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DISPERSAL OF LARVAE OF FALL ARMY WORM *SPODOPTERA FRUGIPERDA* IN MAIZE

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ABSTRACT

A comprehensive understanding of the pattern of larval dispersal is important to establish the criteria for sampling, statistical analysis and the development of reliable and sustainable management strategies. The fall armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), a notorious pest of maize all over the world was reported from the Indian subcontinent in 2018. The present study assessed plant-to-plant dispersal pattern of larvae of *S. frugiperda* in caged field conditions of maize. The mean distance travelled by the larvae after infestation ranged from 0.36± 0.36 to 1.05± 0.18 m. The maximum distance travelled by the larvae was up to 1.50 m. There was no significant difference between the number of larvae recovered concerning the direction (n-s) within the row. The distances covered by them in both directions were not significantly different either. The larval dispersal pattern suggested non-directional movement of the caterpillars.

Key words: *Spodoptera frugiperda*, *Zea mays*, behaviour, larval dispersal, movement, infestation, mean distance, management, sampling, non-directional movement, cages, field, directional movement

The fall army worm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) is a polyphagous pest with a wide host range of > 353 host plants (Montezano et al., 2018). This pest is native to American continent predominantly affecting maize (*Zea mays* L.) (Sparks, 1979; Martin et al., 1980). In 2018, this species invaded the Indian subcontinent and was reported for the first time on maize in the state of Karnataka (Ganiger et al., 2018). Ever since, it has spread to nearly all the Asia-Pacific nations, including Australia and New Zealand (CABI, 2022; EPPO, 2022). It significantly reduces both quality and total grain yield by causing extensive damage to the maize crop (Kasoma et al., 2021). The larvae damage the crop by feeding on leaves remaining inside the whorls during the vegetative crop stage and in the reproductive stage they attack and feed on the cobs. The total loss can be estimated up to 58% under suitable conditions (Chimweta et al., 2020). It has been estimated that India's maize output would be reduced by 37,000-75,000 tonnes, even if 5-10% production losses in the maize growing areas (Suby et al., 2020). The reasons for successful colonizing ability of *S. frugiperda* can be associated with its high reproductive ability, short generation time and dispersal behaviour (Johnson, 1987; Huang et al., 2021). Dispersal is described as a movement away from an area of high population density causing the spreading of individuals (Price, 1997; Shaw, 2020). Insects disperse to find resources such as food, mates, and shelter in order to maximise their potential (Skendzic et al., 2021). In case of *S. frugiperda*, the adult moth lays eggs in masses on some plants, but the infestation can be seen in the entire field within a short period of its initial occurrence. This suggests that the larvae might disperse to neighboring plants after hatching from the egg. In lepidopterans, initially larval dispersal occurs through ballooning with the help of silken thread and wind, whereas as the size of the larva increases in the later stages, movement occurs through walking which may happen at any time (Zalucki et al., 2002). Knowledge regarding the dispersal pattern of a pest, especially the larval movement pattern can provide vital information regarding behavioural and ecological understanding of an insect species including potential infestation levels (Garcia et al., 2021). The present study aimed to understand the plant-to-plant movement of *S. frugiperda* in the maize field which is of utmost importance for establishing adequate sampling criteria, statistical analysis and for the development of more reliable, economic, and sustainable management strategies (Taylor, 1984; Fernandes et al., 2003; Garcia et al., 2021).

MATERIALS AND METHODS

Dispersal pattern of larvae of *S. frugiperda* was studied in the field condition in three separate maize plots during summer season in 2020 at the University of Agricultural Sciences, Bengaluru, India. Sweet corn, variety "Sugarita" was taken with a plot size of 4 x 4 m with five rows of plants, each consisting of 13 plants. The plants were raised with a spacing of 60 cm x 30 cm. After the germination of seeds, each study area was covered with nylon mesh (120 mesh) to prevent the external natural infestation by the *S. frugiperda*. Two weeks after the germination, one plant in every plot was artificially infested with one day old egg mass (≈130 – 140 eggs/ egg mass) obtained from the laboratory-reared culture. Artificial infestation of *S. frugiperda* was carried out by attaching one egg mass to the central plant of the middle row in each plot. The hatching % in every egg mass was recorded two days after release. The plants were inspected at two days of intervals and the new infestation on neighboring plants were recorded. The presence of larvae was ascertained on the 14th day of egg infestation by opening the whorls of plants. This method was followed to minimize the damage to plant whorl while searching for the larvae at every two-days interval.

In each plot, plants were oriented to north-south in the same row and east-west across rows. The larval location for the artificially infested plant (plant attached with egg mass) was considered as 'zero.' The number of larvae, as well as the mean distance and maximum distance moved by the larvae was estimated by the distance of infested plants from the release point with respect to different quadrants: northwest (nw), northeast (ne), southwest (se) and southeast (se); within the row (north and south) and across the rows (east and west). The survival % of larvae was calculated based on the number of larvae recovered fourteen days after infestation. The number of recovered larvae in each quadrant, orientation, and axes with respect to the infested plant as well as the maximum distance travelled by them was determined. Results were tested for normality and homogeneity of variance.

RESULTS AND DISCUSSION

In the three plots, the mean number of eggs infested was 134.67± 2.40. The egg hatching % was 92.12± 1.18%. But we recorded a lower number of larvae on plants after 14 days of artificial egg infestation (11.00± 0.58). Based on the number of larvae recovered after the 14th day, the mean larval survival rate was 8.86± 0.38%. This may be related to the high mortality of lepidopteran caterpillars in early stages. Similarly, high mortality of *S. frugiperda* in the early instars has been reported resulting in mere 5.06% larval survival after 14 days of egg infestation (Pannuti et al., 2016). However, the survivorship pattern has been also observed in western bean cutworm, *Striacosta albicosta* (Smith) in maize wherein a few larvae could stay alive to their maturity despite high egg survival (Paula-Moraes et al., 2013). In general, greater mortality at the early stage of their growth is typically seen in lepidopteran caterpillars. The reasons for low survival of larvae could be abiotic factors and biotic factors that governed mortality in early instars (Zalucki et al*.,* 2002). Most of the recovered larvae were found near to the egg infested plant in the same or adjacent row. Out of total larvae found in the field, 42.42± 0.67% of larvae were recovered within the same row as that of the egg infested plant and 48.48± 1.20% from the first adjacent row. A higher number of larvae (91%) from the nearby plants within the adjacent rows of the infested plant can be related to the food searching behaviour of the larvae. Upon hatching, the young larvae scrape green tissue for some time and then disperse to new plants to avoid competition and harvest food resource for better growth and development. The study from Pannuti et al. (2016) observed that *S. frugiperda* larvae were confined to within two rows from the plants which were artificially infested by the egg mass. A similar movement pattern of *S. frugiperda* was also observed in cotton where larvae travelled to 1 to 2.4 plants from the infested plant, not moving more than five plants from the release site (Ali et al., 1990). In maize cultivation, almost half of the *S. frugiperda* larvae recovered were from the infested row and 91.4% confined themselves within a radius of 1.1 m from the infested plant (Pannuti et al., 2016). Movement within the row is mostly predictable where more leaves are in close contact within a row than across rows (Blickenstaff, 1983; Ross and Ostlie, 1990).

In the present study, most of the larvae were recovered from the south direction within the infested row, but no significant difference was observed between north and south indicating that there is no specific directional movement of larvae, which corroborates with earlier findings by Pannuti et al. (2016). The number of newly infested plants on each alternate day after artificial egg infestation suggests that, greater proportion of healthy plants (more than 80%) got infested within 8 days of artificial infestation. The mean distance travelled by the larvae after infestation ranged from 0.36± 0.36 m to 1.05± 0.18 m. However, the maximum distance travelled by the larvae was up to 1.50 m on the 10th day after artificial infestation (Table 1). On the 14th day after the infestation of eggs, not more than one larva/ infested plant was recorded. The

Table 1. Larval dispersal of *S. frugiperda* in maize

Maximum distance travelled by larvae after artificially infested in caged conditions				
Days after artificial infestation	No. of newly infested plants		Mean distance travelled ± SE (m)	Maximum distance travelled (m)
	Mean± SE	Proportion (%)		
2	2.67± 0.67	24.24	1.04± 0.04	1.34
4	2.67± 0.88	24.24	0.64± 0.19	1.08
6	2.33± 1.20	21.21	0.50± 0.26	1.24
8	1.33± 0.33	12.12	1.05± 0.18	1.34
10	1.67± 1.20	15.15	0.36± 0.36	1.5
12	0.33± 0.33	3.03	0.45± 0.45	1.34
			NS (p= 0.3802)	

Movement of larvae in different directions					
Direction	No. of infested plants	Total No. of larvae recovered		Mean distance travelled (m)	Maximum distance (m)
	Mean± SE	Mean± SE	Proportion (%)	Mean± SE	
Within quadrants					
ne	0.67± 0.67	0.67± 0.67	11.11	0.25± 0.25	0.85
nw	1.33± 0.88	1.33± 0.88	22.22	0.59± 0.32	1.34
se	2.00± 1.00	2.00± 1.00	33.33	0.75± 0.41	1.5
sw	2.00± 1.00	2.00± 1.00	33.33	0.78± 0.39	1.34
p value	NS (p= 0.69)	NS (p= 0.69)		NS (p=0.70)	
Within rows (Spacing between the plants 0.3 m)					
n	1.33± 0.33	1.33± 0.33	33.33	0.55± 0.05	0.6
s	2.67± 0.88	2.67± 0.88	66.67	0.72± 0.22	1.5
p value	NS (p= 0.23)	NS (p= 0.23)		NS (p= 0.50)	
Across rows (0.6 m between the rows)					
e	0.00± 0.00	0.00± 0.00	0	0.00± 0.00	0
w	0.33± 0.33	0.33± 0.33	100	0.20± 0.20	0.6
p value	NS (p= 0.37)	NS (p= 0.37)		NS (p= 0.37)	

NS= Non-significant @ p≥ 0.05; SE= Standard error

mean number of larvae recovered in each quadrant viz., ne, nw, se, se varied from 0.67± 0.67 to 2± 1.00. With respect to the quadrants, the mean distance moved by the larvae varied from 0.25± 0.25 m (ne) to 0.78± 0.39 m (sw). Similarly, the maximum distance travelled by the larvae varied from 0.85 (ne) to 1.50 m (se). There was no significant difference between the number of larvae recovered, the mean distance and the maximum distance moved by the larvae between the four quadrants (Table 1). The larval movement along and across the axes showed that a greater number of larvae moved towards the south within the infested row (n-s) with a recovery frequency of 66.67% and a maximum distance movement of 1.50 m from the infested plant. The mean distance moved by the larvae varied from 0.55± 0.05 m to 0.72± 0.22 m. There was no significant difference between the number of larvae recovered with respect to the direction (north-south) within the row. The distances moved by them in both the directions within the row were also on par. Regarding the larval movement across the infested row (e-w), only one larva was recovered from the west axis, whereas no larvae were recovered from the east axis. There was no significant difference between the number of larvae recovered and the distance travelled across the rows. These results indicate the non-directional movement of the larvae in the field.

In general, the larval movement varies from plant to plant and depends on type of crop and cultivation practices (Tavares et al., 2021). Active movement from one plant to another within or between rows (within or between resources) is correlated with a form of searching behaviour of insects which is also controlled by several factors viz., internal factors, external environmental factors, and biological factors like the ability to perceive sensory information (Bell, 1990). This sensory information can also be non-directional (Barrows, 1975; Bell, 1990) or directional (Baker, 1978; Harris and Miller, 1984). Conversely, information from biological resources like a gradient of pheromone or food odour or sound or direct visual stimuli can be well localised (Baker, 1978; Bell, 1990). This kind of awareness enables the insect to monitor its path towards the biotic source of information (Bell, 1990) which may be correlated with the current finding of non-directional movement of *S. frugiperda* larvae. Further, the dispersal of *S. frugiperda* larvae mainly occurs by ballooning and crawling. This dispersal behaviour can be helpful in incorporating non-host crops or trap crops in crop cultivation practices (Kumar et al., 2022) as well as in spot application of insecticides (Li et al., 2023) in order to manage the notorious pest in a sustainable manner.

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AUTHOR CONTRIBUTION STATEMENT

MK conceived and designed the research. RB conducted the experiments and analysed the data. RB wrote the manuscript and both authors read and approved the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

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