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Comparative Biology and Reproductive Performances of *Helicoverpa armigera* (Hübner) Populations Across India

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ABSTRACT

Background: *Helicoverpa armigera* (Hübner) is an important biotic constraint to major grain legumes in India. Biological characterization of any pest species is critical for making effective management decisions. Thus, this study comprehensively presents the biological and reproductive demographic traits of different geographic populations of *H. armigera* across the country.

Methods: In this field-laboratory investigation (2015-18), populations from 20 localities were evaluated for developmental period of all the life stages, survival and reproduction and growth and fitness indices. All these parameters were recorded from the maintained insect cultures of each location from second filial (F_2) generation.

Result: The mean developmental periods of the immature stages, as well as adult longevity, were found to be longest in the Cooch Behar population. In contrast, the populations from South Zone took significantly shorter duration over others to complete their life cycle. All the populations were found to be female-biased, but significant differences were observed for reproductive competence of female moths. Wide variations were also observed in the relative growth and fitness indices, with the highest recorded from Varanasi population. Cluster analysis differentiated studied populations into two distinct groups. Such variations seem to be due to probable genetic heterogeneity in *H. armigera* populations of India.

Key words: Artificial diet, Fecundity, Growth indices, Longevity, Sex ratio, Variability.

INTRODUCTION

The genera *Heliothis* Ochsenheimer and *Helicoverpa* (Hardwick) belonging to Heliothinae (Lepidoptera: Noctuidae) subfamily include some of the most destructive agricultural pests of worldwide importance (Mitchell and Gopurenko, 2016). Among these, only three species namely, *Helicoverpa armigera* (Hübner), *Helicoverpa assulta* (Guenée) and *Heliothis peltigera* (Denis and Schiffermüller) have been reported from India (Deepa and Srivastava, 2010), with *H. armigera* being most significant and severe in our country (Behere *et al.,* 2013). This insect species is highly polyphagous and has been reported to be feeding upon 96 different crop species in India, including most of the commonly grown grain legumes (Srivastava and Joshi, 2011). Among pulses, it is the key pest of pigeonpea [*Cajanus cajan* (Linneaus) Millspaugh] and chickpea [*Cicer arietinum* (Linneaus)] and causes damage to these crops throughout the country (Tripathy and Singh, 1999). In other pulses like greengram, blackgram, lentil, cowpea and pea, *etc*., it is of minor importance. The larval preference for flowering and fruiting parts results in direct reduction of crop yield (Singh *et al*., 2015) and thereby inflicting substantial monetary loss. The annual loss caused by this insect species in pigeonpea and chickpea has recently been estimated to exceed 2 billion US dollar. The damage caused to other crops will substantially add to the total loss caused by this insect species (Jaba *et al*., 2017).

In addition to polyphagia, *H. armigera* has characteristics like excellent mobility, high reproductive potential and facultative diapause that helps it to adapt under varied agro-climatic conditions of the country (Behere *et al.,* 2013). Moreover, this pest species has also developed resistance against the most extensive range of insecticides, including *Bt* toxin (Venkatesan *et al*., 2016). Further, there are also reports that *H. armigera* populations belonging to different agro-climatic zones also exhibit differential sensitivity/ responses to various groups of chemical insecticides, pheromones and parasitoids (Deepa and Srivastava, 2011), thereby rendering its management even more difficult. These facts elicit a doubt regarding the occurrence of probable variation in the population genetic structure of this species, maybe in the form of different subspecies or host races, or even unidentified cryptic species (Chakravarty *et al.,* 2019). Elucidation of diversity in the life-history traits and reproductive potential of insect pest populations that display geographic variation in behavior is very much essential for understanding the pest population structure and thereby development and implementation of

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sustainable management strategies (Silva *et al*. 2017). Knowledge regarding basic biology also helps in the construction of life tables and pest forecasting models (Nunes *et al*. 2017). Thus the objective of this study was to characterize the biological and reproductive parameters of *H. armigera* populations occurring at varied geographic locations of the country. The information offered here will also serve as a basis for future comparisons based on other markers.

MATERIALS AND METHODS

Larvae of *H. armigera* were collected from 20 different geographical locations of India between March, 2015 and February, 2018 (Fig 1), targeting the four major pulse growing zones *i.e*., North West Plain Zone, North East Plain Zone, Central Zone and the South Zone. Each sampling site was treated as an individual population and from each location/ site minimum of 250 larvae (second to fifth instar) were collected. Sampled insects were brought to the Biocontrol laboratory, Department of Entomology and Agricultural Zoology, Banaras Hindu University and placed in an insect rearing chamber under controlled conditions (25±1°C temperature, 65±5% relative humidity and 12 hours photophase), to initiate the experimental colonies, *i.e*. parental generation. The species identity was morphologically confirmed as *H. armigera* using the keys provided by Brambila (2009). Rearing procedure and diet composition were according to the methodology described by Chakravarty *et al.* (2018). After establishing a colony for each population, individuals from the second filial generation were used for the evaluation of different biological traits. The different parameters accessed were developmental period of the immature stages (egg, larva and pupa), adult longevity, total life span, pre-oviposition, oviposition and post-oviposition periods, fecundity, sex ratio and growth and fitness indices.

The duration of all life stages, including total life span, was calculated following Baikar and Naik (2016). Sex was determined at the pupal stage, according to the position of genital opening. Female genital pore was located medioventrally on the eighth abdominal segment while, the male genital opening was situated on the ninth segment, surrounded by small protuberances (Chakravarty *et al*., 2018). Pre-oviposition, oviposition and post-oviposition periods, along with fecundity, of adult females were calculated as per Chaudhary *et al*. (2016). The larval growth index (LGI), pupal growth index (PGI), immature growth index (IGI), standardized insect-growth index (SII) and fitness index (FI) of the studied populations were calculated using the following equations (Amer and El-Sayed, 2014):

$$LGI = \frac{I_x}{L_d} \qquad IGI = \frac{A}{L_d + P_d} \qquad FI = \frac{P \times P_w}{L_d + P_d}$$

$$PGI = \frac{A}{P_d} \qquad SII = \frac{P_w}{L_d}$$

Where,

I_x = Survival rate of larvae.

L_d = Larval period (days).

P_w = Pupal weight (mg).

P = Per cent pupation.

P_d = Pupal period (days).

A = Per cent adult emergence.

All the data were analyzed by one-way ANOVA using SPSS (Version 16) software. Statistical differences among the mean values were assessed using Tukey's HSD post hoc test at 5 per cent significance level. Cluster analysis of studied populations based on selected traits was done following the standard procedures of 'SAS® University Edition' statistical software.

RESULTS AND DISCUSSION

The life history of *H. armigera* comprises of four stages, *i.e.* egg, larva, pupa and adult. The selected populations exhibited considerable differences in the mean duration of different life stages. The incubation period was recorded to be maximum in the Cooch Behar population (3.72±0.09 days) of the North East Plain Zone which was at par with all the other studied populations except those collected from Hyderabad (3.42±0.07 days), Ayodhya (3.44±0.11 days), Raichur (3.46±0.10 days) and Jabalpur (3.46±0.05 days) (Table 1). Earlier, Jallow and Zalucki (1998) also observed variations in the oviposition behavior and host plant preference among geographic populations of *H. armigera* collected from diverse sources in Australia by offering the same set of host plants. The incubation periods described herein for *H. armigera* are also consistent with what has previously been observed by Deepa and Srivastava (2010); Chaudhary *et al*. (2016) and Chakravarty *et al*. (2018).

Significant variations were also noticed in the duration of different larval instars and the total larval period ranged from 17.47±0.94 days in the Hyderabad population to 23.37±0.62 days in Cooch Behar population (Table 1). Significantly lower larval developmental periods were also recorded for the other locations of the South Zone and all being at par with the Hyderabad population. These are in accordance with earlier reports of Sharma *et al*. (2011); Baikar and Naik (2016) and Chauhan *et al*. (2018). The maximum pre-pupal period was recorded from the Samastipur population (2.32±0.11 days) of the North East Plain Zone and it was at par with all the other northern and central zone populations of the country (Table 1). The South Zone populations, *i.e*. Hyderabad (1.84±0.04 days), Raichur (1.90±0.07 days), Bagalkot (2.06±0.10 days), Bengaluru (1.92±0.05 days) and Coimbatore (1.86±0.05 days) populations recorded significantly lower pre-pupal period in comparison to populations from other three zones. However, evaluation of this stage has not been considered by many authors, probably due to the difficulty involved in observing this development stage (Nunes *et al*., 2017).

The pupal period ranged from 7.96±0.17 days to 13.68±0.24 days with an average of 12.14±0.40 days in

Table 1: Developmental period of various life stages of *H. armigera* populations collected from different locations across India.

Location	Developmental period (days)								
	Incubation period	Total larval period	Pre-pupal period	Pupal period		Adult longevity		Total life cycle	
				Male	Female	Male moth	Female moth	Male	Female
Ludhiana	*3.64±0.14^{abc}	20.01±0.57^{d}	2.18±0.08^{ab}	12.46±0.35^{bcde}	10.18±0.31^{bcd}	8.50±0.22^{ab}	10.64±0.25^{bc}	45.78±0.90^{c}	7.64±0.94^{c}
Hissar	3.60±0.09^{abcd}	21.60±0.29^{b}	2.24±0.10^{ab}	12.66±0.30^{bcde}	10.40±0.34^{bcd}	7.84±0.19^{c}	9.62±0.21^{d}	43.86±1.14^{defg}	47.78±0.21^{c}
Delhi	3.68±0.05^{ab}	19.57±0.64^{de}	2.20±0.07^{ab}	12.10±0.43^{def}	9.94±0.25^{cde}	8.24±0.30^{b}	9.78±0.35^{d}	43.24±1.10^{efg}	45.30±1.06^{ef}
Pantnagar	3.60±0.04^{abcd}	20.40±0.72^{cd}	2.16±0.08^{ab}	12.54±0.62^{bcde}	10.32±0.55^{bcd}	8.62±0.43^{a}	10.56±0.47^{bc}	44.00±1.53^{def}	47.26±0.91^{cd}
Udaipur	3.66±0.06^{abc}	21.16±0.77^{bc}	2.22±0.14^{ab}	13.06±0.46^{abc}	10.64±0.41^{abcd}	7.50±0.26^{d}	10.34±0.32^{c}	45.38±1.37^{cd}	47.12±1.36^{cd}
Kanpur	3.64±0.08^{abc}	19.39±0.53^{de}	2.18±0.11^{ab}	12.34±0.25^{bcde}	10.20±0.30^{bcd}	7.28±0.18^{de}	10.40±0.24^{bc}	44.70±0.91^{cde}	45.82±0.79^{de}
Faizabad	3.44±0.11^{cd}	18.62±0.62^{efg}	2.10±0.09^{bc}	11.96±0.49^{ef}	9.88±0.36^{de}	7.04±0.24^{ef}	8.66±0.29^{e}	42.26±0.82^{gh}	42.68±1.55^{gh}
Varanasi	3.62±0.05^{abcd}	18.80±0.81^{fg}	2.16±0.17^{ab}	12.52±0.31^{bcde}	10.24±0.24^{bcd}	8.56±0.21^{ab}	10.72±0.17^{bc}	42.64±1.19^{fgh}	47.76±1.20^{ce}
Samastipur	3.56±0.07^{abcd}	22.60±0.61^{a}	2.32±0.11^{a}	12.94±0.38^{abcd}	10.72±0.49^{abc}	8.64±0.30^{a}	10.78±0.30^{b}	47.56±0.64^{b}	50.10±1.31^{be}
Cooch Behar	3.72±0.09^{a}	23.37±0.62^{a}	2.30±0.15^{a}	13.68±0.24^{a}	11.36±0.27^{a}	8.82±0.15^{a}	11.40±0.21^{a}	51.82±0.89^{a}	52.36±0.84^{a}
Jabalpur	3.46±0.05^{bcd}	18.62±0.79^{efg}	2.26±0.14^{ab}	12.20±0.36^{cde}	10.14±0.30^{bcd}	7.16±0.24^{ef}	8.62±0.27^{e}	42.80±1.12^{fgh}	44.24±1.07^{efg}
Raipur	3.54±0.19^{abcd}	22.64±1.24^{a}	2.30±0.24^{a}	13.26±0.43^{ab}	10.84±0.45^{ab}	8.68±0.36^{a}	10.58±0.42^{bc}	47.62±1.83^{b}	49.86±1.78^{b}
Nagpur	3.60±0.14^{abcd}	21.50±0.46^{b}	2.24±0.10^{ab}	12.60±0.47^{bcde}	10.38±0.34^{bcd}	7.82±0.25^{c}	9.70±0.30^{d}	45.58±1.13^{cd}	47.42±0.93^{cd}
Akola	3.58±0.11^{abcd}	21.40±0.94^{c}	2.20±0.13^{ab}	12.52±0.52^{bcde}	10.40±0.43^{bcd}	7.90±0.29^{c}	9.68±0.25^{d}	44.64±1.56^{cde}	47.26±1.48^{cd}
Pune	3.54±0.13^{abcd}	22.69±1.15^{a}	2.28±0.17^{ab}	13.20±0.75^{ab}	10.78±0.51^{ab}	8.64±0.24^{a}	10.62±0.23^{bc}	48.52±1.82^{b}	50.54±1.31^{b}
Hyderabad	3.42±0.07^{d}	17.47±0.94^{h}	1.84±0.04^{d}	9.56±0.30^{h}	7.96±0.17^{h}	6.28±0.13^{g}	7.90±0.18^{f}	37.26±1.32^{j}	39.68±1.24^{i}
Raichur	3.46±0.10^{cd}	17.73±0.47^{fgh}	1.90±0.07^{cd}	10.68±0.24^{g}	8.94±0.25^{fg}	6.94±0.15^{ef}	8.02±0.20^{f}	41.40±0.90^{h}	43.74±0.95^{fg}
Bagalkot	3.54±0.09^{abcd}	18.10±0.75^{fgh}	2.06±0.10^{bcd}	10.84±0.36^{g}	9.26±0.21^{ef}	7.26±0.24^{de}	8.54±0.30^{e}	39.78±1.37^{i}	41.50±1.23^{h}
Bengaluru	3.50±0.05^{abcd}	17.56±0.62^{gh}	1.92±0.05^{cd}	11.22±0.43^{fg}	9.00±0.30^{fg}	7.00±0.21^{ef}	8.16±0.24^{f}	42.24±1.09^{gh}	45.76±1.06^{de}
Coimbatore	3.50±0.05^{abcd}	17.84±0.77^{fgh}	1.86±0.05^{d}	10.38±0.25^{gh}	8.42±0.18^{gh}	6.84±0.18^{f}	7.78±0.15^{f}	38.70±0.92^{ij}	41.32±0.98^{h}

*Mean ± standard deviation of five replications and each replication consisted of 20 observations; Means in a column followed by common letter (s) are not significantly different from each other (Tukey's HSD test, p≤0.05).

males and 10.00±0.33 days in females, which interestingly reveals that in case of *H. armigera*, adult female moths appear about two days earlier than males (Table 1). The male pupal period was recorded to be significantly higher in populations from Cooch Behar (13.68±0.24 days), Raipur (13.26±0.43 days) and Pune (13.20±0.75 days). In comparison, it was recorded to be minimum from the Hyderabad (9.56±0.30 days) population closely followed by other South Zone populations, all being at par with each other. The pupal period variation in female populations also exhibited a similar trend and ranged from 7.96±0.17 days in the Hyderabad population to 11.36±0.27 days in the Cooch Behar population. Deepa and Srivastava (2010); Sharma *et al*. (2011) and Baikar and Naik (2016) found similar results while evaluating the biological characteristics of this pest species on different host plants across India. More recently, Chakravarty *et al*. (2018) also conducted biological studies on *H. armigera* under laboratory conditions and recorded its average pupal period as 10.24±0.46 days for females and 12.52±0.34 days for males.

Various studies have shown that heliothine females had a greater tendency to emerge out, especially after diapause than males and had shorter pupal periods (Silva *et al*. 2017). In the present study also, asynchrony was observed in the emergence of the adults, with the females emerging earlier than males. The female moths are skilled in searching for the best habitat for oviposition, while the males need to locate these females (Nunes *et al*. 2017). They explain the importance of the females emerging first as these moths go to find the appropriate host while they mature sexually and prepare to liberate the sexual pheromone to attract the partners, which emerge two days later on average. Similar studies conducted by Tripathy and Singh (1999) on biological parameters of *H. armigera* populations collected from Guntur, Varanasi and Hissar locations of India showed a higher percentage of adult emergence (86.32%) from pupae in Varanasi strain followed by Guntur (84.41%) whereas; only 73.80 per cent emergence was recorded from populations collected from Hissar. The average pupal periods from the three places were 10.53, 12.37 and 39.49 days, respectively.

Further, the studied populations also differed significantly for the longevity of both male and female moths as well as the total life cycle (Table 1). The Cooch Behar population had longest adult longevity (8.82±0.15 days and 11.40±0.21 days, respectively for males and females) and also took maximum duration to complete its entire life cycle (51.82±0.89 days and 52.36±0.84 days, respectively for males and females). The populations from South Zone took a significantly lower duration over others to complete their life cycle. Adults were inactive during most of the day and were active at night (after evening twilight), during which copulation usually starts. Pairs remained in copula for a period of few hours up to one day. The pre-oviposition, oviposition and post-oviposition periods were again recorded to be highest in the Cooch Behar population (2.86±0.04,

Table 2: Comparative reproductive potential of the female moths of *H. armigera* populations across India.

Location	Reproductive attributes				
	Pre-OP	OP	Post-OP	Fecundity	Sex ratio (♂:♀)
Ludhiana	*2.70±0.05^{bc}	6.32±0.24^{ab}	1.62±0.08^{ab}	848.20±71.79 (6.74)^{cde}	1: 1.34±0.13^{abcd}
Hissar	2.56±0.11^{de}	5.54±0.19^{de}	1.50±0.06^{bcd}	835.00±83.52 (6.72)^{def}	1: 1.30±0.17^{abcd}
Delhi	2.48±0.05^{e}	6.12±0.27^{bc}	1.18±0.14^{efgh}	956.80±109.84 (6.86)^{bcd}	1: 1.36±0.14^{abc}
Pantnagar	2.82±0.08^{ab}	6.40±0.20^{ab}	1.34±0.19^{cdef}	984.60±50.61 (6.89)^{bc}	1: 1.41±0.13^{ab}
Udaipur	2.76±0.11^{abc}	6.28±0.21^{ab}	1.50±0.11^{bcd}	842.20±46.15 (6.73)^{def}	1: 1.12±0.08^{cd}
Kanpur	2.64±0.05^{cd}	6.34±0.14^{ab}	1.42±0.04^{bcde}	1058.40±120.53 (6.96)^{ab}	1: 1.43±0.10^{ab}
Faizabad	2.10±0.07^{f}	5.48±0.36^{de}	1.08±0.10^{fgh}	846.00±92.89 (6.74)^{cde}	1: 1.15±0.08^{cd}
Varanasi	2.72±0.09^{bc}	6.60±0.15^{ab}	1.40±0.13^{bcde}	1140.80±161.28 (7.03)^{a}	1: 1.46±0.14^{a}
Samastipur	2.70±0.13^{bc}	6.42±0.11^{ab}	1.66±0.06^{ab}	959.80±74.62 (6.87)^{bcd}	1: 1.25±0.11^{abcd}
Cooch Behar	2.86±0.04^{a}	6.74±0.25^{a}	1.78±0.11^{a}	725.40±98.11 (6.58)^{efg}	1: 1.10±0.07^{d}
Jabalpur	2.12±0.11^{f}	5.42±0.22^{de}	1.10±0.08^{fgh}	840.20±72.20 (6.73)^{def}	1: 1.14±0.08^{cd}
Raipur	2.76±0.15^{abc}	6.18±0.19^{b}	1.64±0.17^{ab}	924.20±90.16 (6.82)^{bcd}	1: 1.31±0.06^{abcd}
Nagpur	2.54±0.08^{de}	5.60±0.15^{cd}	1.56±0.14^{abc}	1025.60±148.64 (6.93)^{ab}	1: 1.46±0.14^{a}
Akola	2.50±0.05^{e}	5.56±0.24^{de}	1.62±0.09^{ab}	992.80±136.76 (6.89)^{b}	1: 1.43±0.07^{ab}
Pune	2.14±0.06^{abc}	6.30±0.43^{ab}	1.58±0.07^{abc}	640.80±65.35 (6.46)^{g}	1: 1.22±0.09^{abcd}
Hyderabad	2.06±0.14^{fg}	4.68±0.30^{g}	1.16±0.05^{efgh}	760.40±77.82 (6.63)^{efg}	1: 1.25±0.04^{abcd}
Raichur	1.94±0.07^{gh}	5.12±0.24^{def}	0.96±0.08^{h}	770.80±56.68 (6.65)^{efg}	1: 1.36±0.10^{abc}
Bagalkot	2.00±0.13^{fgh}	5.26±0.13^{def}	1.28±0.15^{defg}	776.00±122.53 (6. 65)^{efg}	1: 1.19±0.08^{bcd}
Bengaluru	1.90±0.11^{h}	5.04±0.21^{efg}	1.22±0.07^{efgh}	832.80±82.90 (6.72)^{def}	1: 1.28±0.13^{abcd}
Coimbatore	1.92±0.09^{h}	4.82±0.18^{fg}	1.04±0.04^{gh}	698.20±90.68 (6.54)^{fg}	1: 1.21±0.11^{abcd}

*Mean ± standard deviation of five replications; **Figures in parentheses are log (x+1) transformed values; Means in a column followed by common letter (s) are not significantly different from each other (Tukey's HSD test, p≤0.05).

Pre-OP:- Pre-oviposition period (days), OP:- Oviposition period (days), Post-OP:- Post-oviposition period (days).

6.74±0.25 and 1.78±0.11 days, respectively). The minimum duration for these parameters was recorded from the South Zone populations. The minimum pre-oviposition period (1.90±0.11 days) was found in the Bengaluru population, while Hyderabad and Raichur populations had significantly lower oviposition (4.68±0.30 days) and post-oviposition periods (0.96±0.08 days), respectively (Table 2).

All the studied populations were found to be female-biased with male: female sex ratio varying from 1: 1.10 to 1: 1.46 and the average fecundity of the female moths were recorded to be significantly higher in the Varanasi population (1140.80±161.28 eggs) of the North East Plain Zone (Table 2). The growth and fitness indices of *H. armigera* populations also varied significantly (Table 3). The larval, pupal and immature growth indices were found to be maximum (5.12±0.34, 9.87±0.44 and 3.30±0.22, respectively) in Hyderabad population while Varanasi population had significantly higher standardized insect growth index (15.08±0.76) and fitness index (8.71±0.30). The other South Zone populations also exhibited significantly higher growth and fitness. These indexes were recorded to be lowest in Cooch Behar population (3.32±0.16, 6.41±0.21, 2.24±0.08, 11.56±0.35 and 5.84±0.27, respectively). It was also found that the populations having shorter life cycles, in turn, gained adaptive advantages (higher fecundity, better growth and fitness) in relation to other populations. These results are also similar to those described by Sharma *et al*. (2011); Amer and El-Sayed (2014) and Chauhan *et al*. (2018).

Longevity and reproductive potential of *H. armigera* are generally influenced by dietary situations during both the larval and adult stages and poor nutrition experienced by the parents during their development leads to lower fecundity (Bheemaraya *et al*., 2019). Several studies have also shown that the diet quality of parents not only affects the production of offspring but can compromise future generations, by reducing immunity and resistance to parasitism (Sternberg *et al*., 2015). However, in this study, variations in the biological attributes among the populations were observed, even after being fed with the same artificial diet and keeping all the other variables (temperature, humidity and photoperiod) constant for two consecutive generations. This indicates that such variations are probably influenced by genetic differences among populations, as also hinted by Chen *et al*. (2013) and Chakravarty *et al*. (2019). However, in contrast with present findings, Silva *et al*. (2017) found no significant differences in the adult longevity and fertility parameters of *H. armigera* populations collected from different hosts and geographic locations of Brazil. The lack of such differentiation could be due to its recent incursion and expansion in the South American continent.

Variations at the genetic level of this pest species have also been reported by various researchers in India

Table 3: Relative growth and fitness indices of *H. armigera* populations collected from different locations across India.

Location	Growth and fitness indices				
	LGI	PGI	IGI	SGI	FI
Ludhiana	*4.32±0.09^{ef}	7.96±0.35^{efg}	2.87±0.11^{fgh}	13.99±0.27^{abcd}	7.72±0.34^{def}
Hissar	4.17±0.18^{f}	8.04±0.24^{ef}	2.80±0.09^{h}	12.90±0.56^{de}	7.56±0.28^{ef}
Delhi	4.46±0.18^{de}	8.21±0.27^{cde}	2.96±0.11^{ef}	14.85±0.48^{ab}	8.30±0.33^{bc}
Pantnagar	4.40±0.25^{ef}	8.03±0.15^{ef}	2.88±0.06^{fgh}	13.79±0.36^{bcd}	7.96±0.31^{cd}
Udaipur	3.78±0.16^{g}	7.38±0.29^{g}	2.65±0.09^{ij}	13.11±0.46^{cd}	6.72±0.28^{g}
Kanpur	4.71±0.18^{cd}	8.31±0.08^{cde}	3.05±0.06^{cde}	14.77±0.50^{ab}	8.52±0.36^{ab}
Faizabad	4.53±0.13^{de}	8.06±0.12^{ef}	2.98±0.05^{def}	14.20±0.52^{abc}	7.55±0.15^{ef}
Varanasi	4.94±0.18^{abc}	8.23±0.22^{cde}	3.10±0.11^{bcd}	15.08±0.76^{a}	8.71±0.30^{a}
Samastipur	3.83±0.13^{g}	7.54±0.21^{fg}	2.59±0.07^{j}	11.93±0.32^{ef}	6.76±0.18^{g}
Cooch Behar	3.32±0.16^{h}	6.41±0.21^{h}	2.24±0.08^{k}	11.56±0.35^{f}	5.84±0.27^{h}
Jabalpur	4.47±0.16^{de}	7.86±0.18^{efg}	2.95±0.07^{efg}	14.16±0.60^{abc}	7.36±0.25^{f}
Raipur	3.91±0.11^{g}	7.51±0.32^{fg}	2.61±0.06^{j}	11.82±0.66^{ef}	6.81±0.14^{g}
Nagpur	4.30±0.14^{ef}	7.95±0.51^{efg}	2.77±0.14^{hi}	12.91±0.19^{de}	7.78±0.22^{de}
Akola	4.38±0.21^{ef}	8.09±0.38^{def}	2.82±0.09^{gh}	12.84±0.43^{de}	7.83±0.28^{de}
Pune	3.89±0.21^{g}	7.49±0.26^{fg}	2.59±0.09^{j}	11.91±0.58^{ef}	6.85±0.30^{g}
Hyderabad	5.12±0.34^{a}	9.87±0.44^{a}	3.30±0.22^{a}	14.49±0.69^{ab}	8.61±0.42^{ab}
Raichur	4.79±0.17^{bc}	8.95±0.23^{b}	3.20±0.08^{ab}	14.66±0.32^{ab}	8.00±0.23^{cd}
Bagalkot	5.00±0.11^{ab}	8.79±0.21^{bc}	3.14±0.06^{bc}	14.20±0.40^{abc}	8.25±0.09^{bc}
Bengaluru	4.88±0.15^{abc}	8.70±0.15^{bcd}	3.18±0.07^{abc}	14.87±0.49^{ab}	8.08±0.18^{cd}
Coimbatore	4.89±0.19^{abc}	9.24±0.22^{ab}	3.19±0.05^{ab}	13.79±0.67^{bcd}	7.87±0.28^{de}

*Mean ± standard deviation of five replications; Means in a column followed by common letter (s) are not significantly different from each other (Tukey's HSD test, p≤0.05).

LGI: Larval growth index, PGI: Pupal growth index, IGI: Immature growth index, SGI: Standardized insect growth index, FI: Fitness index.

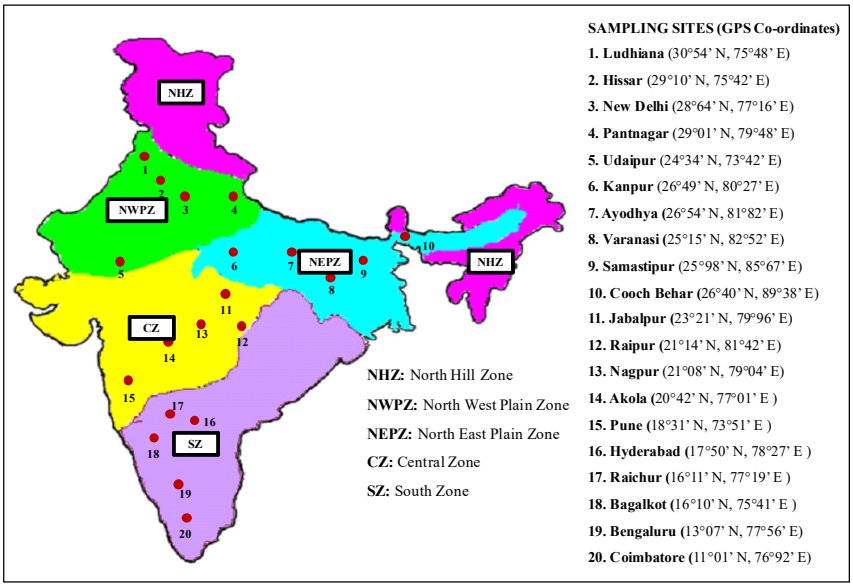


Fig 1: Sampling sites for collection of *H. armigera* populations from major pulse growing zones of India.

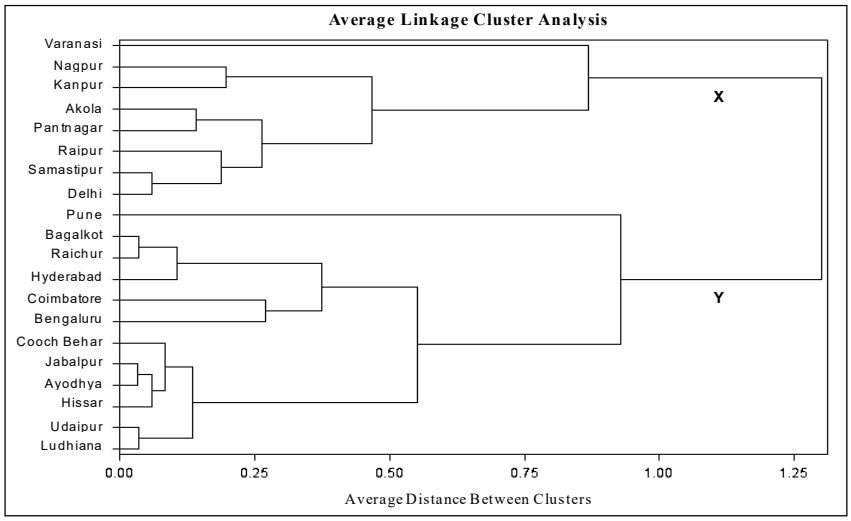


Fig 2: Dendrogram showing clustering of *H. armigera* populations collected from different locations across India based on selected biological attributes.

(Deepa and Srivastava, 2011; Behere *et al.*, 2013 and Venkatesan *et al*., 2016). The pesticide resistance level of the insects may also lead to variations in their life histories (Gandhi and Patil, 2017). The resistance level of *H. armigera* populations used in the present study may also be different because they were collected from different regions of the country having varying pesticide usage patterns and this can also be a probable reason of why they are exhibiting variability in their biological attributes. The cluster analysis of the populations based on the similarity degree of selected biological parameters differentiated them into two major groups/ clusters (Fig 2). Both the clusters showed intermingling of the populations from northern and central pulse growing regions of the country. This supports the presumption that substantial gene flow occurs among populations, probably due to long-range migratory capacity of this species (Silva *et al*., 2017). However, the southern zone populations formed a distinct subclade within the second cluster (Y). The topological and temporal barriers must have led to the isolation of these populations from others. However, they also freely interbreed with populations from other parts of India and produce normal fertile offsprings (Chakravarty *et al*., 2019).

CONCLUSION

Thus, it can be concluded that *H. armigera* is not genetically homogeneous throughout its range in India, but instead, composed of distinct populations genetically adapted to local environmental conditions despite the potential for gene flow via seasonal migration of adults. Such information can be used to plan and implement effective strategies for the management of this pest species in the country.

REFERENCES

Amer, A.E.A. and El-Sayed, A.A.A. (2014). Effect of different host plants and artificial diet on *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) growth and development index. Journal of Entomology. 11: 299-305.

Baikar, A.A. and Naik, K.V. (2016). Biology of fruit borer, *Helicoverpa armigera* (Hübner) on chilli under laboratory conditions. Plant Archives. 16: 761-769.

Behere, G.T., Tay, W.T., Russell, D.A., Kranthi, K.R. and Batterham, P. (2013). Population genetic structure of the cotton bollworm *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in India as inferred from EPIC-PCR DNA markers. Plos One. 8: e53448.

Bheemaraya, Rachappa, V., Teggelli, R., Yelshetty, S. and Amaresh, Y.S. (2019). Biological activity of pod borer, *Helicoverpa armigera* (Hübner) influenced by chickpea genotypes. Legume Research. 42: 421-425.

Brambila, J. (2009). Instructions for dissecting male genitalia of *Helicoverpa* (Lepidoptera: Noctuidae) to separate *Helicoverpa zea* from *Helicoverpa armigera.* http://www.aphis.usda.gov/plant_health/plant_pest_info/owb/downloads/owb-screeningaids2.pdf (Accessed on 5 July 2015).

Chakravarty, S., Srivastava, C.P. and Keval, R. (2018). Biology of *Helicoverpa armigera* (Hübner) on chick pea-based artificial diet under laboratory conditions. Annals of Plant Protection Sciences. 26: 265-269.

Chakravarty, S., Srivastava, C.P. and Keval, R. (2019). Interbreeding status of *Helicoverpa armigera* (Hübner) populations across India. Journal of Experimental Zoology, India. 22: 315-320.

Chaudhary, M.G., Chaudhary, H.K. and Chaudhary, R.J. (2016). Biology of *Helicoverpa armigera* (Hübner) Hardwick on okra in the laboratory condition. Advances in Life Sciences. 5: 5032-5037.

Chauhan, N.N., Chaudhary, F.K., Patel, H.N. and Kachhadiya, N.M. (2018). Biology of pearlmillet ear head worm, *Helicoverpa armigera* under laboratory condition. International Journal of Current Microbiology and Applied Sciences. 7: 2958-2969.

Chen, Y.S., Chen, C., He, H.M., Xia, Q.W. and Xue, F.S. (2013). Geographic variation in diapauses induction and termination of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). Journal of Insect Physiology. 59: 855-862.

Deepa, M. and Srivastava, C.P. (2010). Biological characteristics of *Helicoverpa armigera*. Annals of Plant Protection Sciences. 18: 370-372.

Deepa, M. and Srivastava, C.P. (2011). Genetic diversity in *Helicoverpa armigera* (Hübner) from different agroclimatic zones of India using RAPD markers. Journal of Food Legumes. 24: 313-316.

Gandhi, B.K. and Patil, R.H. (2017). Genetic diversity in *Spodoptera litura* (Fab.) from major soyabean growing states of India. Legume Research. 40: 1119-1125.

Jaba, J., Agnihotri, M. and Chakravarty, S. (2017). Screening for host plant resistance to *Helicoverpa armigera* (Hübner) in chickpea using novel techniques. Legume Research. 40: 955-958.

Jallow, M.F.A. and Zalucki, M.P. (1998). Effect of egg load on the host- selection behavior of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). Australian Journal of Zoology. 46: 291-299.

Mitchell, A. and Gopurenko, D. (2016). DNA barcoding the Heliothinae (Lepidoptera: Noctuidae) of Australia and utility of DNA barcodes for pest identification in *Helicoverpa* and relatives. Plos One. 11: e0160895.

Nunes, M.L.S., Figueiredo, L.L., Andrade, R.S., Rezende, J.M., Czepak, C. and Albernaz-Godinho, K.C. (2017). Biology of *Helicoverpa armigera* (Hübner) rearing on artificial or natural diet in laboratory. Journal of Entomology. 14: 168-175.

Sharma, K.C., Bhardwaj, S.C. and Sharma, G. (2011). Systematic studies, life history and infestation by *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on tomato in semi arid region of Rajasthan. Biological Forum. 3: 52-56.

Silva, I.F., Baldin, E.L.L., Specht, A., Sosa-Gümez, D.R., Roque-Specht, V.R., Morando, R. and Paula-Moraes, S.V. (2017). Biotic potential and life table of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) from three Brazilian regions. Neotropical Entomologia. 47: 344-351.

Singh, D., Singh, S.K. and Vennila, S. (2015). Weather parameters influence population and larval parasitization of *Helicoverpa armigera* (Hübner) in chickpea ecosystem. Legume Research. 38: 402-406.

Srivastava, C.P. and Joshi, N. (2011). Insect pest management in pigeonpea in Indian scenario: A critical review. Indian Journal of Entomology. 73: 63-75.

Sternberg, E.D., de Roode, J.C. and Hunter, M.D. (2015). Trans-generational parasite protection associated with paternal diet. Journal of Animal Ecology. 84: 310-321.

Tripathy, M.K. and Singh, H.N. (1999). Relationship between larval resistance and morphometric characters in *Helicoverpa armigera* populations at Varanasi, Uttar Pradesh. Indian Journal of Entomology. 61: 28-34.

Venkatesan, T., Sridhar, V., Tomason, Y.R., Jalali, S.K., Behere, G.T., Shanthi, R.M., Kumar, R., Vajja, V.G., Nimmakayala, P. and Reddy, U.K. (2016). Use of expressed sequence tag microsatellite markers for population genetic research of *Helicoverpa armigera* (Lepidoptera: Noctuidae) from India. Canadian Entomologist. 148: 187-199.