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EFFECTS OF TEMPERATURE ON THE DURATION OF THE LIFE CYCLE, GROWTH AND FECUNDITY OF *HYMENIA RECURVALIS* (AMARANTHUS LEAF WEBBER) (PYRALIDAE : LEPIDOPTERA)

by

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Abstract

The productivity of amaranth in Uttarakhand hills is constrained by the unholy triple alliance of insect, diseases and weeds resulting drastic reduction in yields. *H. recurvalis* is not only causing loss to amaranths but to a wide range of plants in India and abroad. To study the life history, fecundity, larval period, longevity, a stock culture was maintained in the laboratory by collecting the larvae from amaranth fields. Moths of *H. recurvalis* emerged mostly during the night in between 8.00 to 10.00 pm. On sunset they become active and chase each other in their nuptial-flight. The average duration of mating was recorded between 1.20 to 1.35 minutes. The eggs are generally laid singly but sometimes in batches of 2 to 5, usually in groove of leaf veins on lower surface. The freshly laid eggs are ovoid or spherical, translucent, smooth, shiny and snow white. There were five larval instars. The neonate larvae were pale green with blackish head and measured 2.9 ± 0.019 mm in length and 0.9 ± 0.30 mm in breadth. The earthen cocoon sometimes attached to the rhizosphere of the host plant. Pupae measured 12.0 ± 0.18 mm. The moths were about 1.6 cm long across the outstretched wings. The fore and hind wings are dark brown in colour. The total duration of life cycle was recorded 32.66 ± 0.29 days. The duration of different developmental stages of this pest decreased with the rise in the temperature. Rise in temperature from 18^0C, 20^0C, 25^0C and 30^0C brought significant reduction in incubation period.

Keywords : Hymenia recurvalis, Amaranthus, Temperature, lifecycle.

Introduction

Garhwal himalaya is extremely rich in grain amaranths diversity which has assumed considerable importance as an underutilized food plant. The amaranths grain has recently gained attention as a supplementary food crop having great potential for the future. It possesses high nutritional quality and grain yield apart from high bio-mass production. Amaranthus crop is largely cultivated in the mountain regions Garhwal Himalayas above 600m and extends upto 3500m elevation.

The grain species i.e., *Amaranthus hypochondriacus* and *A. caudatus* are mostly grown and often intercropped with maize, finger millet, barnyard millet and sometime as sole crop. No other hilly region in the world has so much of area under this crop. The crop is also sporadically grown in the Northern plains, Central and Southern India. Singh and Thomas (1978) estimated that in the Kullu valley of Himachal Pradesh alone it is grown in 890 hectare while in Gujarat it occupies 120 hectare. In the interior of north-west hills of India under traditional farming method it occupies nearly 60% non-irrigated land of higher hills (Joshi, 1981).

Among the insect pests, amaranth leaf webber, *Hymenia recurvalis* (Fab.) has mainly

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created havoc among the hill farmers inflicting substantial crop loss. The moths of *H. recurvalis* are nocturnal and positively phototrophic inhabit.

H. recurvalis is not only causing loss to amaranths but to a wide range of plants in India and abroad. In India, the pest is found on all the species of Amaranthus but *A. gangeticus, A. mangostanus*, *A. cruentatus* and *A. dubius* also show a fairly high attack. Other reported host plants includes *Trienthema monogyna*, silver beet, sugar beet, mangold and urgul (*Beta vulgaris*), mung, soybean, *Coleus parviflorus*, *Celosia cristata*, *Digera arvensis*, *Gomphrena celonoides*, spinach, melon, French been, ridge gourd (*Luffa acutangula*) and various grasses. Besides this, it has also been recorded from *Alfa alfa* Bhattacherjee & Menon, 1964; Aswal *et al.,* 2003, 2005; Bisht *et al.,* 2006.

Outside India the pest has been recorded from sunflower and cotton in Africa, beet, spinach, *Chinopodium album*, *Amaranthus* spp., catnip, sunflower, carrots, cotton, cucurbits, purslane (*Portulaca oleracea*), kale swiss chard in the USA; silver beet, common beet, *Amaranthus* spp., *Chenopodium sp.*, *Portulaca oleracea,* cotton, maize, salt brush (*Atripex*) and cucurbits (melon etc.) in Australia; sugar beet, *Amranthus hybridus and Portulaca oleracea* in Bermuda; beet in Ceylon; sugar beet in China; beet, *Amaranthus* sp. and sweet potato in Fiji; beet and spinach in Hawaii; maize in Indo-china; beet and spinach in Japan; crucifers and melon in New Zealand; *Chinopodium quinoa* in Peru; soybean in Puerto Rico and *Amaranths* sp. in Tahity Island Harris *et al.,* 2004; Yarger, 2006; French, 2006; Shirai, 2006; James *et al.,* 2006.

Materials and Methods

The biology of an insect pest is of prime importance, since it forms the base for developing the suitable control measure. Being a serious pest of economically important crop plant especially amaranths, the biology of *H. recurvalis* was studied in laboratory as well as in different temperatures.

To study the life history, fecundity, larval period, longevity, a stock culture was maintained in the laboratory by collecting the larvae from amaranth fields. Larvae were placed into the wire mesh wooden cage 0.5 m x 1.5 m size containing amaranth plant. Pair of freshly emerged moths, collected from stock culture were released for oviposition on an insect free 30 day old potted amaranths plant *var*. PRA-1 enclosed by 0.5 m x 1.5 m wire mess wooden cage. The moths were supplied with 10 per cent honey solution in a cotton swab as its food. Ten replicates of this set were maintained at a time for 3-4 days. The number of eggs laid by female in set was counted after 3-4 days so as to determine the fecundity.

Leaf sections with fifty newly laid eggs were cut from the plants in the oviposition cages and kept the petridishes (35 cm dia.) lined with moist filter paper to study the incubation period. Twenty newly hatched larvae were reared individually on newly amaranth leaves in a glass tube (10 cm. x 2 cm.) lined with moist filter paper and then recorded complete life history. The leaves were changed every day. The number of moults, duration and measurement of the life stages were recorded. The fifth instar larvae were kept into the petridishes (35 cm. dia.) having moist sterile soil with amaranth leaves and allowed pupation to record pupal duration.

Life history parameters viz., percentage of hatching, incubation period, larval, pupal period were thus studied at different constant temperatures i.e. 15^{0}C, 18^{0}C, 20^{0}C, 25^{0}C and 30^{0}C. For studying the incubation period and viability of eggs five specimen tubes (7cm. x 2.5 cm.) each having 100 eggs covered with muslin cloth was placed at above constant temperatures separately. The specimen tubes were observed thrice a day to record the duration of egg hatching. Per cent hatched eggs were recorded at different temperatures from each specimen tubes. For observing larval development, rearing was done at constant temperatures. Larvae were reared by keeping ten larvae in one replication. During the process rearing at different temperatures tender leaves of amaranth obtained from the field were provided to the larvae. Numbers of days required for larval and pupal development at different temperature were recorded.

Results and Discussions

The life history of *H. recurvalis* was studied from egg to adult. Adults were collected from the fields and allow to mating and oviposition. Fecundity, incubation period, larval and pupal duration and adult longevity were recorded.

Mating behavior and fecundity (Pre-oviposition and oviposition):

Moths of *H. recurvalis* emerged mostly during the night in between 8.00 to 10.00 pm after emergence they rest for whole of the following day on some low laying host plants or grasses. On sunset they become active and chase each other in their nuptial-flight. The average duration of mating was recorded between 1.20 to 1.35 minutes. The eggs are generally laid singly but sometimes in batches of 2 to 5, usually in groove of leaf veins on lower surface. The freshly laid eggs are ovoid or spherical, translucent, smooth, shiny and snow white.

Bhattacherjee and Menon (1964), Miyahara (1990) noted that mating rate of female was highly correlated with the percentage of mature adults or the females had already mated. In contrast to Diptera or Orthoptera, a larger number of lepidopterous insects take food nourishment for egg production and propagation in the larval stage rather than in the adult stage. Species that have fully matured ovaries before eclosion are shorter-lived and have only rudimentary mouthparts Wheeler, (1996). Bhattacherjee and Menon (1964) observed that eggs are generally laid in grooves of leaf veins as many as 156 eggs per female with maximum oviposition on the third night. Singh (1970), recorded that about 150 eggs per female are laid during oviposition period of female moths was 3 to 4 days at 25^{0}C and of 210 eggs.

Shirai (2006) pointed out that young aged adults can withstand several days of starvation and fly actively without feeding on nectar, and these young adults begin reproductive behavior after active flight and feeding on nectar. If there is appropriate vegetation with flower nectar and near the point of birthplace, it is a disadvantage for newly emerged adults to take a long flight before feeding on the nectar. Oviposition generally follows copulation on the second or third night. Once the egg laying started, it continued for 2-3 days. A female moth laid as may as 142.30 ± 5.44 eggs. The preoviposition and oviposition period was observed 1.16 and 3.33d respectively. The older aged adults or mated females can maintain the capacity of dispersing to more suitable habitats because this species lives longer and can lay eggs for 20d.

The incubation period was observed 3.4 ± 0.65 days. The present study on incubation period showed similarity with the observations made by Bhattacherjee and Menon (1964), and Walsh and Hargreaves (2002), and Martin *et al.*, (2003).

Larval: There were five larval instars.

First instar:

The neonate larvae were pale green with blackish head and measured 2.9 ± 0.019 mm in length and 0.9 ± 0.30 mm in breadth. They were gregarious in habit and scraped the chlorophyll of the young leaves and did not web the leaves. These larvae became fully grown in 1.0 ± 0.11 days and measured 4.2 ± 0.035 mm in length and 1.5 ± 0.016 mm in breadth.

Second, third and fourth instar:

The larvae were grayish-green and black marks subsequently appear on the body. The larvae characterized by a distinct line down to the middle of the back. The larvae of these instars started feeding by webbing the leaves, which usually started from the lower epidermal layer. Freshly moulted second instar larvae measured 4.5 ± 0.028 mm in length and 1.9 ± 0.021 mm in breadth and attained the size of 5.3 ± 0.030 mm in length and 2.5 ± 0.022 mm in breadth in 1.85 ± 0.18 days. Physical characters remained same as in case of second instar except the larger size. Just moulted, third instar larvae measured 7.10 ± 0.089 mm in length and 2.3 ± 0.028 mm in breadth and grew to 7.5 ± 0.093 mm in length and 2.8 ± 0.039 mm in breadth in 2.31 ± 0.18 days. The fourth instar larvae measured 12.5 ± 0.026 mm in length and 3.10 ± 0.01mm in breadth just after moulting and increased to 15.4 ± 0.048 mm in length and 4.30 ± 0.029 mm in breadth in 3.25 ± 0.21 days.

Fifth instar:

The larvae somewhat spindle shaped and usually stretched out so that the two prolegs on

Table 1 : Biological observations on *H. recurvalis*.

Life stages	Fecundity	Incubation / Larval period (Days)	Physical measurement of larvae	
			Length (mm)	Breadth (mm)
Preoviposition	-	1.16	-	-
Oviposition	-	3.33	-	-
Eggs	142.30±5.44	3.4±0.65	-	-
Larvae				
I Instar	-	1.0±0.11	2.9±0.019 4.2±0.035	0.9±0.030 1.5±0.016
II Instar		1.85±0.18	4.5±0.028 5.3±0.030	1.9±0.029 2.5±0.022
III Instar	-	2.31±0.18	7.1±0.089 7.5±0.093	2.3±0.02 2.8±0.039
IV Instar	-	3.25±0.21	12.5±0.026 15.4±0.048	3.1±0.01 4.3±0.029
V Instar	-	5.71 ±0.27	16.3±0.020 17.0±0.029	5.0±0.007 5.5±0.018
Total larval period	-	14.12	-	-
Pre pupal period	-	2.35±0.19	-	-
Pupal period	-	8.30±1.0	12.0	2.0
Earthen cocoon	-	-	14.0 ±0.20	4.0±0.09
Total period	-	32.66 ±0.99	-	-
Adult Longevity				
Male	-	2.15±0.20	15.10±0.021 (wing span)	-
Female	-	5.10±0.81	17.18±0.024 (wing span)	-

the last abdominal segment are distinctly visible. 2-3 days old larvae became pink and leaved the plant for pupation in the soil. The larvae when freshly moulted were 16.3 ± 0.02 mm long and 5.0 ± 0.007 mm wide, but increased upto 17.0 ± 0.029 mm in length and 5.55 ± 0.018 mm breadth in 5.71 ± 0.27 days.

Pre pupal period:

After being full fed, the fifth instar larvae ceased feeding. During the prepupal period the larvae changed thier colour from green to yellow, brown to bright pink and then leaved the plant for pupation into the soil and prepuated for 2.35 ± 0.19 days. The prepupae were light yellowish pink and they formed inside the soil, sometimes in fallen leaves without any silky cocoon.

Pupal period:

Fresh pupae were light brown and turned into reddish brown with age and showed brisk movement when disturbed. The pupation takes place inside the earthen cocoon, which remain 1-2 cm deep into the soil. The earthen cocoon sometimes attached to the rhizosphere of the host plant. Pupae measured 12.0 ± 0.18 mm in length and 2.0 mm in breadth and the pupal period occurred 8.30 ± 1.0 days. Whereas, the earthen cocoon measured 14.0 ± 0.20 mm in length and 4.0 ± 0.09 mm in breadth.

Adults:

The moths were about 1.6 cm long across the outstretched wings. The fore and hind wings are dark brown in colour. The forewings have two oblique white translucent bands one of which was about half way along the wing and starts about a quarter of the distance from the front edge of the wing. The second is situated about three-quarters of the distance to the wing tip from the base, starts at the leading edge of the wing and finishes about half way across the wing. The rear wings are divided into two parts by a broad oblique white band. Outer margins of both pairs of wing are fringed with short hairs. The tip of the abdomen of the male was observed pointed while that of the female was broad and dilated. Wing span of the male moth was 15.10 ± 0.021 mm while that of the female was 17.18 ± 0.024 mm. The males and females lived after mating for 2.15 ± 0.20 and 5.10 ± 0.81 days in normal laboratory conditions fed with 10 per cent honey solution (Table.1)

Bhattacherjee and Menon (1964) observed that moths survived up to 13 days in normal laboratory condition with 5 per cent honey solution without mating. After mating males die in a day or two and the females die after oviposition. French (2006) observed that the females survive 18-21 days. Shirai (2006) observed that the mean longevity did not differ significantly between females (11.1d) and males (10.1d). Both sexes lived significantly shorter in mated group in comparison with the unmated adults. The total duration of life cycle was recorded 32.66 ± 0.29 days.

Effect of temperatures on the life cycle of *H. recurvalis*

The present study revealed that the duration of different developmental stages of this pest decreased with the rise in the temperature. Number of days (11.67) required for egg hatching were more at 18^{0}C and less (3.16 days) at 30^{0}C. Rise in temperature from 18^{0}C, 20^{0}C, 25^{0}C and 30^{0}C brought significant reduction in incubation period. Per cent hatchability increased with rise in temperature from 18^{0}C to 30^{0}C. The highest per cent of hatched eggs (95.57%) were recorded at 30^{0}C (Fig.1). There was negative relationship between increase in the temperature and larval period. Significant decrease in larval period (22.80 days to 10.65 days) was observed with increase in temperature from 18^{0}C to 30^{0}C. Similar

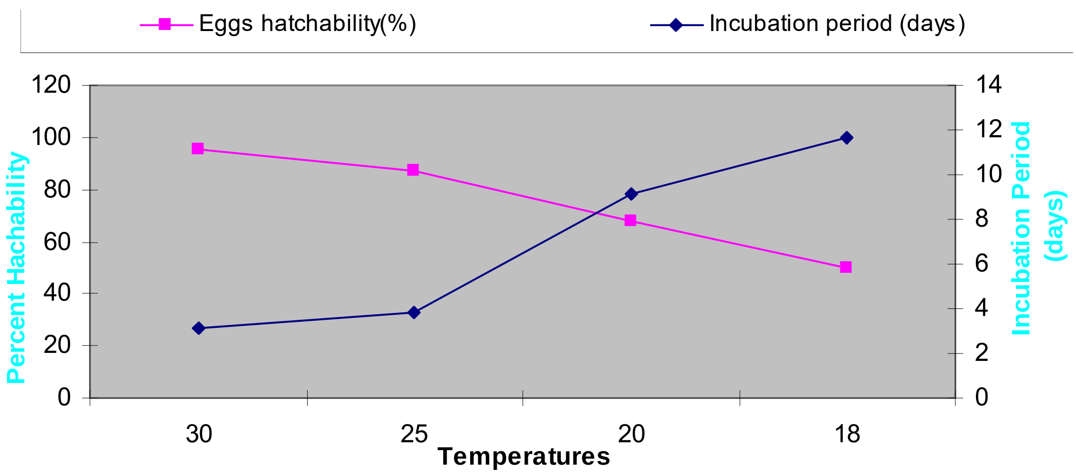

Fig. 1 : Effect of temperature on hachability and incubation period

Table 2 : Co efficient correlation (r) and linear regression equation (y=a + b x) obtained in life stages of *H. recurvalis* at different temperatures.

Sl no.	Relationship		Regression equation	Correlation coefficient	Probability
1	Temperature Hatchability	(X) (y)	X= -9.1904 Y= 3.6235	0.957961	0.016
2	Temperature Incubation	(X) (y)	X= 23.841 Y=0.7263	-0.94482	0.090
3	Temperature Larval period	(X) (y)	X= 38.674 Y= 0.9457	-0.98072	<0.002
4.	Temperature Pupal period	(X) (y)	X= 26.979 Y= 0.6336	-0.93665	<0.002
5	Temperature Life span	(X) (y)	X= 89.495 Y= 2.3056	-0.96655	<0.002

Fig. 2 : Effect of temperature on life stages of *H. recurvalis*

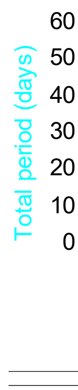

Fig. 3 : Total life span of *H. recurvalis*

trend was also recorded for pupal period and total life span of this pest. Pupal period shortened with increase in temperature from 17.0 days at 18^{0}C to 8.65 days at 30^{0}C. There was no hatching was observed at 15^{0}C (Fig.2). The results obtained from the present study are more or less agreement with the results of Bhattacherjee and Menon (1964).

The incremental increase in the temperatures from 18^{0}C to 30^{0}C caused decrease in the total life span of pest. At 18^{0}C, maximum 51.47 days required for completion of one generation of *H. recurvalis*. While, the same took only 22.47 days to complete its life cycle at 30^{0}C. Under a controlled temperature of 18^{0}C development period of all the stages increase progressively (Fig. 3). However, Bhattacherjee and Menon (1964) reported that first moulting takes place on the 2^{nd} day of hatching; second on the 3^{rd} or 4^{th} day; third on the 5^{th} or 6^{th} day; fourth on the 7^{th}, 8^{th} or 9^{th} day of hatching at open air temperature ranging from 25-38^{0}C. Under a controlled temperature of 26/27^{0}C the development period of all the stages increase progressively. Yamada *et al.,* (1979) observed that optimum temperature (25 to 28^{0}C) was more suitable for larval and pupal development. He further included that below 15^{0}C and above 30^{0}C caused to retardation in the growth and development. Seham *et al*., (2006) worked on threshold of development and thermal units for *H. recurvalis* and observed that, at 18.6 $\pm 2^{0}$C and 70 ±5 per cent relative humidity the incubation period ranged between 5 and 7 days. The mean duration of larval, pre pupal and pupal stages were 26.29 ± 0.3, 5.04 ± 0.08 and 16.86 ± 0.18 days, respectively.

The correlation coefficient (r) and regression equations (y= a+bx) obtained between temperatures (18^{0}C, 20^{0}C, 25^{0}C and 30^{0}C) and different development stages of *H. recurvalis* indicated the existence of significant negative correlation (table 10). The different correlation coefficient (r) values viz., incubation period (r= -0.94482), larval period (r= -0.98072), pupal period (r= -0.93665) and total life span (r=-0.96656) clearly indicated the decrease in incubation period, larval period, pupal period and total life span with increase in temperature. Whereas, correlation between different temperatures and per cent hatchability was positive (r=0.957961). Regression equations obtained for different development stages, however, indicated that the effect of different temperatures was highly significant on larval and pupal period at p= <0.002 (Table.2).

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