Aseptic conditions were maintained throughout the experiment. Petri plates with treated and control sets were incubated at 27±1°C in BOD incubator and observations were recorded daily on mortality.

3. RESULTS AND DISCUSSION

3.1 Biology of *Spodoptera litura* on Cabbage

3.1.1 Eggs

The eggs were spherical in shape. The colour in the beginning was pale green, which become dark before hatching and covered with brown coloured tuft of hairs. Similarly Jadhav et al., 2024 observed that egg masses were golden brown to cream in colour and before hatching turned into black colour from brown. The average number of eggs observed per egg mass was 420 eggs which were arranged in 3-4 layers.

3.1.2 Incubation period

The incubation period of the eggs under laboratory conditions was 3 days with an average of 3±0 days. Similar findings were revealed by many workers. Kumar (2019) has also recorded 3 days of egg period in cabbage and cauliflower, whereas the findings of Tuan et al., 2016 and Ashwini et al., 2016 were 3.9 days and 2.0-2.7 days, respectively. Jadhav et al., 2024 observed an egg period of 4.53 ± 0.01 days to 4.80 ± 0.01 days which was more or less similar to our findings. Ramzan et al., (2021) observed an incubation period of 2-4 days with an average of 3.12±0.39 days on cabbage.

3.1.3 Larval period

The larva moulted five times and passed through six instars before becoming pupa. Neonates were translucent green with prominently big black head. The body had several black short hairs arising from dark coloured tubercles. The second and third instar larvae were morphologically similar but third instar larva was longer than second. The duration of first, second, third, fourth, fifth and sixth instar ranged from 2 to 3, 2 to 4, 2 to 5, 4 to 5, 1 to 4, 1 to 3 and 1 to 3 with an average of 2.1, 3.0, 3.9, 4.7, 1.3, 2.0 days respectively. The total immature period was completed in 27 to 35 days with an average of 29.60 days, whereas Kumar (2019) recorded a larval period of 22.4 days and Jadhav et al., 2024, has observed 17.87 ± 0.29 days to 20.47 ± 0.04 days of larval period.

3.1.4 Pre-pupal and pupal Period

Pre-pupal stage was characterized by shortening of the larva in length, suspended feeding, and movement to the periphery. Larva becomes blackish with less prominent stripes. Pre-pupal period ranges from 1 to 3 days with an average of 1.50±0.71 days. Pupation occurred in soil. The newly formed pupa was light greenish in colour and later changed to reddish brown in colour. Pupa was obtect type with the anterior end broad, round, and tapering posterior to a pointed tip. The pupal period lasts about 8 to 11 days with an average of 8.80±1.48 days whereas, Kumar (2019) observed a pupal duration of 4.8 days which was nearly half the duration compared to our findings and 2.78 ± 0.05 days to 2.94 ± 0.02 days of pre-pupal period, 8.66 ± 0.09 days to 9.55 ± 0.10 days of pupal period as worked out by Jadhav et al., (2024).

3.1.5 Adult

Generally, adult emergence occurred during night time. The adult males and females were hairy greyish brown in colour. Sexes can easily be identified on the basis of markings on wings. In males, forewings were pale brown with variegated brownish stripes and greyish spots on posterior portion of the wings. In females, markings on forewings are same as male except for greyish spots. The adult female longevity was in the range 7 to 10 days with an average of 8.20±0.92 days and male longevity was 5 to 8 days with an average of 5.90±1.10 days. The minimum female and male longevity of 7.0 and 5.0 days were found, respectively, and the

Table 1. Biological parameters (days) of *Spodoptera litura* on cabbage leaves

Observation (No. of insects)	Incubation period	Duration of larval instars						Pre pupal period	Pupal period	Total immature period	Longevity	
		I	II	III	IV	V	VI				Male	Female
10	3	3	2	3	5	4	2	3	10	35	8	10
10	3	2	2	4	5	2	2	1	10	31	5	9
10	3	2	2	3	5	2	1	2	9	29	6	7
10	3	2	2	3	5	1	2	2	11	31	7	9
10	3	2	3	2	5	1	3	1	10	30	5	8
10	3	2	9	5	4	1	1	1	6	32	5	7
10	3	2	2	3	4	1	3	1	8	27	6	8
10	3	2	3	5	5	2	1	1	8	30	7	8
10	3	2	3	7	5	1	3	2	5	31	5	8
10	3	2	2	4	4	1	2	1	8	27	5	8
Minimum	3	2	2	2	4	1	1	1	6	27	5	7
Maximum	3	3	4	5	5	4	3	3	11	35	8	10
Mean ± SD	3.0 ±0.0	2.10 ±0.32	3.0 ±2.16	3.90 ±1.45	4.70 ±0.48	1.30 ±0.97	2 ±0.82	1.50 ±0.71	8.50 ±1.90	30.30 ±2.36	5.90 ±1.10	8.20 ±0.92

Table 2. Comparision of the efficacy of *Beauveria bassiana* with insecticides on *Spodoptera litura*

Insecticides	Concentration (%)	I instar		II instar		III instar		IV instar	
		Mean % mortality of *S. litura* at indicated days							
		3	7	3	7	3	7	3	7
Neem kernel extract	0.20	33.33^{c}	0.00	0.00	0.00	11.11^{c}	0.00	0.00	0.00
Spinosad	0.025	100.00^{a}	0.00	100.00^{a}	0.00	100.00^{a}	0.00	100.00^{a}	0.00
Novaluron	0.01	100.00^{a}	0.00	100.00^{a}	0.00	100.00^{a}	0.00	100.00^{a}	0.00
Green Beauveria	2.0	43.33^{b}	43.33^{b}	0.00	0.00	0.00	0.00	0.00	0.00
Green Beauveria	4.0	0.00	0.00	43.33^{d}	73.33^{b}	0.00	0.00	0.00	0.00
Multiplex Baba	4.0	0.00	0.00	0.00	0.00	10.00^{c}	20.00^{b}	16.67^{c}	23.33^{b}
Multiplex Baba	2.0	0.00	0.00	0.00	63.33^{c}	0.00	0.00	0.00	0.00
P		0.003	-	0.021	-	0.106	-	0.24	-
F		13.33	-	5.78	-	3.07	-	1.87	-
DF		8,14	-	10,17	-	8,14	-	8,14	-
LSD		2.31	-	2.17	-	2.20	-	2.57	-

DF - degrees of freedom; LSD - Least significant difference at 5%

maximum longevity of females and males was 10.0 and 8.0 days, respectively (Details are mentioned in Table 1), while Soni et al., 2001 recorded female longevity of 8.20 days and males as 7.0 days on cabbage. Narvekar (2018) has worked on the biology of *S. litura* on various crops such as castor, okra, tapioca, sweet potato, mulberry, groundnut, cowpea and taro and found minimum and maximum adult longevity of 5.33 and 7.67 days, respectively. Jadhav et al., 2024 found that adult longevity ranged from 4.84 ± 0.04 to 4.91 ± 0.02 days for men and 6.15 ± 0.04 to 6.37 ± 0.02 days for women, which differed from our findings.

3.1.6 Comparison of the efficacy of *Beauveria bassiana* with neem based insecticide (Neem kernel extract) and new molecules on different stages of *Spodoptera litura* under laboratory conditions

Data presented in Table 2 shows that insecticides were highly effective than *Beauveria bassiana*. Spinosad (2.5% SC) @ 0.025 per cent and novaluron (10% EC) @ 0.01 per cent resulted in 100 per cent mortality of *Spodoptera litura* first instar larva at 3 DAT followed by Green Beauveria (2 per cent) with 43.33 per cent mortality and Neem kernel extract with 33.33 per cent mortality at 3 DAT. In second instar larvae 100 per cent mortality was observed when treated with spinosad and Novaluron at 3 DAT which was non-significant among themselves but significant with other treatments followed by 4 per cent Beauveria (73.33 per cent), 2 per cent Multiplex Baba (63.33 per cent) at 7 DAT and 2 per cent Green Beauveria (43.33 per cent) at 3 DAT. In third instar 100 per cent mortality was observed when treated with Spinosad and Novaluron followed by Neem kernel extract (11.11 per cent) and Multiplex Baba (10 per cent) at 3 DAT. *S.litura* when treated with *Beauveria bassiana* and insecticides, has proven that Spinosad and Novaluron were at par with 100 per cent mortality at 3 DAT, which was significantly different from the rest of the treatments of *Beauveria bassiana*. The reason behind the delayed effect of *Beauveria bassiana* can be justified by the fact that being a fungal biopesticide, it takes more time for it to grow and spread inside an insect's body. Sumanjali et al., 2020 have revealed that Spinosad 45 SC @ 96ml/ha with a mortality rate of 56.20% was significantly superior to the *Beauveria bassiana* @ 1.5kg/ha (51.83%) and and NSKE @ 5% (42.70%) which is similar to our findings. Similarly, Chowdary and Sharma, (2019) showed that percent larval mortality was higher in *Plutella xylostella* when treated with spinosad @15 g a.i./ha (78.13%) when compared to azadirachtin (45.52%). The investigations of Pushpalatha et al., 2020 showed that Novaluron 10% EC @ 1 ml/l was found to be highly effective in reducing the larval load with 75.60 % reduction in larvae compared to NSKE 5% @50 ml/l with 65.91 per cent larval reduction on the cabbage crop.

4. CONCLUSION

In conclusion, this study investigated the biology and management of *Spodoptera litura*, a significant pest of cabbage, under controlled laboratory conditions. Novaluron and Spinosad's efficacy was better than *Beauveria bassiana* and NSKE as they killed 100% of the *S. litura* population under controlled conditions within 3 days. The findings on management strategies can contribute to the development of more effective and sustainable pest control methods for this important crop. Further research should focus on field trials to validate laboratory findings exploring integrated pest management approaches.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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