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Comparative biology of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) on different hosts

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Abstract
The study of biology of pink bollworm was carried out in the Climate Change Laboratory, University of Agricultural Sciences, Raichur during 2017-18 in BOD incubator under controlled conditions of temperature, 27±2°C and relative humidity of 65±5 per cent wherein the larvae were reared on *Bt* cotton bolls and okra fruits. Considerable variation in larval period of *Pectinophora gossypiella* (Saunders) feeding on different host plants was recorded. The shorter larval period of 23.50± 1.45 days was recorded when the larvae were fed okra fruits, whereas the longer larval period of 26.10±0.66 days was observed on *Bt* cotton. Generally, female lived longer than males in the present study on both the hosts. The females that were fed on okra laid maximum number of eggs (125.95 eggs/female) as compared to those on *Bt* cotton (103.8 eggs/female). The total life cycle of *P. gossypiella* from egg to death of adult varied on two hosts, which was significantly longer on *Bt* cotton (46.82 days) than on okra (40.58 days).

Keywords: *Pectinophora gossypiella*, comparative biology, *Bt* cotton, okra, morphometry

1. Introduction
Cotton is the most important commercial crop grown for fiber, fuel and edible oil under diverse agro-climatic conditions. It provides a source of livelihood and employment to millions of farmers, farm workers and persons employed in related industries. The crop is cultivated in more than 100 countries in 32 million hectares [1]. Earlier, a loss to the extent of 2.8 to 61.9 percent in seed cotton yield, 2.1 to 47.10 per cent loss in oil content and 10.70 to 59.20 per cent loss in normal opening of bolls was caused by the pink bollworm infestation in non *Bt* cotton [2].

The pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is one of the most important destructive pests of cotton and is distributed throughout the world's cotton-growing areas causing maximum seed cotton loss in quantity and quality [3]. PBW is emerging as a serious pest and its activity is observed for a brief period from January to till the end of the season in April. In the recent past, the pest has been frequently noticed from early flowering. Soon after emergence, the PBW larvae enter the fruiting body. As a result, farmers remain totally ignorant about the damage caused by PBW till the boll opening and hence could not exercise any target specific control measures against the pest.

In addition to reported resistance to insecticides [4, 5] and to cry toxin of *Bt* cotton [6-11], pink bollworm apart from its main host cotton, is known to feed on other hosts like okra (*Abelmoschus esculentus*), *Abutilon* spp and *Hibiscus* spp and is recorded as pest on them [12, 13]. May be because of this shift in monophagy to oligophagy and its ability to survive on other hosts during off season, there is increased aggravation by this pest on *Bt* cotton. To assess this, the following study was carried out to see if pink bollworm could survive on okra or not.

2. Materials and Methods
The present investigation on comparative biology of pink bollworm, *Pectinophora gossypiella* (Saunders) (Gelechiidae: Lepidoptera) was carried out in the Agro-climatic study centre laboratory in BOD incubator having controlled conditions *viz.*, 27±2°C temperature, 65±5% RH and photoperiod of 14:10 hours (light: dark) during 2017-18 season. The pink bollworm larvae were collected from the field by plucking damaged bolls and larvae were reared on natural food till their pupation. Later they were sexed based on pupal characters *i.e.* position of

genital and anal openings wherein, the genital and anal pores are situated mid-ventrally on the 9th and 10th, 8th and 10th abdominal segments in males and females respectively (plate 1.). The distance between the genital pore and anal pore affords a good character for the separation of the sexes. In case of female this distance is more than double as compared to male [14]. Such sexed pupae were kept in emergence cages (45×45×60cm) for adult eclosion. Five pairs of freshly emerged adults were released into oviposition cage for mating purpose. A small cotton twig bearing tender leaves, squares and small bolls was placed in a small conical flask filled with water and flask was placed in the oviposition cage.

A cotton swab dipped in 10 per cent honey solution was hung by means of a thread in the oviposition cage to facilitate feeding of adult moths and fresh food was provided everyday by changing the swab. The eggs laid by the adult female moth of pink bollworm were recorded every day and provided fresh twigs.

After hatching from eggs, 25 neonate larvae were transferred to different plastic jars(16" dia x 18" height) with the help of a moist camel brush and thereafter the larvae were reared on different hosts food materials *viz*., cotton bolls, tender okra fruits and riped tomato fruits. These jars were kept in the BOD incubator with suitable temperature (27±2 °C) and relative humidity (65±5%). Observations were recorded on fecundity, per cent egg hatching, larval period, pupal period and adult longevity along with survival rates and morphometric measurements of all the life stages were recorded. Observations registered on each of the biological stages are detailed below.

2.1 Fecundity

To assess the total number of eggs laid by an individual female pink bollworm, fresh *Bt* cotton twig dipped in vial of sucrose solution was kept in plastic jars (16" dia x 18" height) and 5 pairs of adults were released. Daily the twig was changed and the old twig was counted for number of eggs laid.

2.2 Egg

The incubation period was studied by keeping the cotton twig containing eggs under room temperature in the laboratory during which the average temperature was 27-30°C. Later it was placed in plastic jars and the duration between the egg laid and the emergence of first instar larva was recorded as the incubation period.

2.3 Larvae

The newly hatched neonate larvae were transferred to plastic jars containing different food hosts *viz.*, cotton bolls, tender okra fruits and ripe tomatoes. The duration from hatching to pre-pupation was recorded as larval period. The duration of individual instars was recorded by cutting the fruits and observed for casted skin (plate 2 and 3).

2.4 Pupae

The pupae of pink bollworm were kept in the emergence cage for adult eclosion. Time from prepupation to adult eclosion was recorded as pupal period.

3. Results

3.1 Biology

Comparative biology of pink bollworm was studied in BOD incubator having controlled conditions *viz.*, 27±2°C temperature, 65±5% RH and photoperiod of 14:10 hours (light: dark) in the laboratory during 2017-18 and the results of same are presented here in detail.

3.1.1 Egg period (days)

Eggs were white when laid but turned yellowish and finally orange red before hatching, and were flattened oval, sculptured with longitudinal lines, which were laid in axils of petioles, underside of young leaves, under old leaves at junction of veins or on squares and flowers before boll formation. Whereas, after boll formation eggs were laid in structure near the boll tip or under the bracteoles at the base of bolls (plate 4).

The incubation period of PBW eggs ranged from 2.50 to 4.50 days in both cotton and okra, with a mean value of 3.81± 0.10 and 3.89± 0.25 days on *Bt* cotton and okra respectively, which did not show significant difference (Table 1 and 2).

3.1.2 Larval period (days)

On hatching first instar larvae were whitish with a pale brown head capsule, which were very active and tried to enter the bolls and fruits immediately. A total of four instars were observed in *Bt* cotton and okra, since it was an internal borer recording the individual instar duration was difficult so entire larval period was recorded. Larval period of PBW was in a range of 22.5 to 28.5 days on *Bt* cotton and 20.5 to 24.5 days on okra, with the mean of 26.1± 0.66 and 23.5± 1.45 in *Bt* cotton and okra, respectively which showed significant difference from each other (Table 1 and 2).

3.1.3 Pupal period (days)

Pupation took place in the bracteoles of *Bt* cotton bolls and underside of okra fruits, wherein, the pupae were light brown initially which turn dark brown later and the pupae were oval in shape with pointed tip. Male pupa is smaller in size compared to female and the distance between the pores on ventral side is less in comparison to female pupa (plate 5.). The pupal period lies in the range of 7.50 to 9.50 and 8.0 to 9.50 days in cotton and okra, respectively. The mean pupal period on *Bt* cotton and okra differ significantly with a shorter duration of 8.14± 0.29 days on okra compared to longer duation of 8.43± 0.18 days noticed on *Bt* cotton (Table 1 and 2).

3.1.4 Adult emergence

Pupae turned dark brown before emergence indicating eclosion of adults soon. Difference in per cent adult emergence was non-significant, with the mean values of 88.32± 10.55 per cent and 91.66± 8.47 per cent in a range of 75.5 to 90.5 and 81.5 to 96.5 in *Bt* cotton and okra, respectively (Table 1 and 2).

3.1.5 Adult longevity (days)

Adult is a small moth having dark brown, with irregular black markings on the forewing, hind wings are silvery grey with no distinct markings, both the wings are elongated, fringed with long hairs posteriorly and tip of hind wing is sharply pointed (plate 6).

3.1.5.1 Male

Longevity of adult male was 9.04± 0.18 days and 9.45± 0.81 days in cotton and okra respectively with a range of 8.50 to 9.50 days on both the hosts, which did not differ significantly (Table 1 and 2).

3.1.5.2 Female
Longevity of adult female was 9.85± 0.31 days and 12.52± 0.47 days in cotton and okra, respectively with a range of 8.0 to 11.5 days and 10.0 to 13.5 days, which did not differ significantly (Table 1 and 2).

3.1.6 Fecundity
The mean number of eggs laid by PBW female was 118.65± 16.81 in a range of 100 to 185 on okra which was significantly higher than that on cotton, wherein the mean number of eggs laid was 103.8± 16.14 in a range of 95 to 175 (Table 1 and 2).

3.1.7 Total life cycle (days)
Total life cycle of pink bollworm on okra was completed in significantly shorter duration of 40.58± 2.93 days compared to cotton *i.e.,* 46.82± 1.20 days within the range of 40 to 50 days and 40 to 55 days on okra and cotton, respectively (Table 1 and 2).

3.2 Morphometry of pink bollworm on *Bt* cotton and okra
Morphometric measurements of different stages of pink bollworm reared on cotton and okra were taken separately for comparison and the results of the same are being presented below in detail.

3.2.1 Egg
The length and breadth of PBW egg ranged from 0.39 to 0.47 and 0.16 to 0.20 mm on *Bt* cotton, respectively with an average of 0.44± 0.02 and 0.19± 0.01 mm, which did not differ significantly from the eggs collected on okra, where the length and breadth had a same range but with an average of 0.45± 0.02 and 0.19± 0.01 mm, respectively (Table 3 and 4).

3.2.2 First instar larva
First instar larvae were whitish with a pale brown head capsule (plate 7.), whose average length and breadth was 0.54±0.01 and 0.17±0.02 mm, with a range of 0.48 to 0.55 mm and 0.11 to 0.21 mm respectively on *Bt* cotton. Whereas, average length and breadth of first instar larvae obtained from okra was 0.54±0.02 and 0.19±0.02 mm, with a range of 0.48 to 0.58 mm and 0.12 to 0.21 mm respectively, showing non significant difference with *Bt* cotton (Table 3 and 4).

3.2.3 Second instar larva
Second instar larva is creamy white with a conspicuous dark brown head with dark spots on the dorsal side of body in male which is absent in female (plate10.). The length and breadth of second instar larvae reared on *Bt* cotton ranged from 0.85 to 0.94 and 0.17 to 0.19mm respectively with an average of 0.91±0.02 and 0.18±0.005 mm. However, these dimensions were numerically more but statistically on par in case of larvae reared on okra *i.e.,* length and breadth ranging from 0.85 to 0.98 and 0.16 to 0.20 mm with an average of 0.93±0.03 and 0.18±0.005 mm respectively (Table 3 and 4).

3.2.4 Third instar larva
Third instar larva is glossy white with pink transverse dorsal band interpreted by pale medium lateral streaks per body segment (plate 10.). The average length and breadth of third instar was 5.39±0.40 and 0.16±0.03mm, with a range value of 4.92 to 5.92 mm and 0.12 to 0.21 mm, respectively on cotton. Whereas, larvae obtained from okra whose average length and breadth was 5.46±0.35 and 0.17±0.03 mm, with the range of 4.94 to 5.92 and 0.12 to 0.21 mm respectively, depicting no significant difference with the larvae obtained from *Bt* cotton (Table 3 and 4).

3.2.5 Fourth instar larva
Fourth instar larva is pink in colour with dark brown head, having pinkish bands on body segments (plate 10.).The length and breadth of fourth instar larva ranged from 6.15 to 11.42 and 0.35 to 0.51 mm on cotton, respectively with an average of 9.16±2.04 and 0.48±0.05 mm, which did not differ significantly from the larvae reared on okra, where the length and breadth ranged from 6.15 to 11.46 and 0.35 to 0.61mm with an average of 10.12±1.69 and 0.50±0.07 mm, respectively (Table 3 and 4).

3.2.6 Pupa
3.2.6.1 Male
The average length and breadth of male pupa was 4.22±0.13 and 1.34±0.12 mm, with the range of 4.15 to 4.54 mm and 1.17 to 1.61 mm respectively on *Bt* cotton. Whereas, the pupal dimension from those reared on okra was 4.32±0.16 and 1.39±0.11 mm, with the range of 4.16 to 4.56 and 1.19 to 1.61 mm respectively, which was on par with pupae obtained from *Bt* cotton (Table 3 and 4).

3.2.6.2 Female
The length and breadth of female pupa was in range of 4.52 to 4.71 and 1.09 to 1.39 mm on cotton respectively with an average of 4.63±0.05 and 1.24±0.11 mm, which did not differ significantly from those obtained from okra, where the length and breadth ranged from 4.52 to 4.87 and 1.09 to 1.39 mm with an average of 4.72±0.09 and 1.32±0.09 mm, respectively (Table 3 and 4).

3.2.7 Adult
3.2.7.1 Male
Average length and breadth of adult male moth of PBW was 3.62±0.29 and 2.37±0.26 mm, with the values ranging from 3.21 to 4.05 mm and 2.11 to 2.77 mm respectively on *Bt* cotton. Whereas, the same sex obtained from okra could record 3.84±0.27 and 2.43±0.35 mm of length and breadth, with the values ranging from 3.24 to 4.09 and 2.14 to 2.77 mm, respectively, which was on par with cotton (Table 3 and 4).

3.2.7.2 Female
Length of adult female moth of PBW ranged from 4.21 to 4.6 mm when it was on diet of *Bt* cotton with an average of 4.38±0.14 mm, which was significantly less from those on okra, where the length was in range of 4.52 to 4.87 mm with an average of 4.62±0.09 mm. Whereas, there was no significant difference in both the treatments for breadth. Wherein, it was in range of 1.03 to 1.47 and 1.07 to 1.47, with an average of 1.26±0.15 and 1.30±0.11 mm on cotton and okra, respectively (Table 3 and 4).

4. Discussion
Incubation period of eggs of *P. gossypiella* did not vary considerably due to host plants during the period of study. Incubation period of 3.81 days was recorded on *Bt* cotton, which was numerically less compared to okra (3.89 days), which resulted in non-significant difference among them. The morphometric results revealed no significant difference in the dimensions of eggs obtained from individuals reared on both

hosts, wherein, the average length and breadth of eggs was 0.44±0.02 and 0.19±0.01 mm on *Bt* cotton, where as 0.45±0.02 and 0.19±0.01 mm on okra. The present findings are in contrary with Syed *et al.* (2011) [15] where they found that incubation period of eggs of *Earias vittella* (Fab) (Noctuidae: Lepidoptera) was less on okra (2.3±0.5 days) than cotton (3.0±0.0 days). Whereas, Zinzuvadiya *et al.* (2017) [16] reported that egg period of pink bollworm to be 4.9±0.99 days on artificial diet.

Considerable variation was recorded in larval period of *P. gossypiella* feeding on different host plants. The shorter larval period of 23.50 days was recorded on okra, whereas the longer larval period of 26.10 days was observed on *Bt* cotton. The results of morphometry on different larval instars obtained from both hosts did not show any significant difference, with average length and breadth of fourth instar larva 9.16±2.04and 0.48±0.05 mm on *Bt* cotton and 10.12±1.69 and 0.50±0.07 mm on okra. These results are in clear agreement with the results obtained by Syed *et al.* (2011), who could record that larval period of *E. vittella* was shorter on okra (10.8±2.5 days) than cotton(11.5±1.1 days). Mean larval period of PBW is reported to be 17.50 to 18.15 on artificial diet, which was less than that obtained on *Bt* cotton in the present investigation.

The shortest pupal period of 8.14 days was observed on okra, while the pupal period of 8.43 days was recorded on *Bt* cotton that was longer than the former. The analytical comparison of morphometric dimensions of pupae of pink bollworm reared on two different hosts did not differ significantly, where in the average length and breadth of pupa was 4.22±0.13and 1.34±0.12mm and 4.32±0.16 and 1.39±0.11 mm in male and female pupae obtained from *Bt* cotton and 4.63±0.05 and 1.24±0.11 mm and 4.72±0.09 and 1.32±0.09 mm on okra. The findings of the present investigation are in contrast with those obtained by Syed *et al.* (2011), from the studies on comparative biology of *E. vittella* on different hosts, they could record pupal duration of 11.8±1.9 days on okra and 10.7±3.1 days on cotton which was shorter than the previous host.

Although male longevity did not follow a fixed trend, the minimum adult male longevity of *P. gossypiella* was recorded as 9.05 days on *Bt* cotton and the maximum longevity as 9.45 days on okra. The analytical comparison of morphometric dimensions of adults of pink bollworm reared on two different hosts did not differ significantly, where in the average length and breadth of adult insect was 3.62±0.29and2.37±0.26 mm and 3.84±0.27and 2.43±0.35mm in males obtained from *Bt* cotton. Whereas, the adult females that were emerged out of pupae maintained on diet of okra fruits were larger than those reared on *Bt* cotton, with the average length and breadth of 4.62±0.09 and 1.30±0.11 mm and4.38±0.14 and 1.26±0.15 mm on okra and *Bt* cotton respectively. Contrary to the findings of present study, Syed *et al.* (2011) have reported adult male longevity to be longer on okra (11.66 days) than on cotton (9.0 days) in case of *Earias vittella.* While, longevity of adult females of PBW on *Bt* cotton and okra was 9.85 and 12.52 days respectively. Generally, female lived longer than males in the present study on both the hosts, which was in agreement with the findings of Syed *et al.* (2011) where he reported the females of *E. vittella* to be long lived than males on both cotton and okra.

Various workers have reported the fecundity of *P. gossypiella* females, Adkisson (1961) reported it to be 98.1 eggs from moths reared on cotton square, 204.3 eggs from moths reared on cotton bolls, 336.7 eggs from moths reared on diet of one per cent cotton seed meal, 302.1 eggs from 5 per cent cotton seed meal and 312.2 eggs from wheat germ diet. Whereas, Zinzuvadiya *et al.* (2017) reported fecundity of PBW females to be 110.6 eggs per individual. In the present study host plant exerted significant effect on egg laying capacity of females fed on different hosts as larvae. The maximum number of eggs was laid by females that were fed on okra (125.95 eggs/female) as larvae followed by those on *Bt* cotton (103.8 eggs/female). Results are in clear agreement with the findings of Syed *et al.* (2011) who reported that, fecundity of females that were fed on okra was more than those that were fed on cotton as larvae.

The total life cycle of *P. gossypiella* from egg to death of adult varied on two hosts, which was significantly longer on *Bt* cotton (46.82 days) than on okra (40.58 days). The results were contrary to the findings of Syed *et al.* (2011) who report life cycle of *E. vittella* to be longer on okra (39.4 days) than on cotton (35.1 days). The morphometric measurements of individuals of different stages of *P. gossypiella* that were collected from two hosts did not show any significant difference in their dimensions, the difference was only with respect to duration of different life stages and total life cycle.

5. Conclusion

Specialised pheromone lure application technology (SPLAT@ 500 g/ acre) proved significantly superior over rest of the treatments with less rosette flowers, green boll and locule damage and also recorded higher yield with more B: C ratio. SPLAT is environmentally viable, economically feasible, slow and sustained release formulation with trap free auto confusion technology for the management of pink bollworm. SPLAT is one of the best technology for the management of PBW in present scenario and suits well in the IPM programs.

Table 1: Biological parameters of pink bollworm *Pectinophora gossypiella* (Saunders) on *Bt* cotton and okra

Biological parameters	*Bt* cotton	
	Mean ±SD	**Range**
Egg period (Days)	3.81±0.10	2.50- 4.50
Larval period (Days)	26.1±0.66	22.50- 28.50
Pupal period (Days)	8.43±0.18	7.50- 9.50
Adult Emergence (%)	88.32± 10.55	75.50- 90.50
Adult Longevity		
Male (Days)	9.04±0.18	8.50-9.50
Female (Days)	9.85±0.31	8.00-11.50
Fecundity (Numbers)	103.8± 16.14	95-175
Total Life Cycle (Days)	46.82 ±1.20	40- 55

Biological parameters	Okra	
	Mean ±SD	**Range**
Egg period (Days)	3.89 ± 0.25	2.50- 4.50
Larval period (Days)	23.5 ± 1.45	20.50- 24.50
Pupal period (Days)	8.14 ± 0.29	8.00- 9.50
Adult Emergence (%)	91.66 ± 8.47	81.50- 96.50
Adult Longevity		
Male (Days)	9.45 ± 0.81	8.50-9.50
Female (Days)	12.52 ± 0.47	10.50-13.00
Fecundity (Numbers)	118.65 ± 16.81	100-185
Total Life Cycle (Days)	40.58 ± 2.93	40- 50

Table 2: Comparative biology of pink bollworm, *P. gossypiella* on *Bt* cotton and okra

Biological parameters	Statistical tools	Host	
		***Bt* Cotton**	**Okra**
Egg period (Days)	Mean	3.81	3.89
	Variance	0.011	0.059
	t-test	NS	
Larval period (Days)	Mean	26.1	23.5
	Variance	0.439	2.095
	t-test	0.0025*	
Pupal period (Days)	Mean	8.43	8.14
	Variance	0.033	0.084
	t-test	0.0454*	
Adult Emergence (Percentage)	Mean	88.32	91.66
	Variance	111.285	71.750
	t-test	NS	
Adult male longevity (Days)	Mean	9.05	9.45
	Variance	0.033	0.657
	t-test	NS	
Adult female longevity (Days)	Mean	9.85	12.52
	Variance	0.097	0.223
	t-test	NS	
Fecundity (Number)	Mean	103.8	125.95
	Variance	260.60	17.211
	t-test	0.0090*	
Total life cycle (Days)	Mean	46.82	40.58
	Variance	3.994	8.604
	t-test	0.0005**	

Table 3: Morphometry of different stages of pink bollworm reared on *Bt* cotton and okra

Host	***Bt* cotton**				**Okra**			
Stage	**Length (mm)**		**Breadth (mm)**		**Length (mm)**		**Breadth (mm)**	
	Mean ±SD	**Range**	**Mean ±SD**	**Range**	**Mean ±SD**	**Range**	**Mean ±SD**	**Range**
Egg	0.44±0.02	0.39-0.47	0.19±0.01	0.16-0.20	0.45±0.02	0.39-0.47	0.19±0.01	0.16-0.20
Larval stages								
I instar	0.54±0.01	0.48-0.55	0.17±0.02	0.11-0.21	0.54±0.02	0.48-0.58	0.19±0.02	0.12-0.21
II instar	0.91±0.02	0.85-0.94	0.18±0.005	0.17-0.19	0.93±0.03	0.85-0.98	0.18±0.005	0.16-0.20
III instar	5.39±0.40	4.92-5.92	0.16±0.03	0.12-0.21	5.46±0.35	4.94-5.92	0.17±0.03	0.12-0.21
IV instar	9.16±2.04	6.15-11.42	0.48±0.05	0.35-0.51	10.12±1.69	6.15-11.46	0.50±0.07	0.35-0.61
Pupa								
Male	4.22±0.13	4.15-4.54	1.34±0.12	1.17-1.61	4.32±0.16	4.16-4.56	1.39±0.11	1.19-1.61
Female	4.63±0.05	4.52-4.71	1.24±0.11	1.09-1.39	4.72±0.09	4.52-4.87	1.32±0.09	1.09-1.39
Adult								
Male	3.62±0.29	3.21-4.05	2.37±0.26	2.11-2.77	3.84±0.27	3.24-4.09	2.43±0.35	2.14-2.77
Female	4.38±0.14	4.21-4.6	1.26±0.15	1.03-1.47	4.62±0.20	4.26-4.83	1.30±0.11	1.07-1.47

Table 4: Comparative biology of pink bollworm, *P. gossypiella* on *Bt* cotton and okra

Developmental stages		**Statistical tools**	**Host**			
			Length (mm)		**Breadth (mm)**	
			Cotton	**Okra**	**Cotton**	**Okra**
Egg		Mean	0.44	0.45	0.19	0.19
		Variance	0.0006	0.0007	0.0002	0.0002
		t-test	NS		NS	
I instar		Mean	0.54	0.54	0.17	0.19
		Variance	0.0001	0.0009	0.0009	0.0010
		t-test	NS		NS	
II instar		Mean	0.91	0.93	0.18	0.18
		Variance	0.0008	0.0017	3.3333	3.3333
		t-test	NS		NS	
III instar		Mean	5.39	5.46	0.16	0.17
		Variance	0.1911	0.1502	0.0015	0.0012
		t-test	NS		NS	
IV instar		Mean	9.16	10.12	0.48	0.50
		Variance	4.8817	3.3329	0.0034	0.0058
		t-test	NS		NS	
Pupa	Male	Mean	4.22	4.32	1.34	1.39
		Variance	0.0214	0.0316	0.0169	0.0160

		t-test	NS		NS	
	Female	Mean	4.63	4.72	1.24	1.32
		Variance	0.0038	0.0103	0.0143	0.0111
		t-test	NS		NS	
Adult	Male	Mean	3.62	3.84	2.37	2.43
		Variance	0.0986	0.0913	0.0797	0.1461
		t-test	NS		NS	
	Female	Mean	4.38	4.62	1.26	1.3
		Variance	0.0258	0.0472	0.0293	0.0167
		t-test	0.037*		NS	

Plate 1: Female and male pupae of pink bollworm

d. Larva entering into pupation in okra fruit

Plate 2: Pink bollworm larvae feeding on okra fruits

a. Pink bollworm neonates feeding on okra fruits

a. Pink bollworm larvae feeding on *Bt* cotton pollen

b. Third instar pink bollworm feeding on okra

b. Pink bollworm larvae feeding on *Bt* cotton bolls

Plate 3: Pink bollworm feeding on *Bt* cotton

c. Fourth instar pink bollworm feeding on okra

a. On squares

b. On leaves

Plate 4: Eggs laid by pink bollworm moth on *Bt* cotton

a. Freshly formed pupa

b. Late age pupa

Plate 5: Pupae of pink bollworm

Plate 6: Adult pink bollworm moth

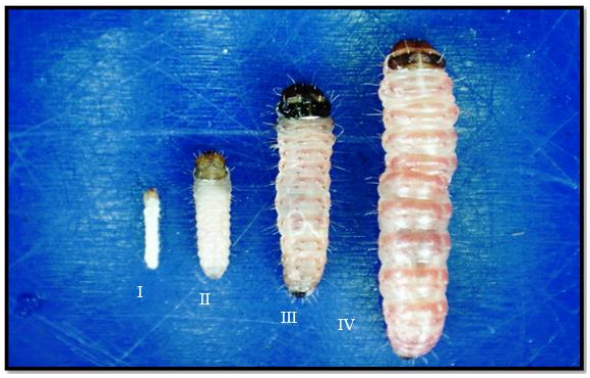

Plate 7: Larval instars of pink bollworm

References

1. Anonymous, Area, production and productivity of cotton in India: State wise production of cotton. Cotton Advisory Board, Mumbai, 2015. (Fide: www.cotcorp.gov.in).
2. Patil SB. Studies on management of cotton pink bollworm, *Pectionophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), Ph. D. Thesis (unpublished) submitted to University of Agricultural Sciences, Dharwad (India), 2003.
3. Pearson EO. The Insect Pests of Cotton in Tropical Africa, Empire Cotton Growing Corporation and Commonwealth Institute of Entomology, London, 1958, 355.
4. Li YC, Wanf QS, Zhang GJ, Zhang SS, Luo CX, Ding SY. Insecticide resistance in field strains of *Pectinophora gossypiella* in China and effects of synergists on deltamehtrin and parathion-methyl activity. Pesti sci. 1997; 50:183-186.
5. Sabry KH, Nahed FA. Resistance and enzyme assesment of the pink bollworm, *Pectinophora gossypiella* (Saunders) to spinosad. J. Ani. Pl. Sci. 2013; 23:136-142.
6. Tabashnik BE, Liu YB, Unnithan DC, Carriere Y, Dennehy TJ, Morin S. Shared genetic basis of resistance to *Bt* toxin *Cry1Ac* in independent strains of pink bollworm. J. Eco. Entomol. 2004; 97:721-726.
7. Tabashnik BE, Biggs RW, Higginson DM, Henderson, Unnithan DC. Association between resistance to *Bt* cotton and cadherin genotype in pink bollworm. J. Eco. Entomol. 2005; 98:635-644.
8. Dhurua S, Gujar GT. Field-evolved resistance to *Bt* toxin Cry1Ac in the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), from India. Pest Mgt Sci. 2011; 67:898-903.
9. Wan P, Huang Y, Wu H, Huang M, Cong S, Tabashnik BE. Increased frequency of pink bollworm resistance to *Bt* toxin Cry1Ac in China. *PLoS ONE*. 2012; 7:29975.
10. Ojha A, Sree KS, Sachdev B, Rashmi MA, Ravi KC, Suresh PJ. Analysis of resistance to Cry1Ac in field-collected pink bollworm, *Pectinophora gossypiella* (Lepidoptera: Gelechiidae), populations. GM. Crops Food. 2014; 5:280-286.
11. Mohan SK, Ravi KC, Suresh PJ, Sumerford D, Graham P H. Field resistance to the *Bacillus thuringiensis* protein Cry1Ac expressed in Bollgard® hybrid cotton in pink bollworm, *Pectinophora gossypiella* (Saunders), populations in India. Pest Mgt Sci. 2015, 7-10.
12. Rajpalsingh, Joshi AK. Pests of okra (*Abelmoschus esculentus* Moench.) in Paonta Valley, Himachal Pradesh. Ins. env. 2003; 9:173-174.

13. Anonymous, Pectinophora gossypiella, 2017. http://www.cabi.org/isc/mobile/datasheet/30417
14. Dharjothi B, Valarmathi R, Nagarajan T, Sonai Rajan T. Larval sex differentiation of pink bollworm-an easy tools for pairing of adults in mass rearing programmes, CICR central institute for cotton research news letter, Nagpur. 2010; 26(3):1-8.
15. Syed ST, Abro GH, Khanum A, Sattar M. Effect of host plants on the biology of *Erias vittella* (Fab) (Noctuidae: Lepidoptera) under laboratory conditions. Pakistan. J. Zoo. 2011; 43:127-132.
16. Zinzuvadiya HD, Desai HR, lakum MB, Rajkumar BK. Biology of Pink Bollworm, *Pectinophora gossypiella* Saunders (Lepidoptera: Gelechiidae) on artificial diet under controlled condition. Trends in Biosci. 2017; 10:5363-5371.