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Assessment of yield loss at different levels of infestation by fall armyworm, *Spodoptera frugiperda* J.E. Smith, (Lepidoptera: Noctuidae) in maize

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Abstract
The present investigation was carried out for assessing yield loss caused by fall armyworm *Spodoptera frugiperda* J.E. Smith in field condition at college of Agriculture, V. C. Farm, Mandya (Karnataka) during *Kharif* and *Rabi* 2019-20. The experiment was carried out at different treatments including different levels of infestation. A maize hybrid, MAH 14-5 was used in this study. Yield loss caused by this pest was estimated by comparing the treatments including different levels of infestation with respect to growth and yield attributing characters. The mean of two seasonal data reveals that lowest grain (57.83 q ha^{-1}), straw (9.73 t ha^{-1}) yield and test weight (19.48 g) was at recorded at 25-30 % level of infestation followed by 20 -25 % level of infestation. Similarly, lowest plant height (1.71 m), cob length (16.75 cm), cob diameter (4.40 cm), number of kernel rows per cob (14.37) and number of kernels per rows (36.29) was recorded at 25-30 % level of infestation followed by 20 -25 % level of infestation. this study suggested that application of insecticide at proper level of infestation will reduce the significant yield loss and increases the productivity.

Keywords: Fall armyworm, yield loss, *Spodoptera frugiperda*, assessment, Maize

Introduction
Maize is the second most important cereal grain crop globally in terms of area and is known as Queen of Cereals. This belongs to the family Poaceae. 'Global maize production has accounted approximately 1050 million mt during 2019-20, and US was the leading producer, followed by China, accounting around 37% and 22%, respectively. India accounts More than two per cent to this production map with an amount of 28.08 mt in the year 2019-20. In Indian scenario, Maize has become the third largest food crop next to rice and wheat and grown in an area of 8.69 m ha with the production of 21.8 mt and productivity was 2509 kg ha^{-1} [2]. Insect pests are among the main factors leading to lower maize yield [5, 9]. Over 40 species of insect pest have been identified in maize. The fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), is one of the main pests in maize and known to cause severe reduction of yields. The fall armyworm is native to the tropical and sub-tropical region of Americas. In addition to maize. The most preferred host plants are maize, barley, sorghum and sugarcane. The neonate larvae of FAW mainly feed on leaf tissue while the subsequent instars feed on the leaf whorl, causing leaf holes; which a typical FAW damage symptom [3]. There is an urgent need to control this pest for lowers the yield loss by management strategy. To get relative information on maize yield loss caused by this pest, it is an essential prerequirement for entomologists to take any management action towards mitigating this pest. This study showed the assessment of maize yield loss caused by *S. frugiperda* and impact of its damage on various yield affecting factors.

Materials and methods
A maize hybrid MAH 14-5 was sown during *Kharif* and *Rabi* 2019 with a plot size of 1.5x2 m for each treatment with three replications. Percent infestation was assessed during the vegetative stage visually by counting healthy and damage plants and yield loss assessment was carried out in Maize at COA, V. C. Farm, Mandya. Fall armyworm infestation was recorded for 7 treatments including infestation of 0-5 percent, 5-10 percent, 10-15 percent, 15-20 percent, 20-25 percent, 25-30 percent and protected with three replications.

For protected chemical spray was taken at 10 days interval and activity of pest was observed. When particular treatment attains it's percent of infestation, the further increase of damage was avoided with chemical spray. The various treatments subjected to Randomized Complete Block Design (RCBD). The data from each treatment was subjected for ANOVA [10, 11] and means were separated by Tukey's HSD [16].

Table 1: Treatment details for assessment of yield loss at different levels of infestation by fall armyworm on maize

S. No	Treatments (% infestation)
1	0-5
2	5-10
3	10-15
4	15-20
5	20-25
6	25-30
7	Protected

$$\text{Percent infestation} = \frac{\text{No. of infested plants}}{\text{Total number of healthy plants}} \times 100$$

Observations
The data were recorded for growth and yield parameters for assessment of yield loss.

Plant height (m)
At physiological maturity 70 days after sowing, plant height was measured by using large scale, from bottom soil surface to top flag leaf and expressed in metre (m).

Cob length (cm)
The length of five cobs was measured from base to tip of the cob and the mean was taken as cob length and expressed in centimetre (cm).

Cob diameter (cm)
By using thread, in middle of cob, the circumference was measured by using formula of circumference of circle ($C= 2\pi r$), then radius was calculated by dividing circumference of circle by the value of 2π (6.28), then doubling the value of radius, cob diameter was calculated for every treatment.

Number of kernel rows
In each treatment, the average number of kernel rows per cob was worked out by counting the total rows from all the observational cobs.

Number of kernels per row
In each treatment, number of kernels per row was counted.

Test weight (g)
The weight of 100 kernels from the cobs were recorded separately and averaged and it was taken as test weight of maize and expressed in grams.

Grain yield (q ha^{-1})
After harvesting, grains were separated from cob and weight of the grains was calculated for each treatment. The kernel yield recorded from each net plot at 14 percent moisture was computed for both plot basis and hectare basis and expressed in kg per plot and hectare (q ha^{-1}) respectively.

Straw yield (t ha^{-1})
Straw yield was recorded from each net plot after complete sun drying and weight was expressed in tonnes per hectare (t ha^{-1}).

Results and discussion

Mean of two seasons (*Kharif* and *Rabi*) observations on yield attributes influenced by different levels of infestation of fall armyworm

The mean of two seasonal data on growth and yield attributes of maize were greatly influenced by fall army worm infestation at various levels and are shown in the table 2

There was significant difference was observed in grain yield between treatments concerned and results for grain yield are presented below. The results of the yield loss assessment revealed that the maximum grain yield was recorded in the protected treatment (76.00 q ha^{-1}), where there was complete absence of infestation was maintained. This was followed by 0-5 percent level of infestation (74.33 q ha^{-1}), which was on par with 5-10 percent level of infestation (71.33 q ha^{-1}), 10-15 percent level of infestation (70.33 q ha^{-1}) and 15-20 percent level of infestation (68.33 q ha^{-1}), lowest grain yield was recorded in 25-30 percent level of infestation (57.83 q ha^{-1}), which was on par with 20-25 percent infestation (62.33 q ha^{-1}) by fall armyworm (Table 2 and Fig 1).

There was a significant difference was observed between the treatments regarding straw yield were concerned. The results on impact of different levels of infestation on straw yield revealed that highest straw yield was recorded in protected treatment plot (12.35 t ha^{-1}) followed by 0-5 percent level of infestation (11.81 t ha^{-1}), which was on par with 5-10 percent level of infestation (11.46 t ha^{-1}), also similar trend 10-15 percent level of infestation (11.23 t ha^{-1}) and 15-20 percent level of infestation (10.96 t ha^{-1}). Lowest straw yield was recorded in 25-30 percent level of infestation (9.73 t ha^{-1}), which was on par with 20-25 percent level of infestation (10.21 t ha^{-1}) by fall armyworm (Table 2 and Fig 1).

The significant impact on test weight of maize due to fall armyworm infestation at different levels of infestations are presented in table 2. The absence of infestation at protected treatment recorded higher test weight (31.28 g) which was close to the 0-5 percent level of infestation (28.69 g) and was on par with 5-10 percent (27.65 g), 10- 15 percent (27.05 g) and 15-20 percent level of infestation (26.49 g). Finally, lowest test weight was recorded with 20-25 percent level of infestation (22.67 g) followed at 25-30 percent level of infestation (19.48 g) of fall armyworm (Table 2 and Fig 1).

Mean of two seasons (*Kharif* and *Rabi*) observation on growth and yield attributes influenced by different levels of infestation of fall armyworm

The mean of two seasonal (*Kharif and Rabi*) observations on plant height showed significantly taller in protected treatment (2.16 m) which was free from infestation which was almost on par with 0-5 percent (2.08 m), 5-10 percent (2.05 m), 10-15 (2.01 m) and 15-20 percent level of infestation (1.96 m). The lowest plant height was observed in 25-30 percent level of infestation (1.71 m) which is on par with 20-25 percent infestation (1.82 m) by fall armyworm (Table 3 and Fig 2).

Larger cob length was noted in protected treatment (20.29 cm), where complete absence of fall armyworm infestation was maintained. This was followed by 0-5 percent level of infestation (20.08 cm), and comparatively at 5-10 percent infestation (19.55 cm), 10-15 percent (19.87 cm) and 15-20 percent level of infestation (19.80 cm). The inferior cob length was observed in 25-30 percent level of infestation (16.75 cm), which is on par with 20-25 percent level of infestation (18.07 cm) of fall armyworm (Table 3 and Fig 2).

The results presented on maize's cob diameter (cm) showed that significant difference was observed among the treatments

due to fall armyworm infestation at various levels and are presented in table 3. Significant higher cob diameter was observed in protected treatment (5.22 cm) due to complete control of infestation, and followed by 0-5 percent level of infestation (5.14 cm) which was on par with 5-10 percent level of infestation (5.11 cm), 10- 15 percent level of infestation (5.08 cm) and 15-20 percent level of infestation (5.04 cm). The lowest cob diameter was observed in 25-30 percent level of infestation (4.40 cm) which was on par with 20-25 percent level infestation (4.51 cm) due to fall armyworm (Table 3 and Fig 2). There was a significant influence on number of kernel rows per cob of maize due to fall armyworm infestation at different levels and are presented in table 3. The results of impact of different levels of infestation on number of kernel rows per cob revealed that highest No. of kernel rows was recorded in protected control plot (16.8 rows per cob), where infestation was controlled, followed by 0-5 percent level of infestation (16.57 rows per cob) which was on par with 5-10 percent level of infestation (16.44 rows per cob), 10-15 percent level of infestation (16.37 rows per cob) and 15-20 percent level of infestation (16.33 rows per cob). At the end least number of kernel rows per cob was recorded in 25-30 percent level of infestation (14.37 rows per cob) which was on par with 20-25 percent level of infestation (14.68 rows per cob) of fall armyworm (Table 3 and Fig 2).

The observation recorded on number of kernels per row of maize was showed significant difference among the treatments due to fall armyworm infestation at different levels and are presented in table 3. The higher number of kernels per row was varied from 43.11 (protected treatment) to 36.29 (25-30 percent level of infestation) which was on par with 20-25 percent level of infestation (36.99 kernels per row). The subsequent treatments was recorded on par each other next to protected treatment (43.11 kernels per row) as 0-5 percent level of infestation (41.48 kernels per row), 5-10 percent level of infestation (40.06 kernels per row), 10- 15 percent infestation (39.41 kernels per row) and 15-20 percent level of infestation (39.09 kernels per row) were also found to be on par with the protected treatment (Table 3 and Fig 2).

The results of the present study are in accordance with the findings of [17] as they also noticed the increase in number of borers (*Busseola fusca*) leads to decrease yield of grain and quality of the cobs produced, here different number of borers for different treatments are very much similar to different levels of infestation of fall armyworm in our study. [13] also reported that 25 percent infestation by *Chilo partellus* caused significant grain yield reduction compare to less than 20 per cent infestation of *Chilo partellus* in maize during spring season. Similar findings were recorded by [6], where they revealed that yield impact of larval infestation of fall armyworm in corn. Grain yield was significantly affected by different levels of infestation of fall armyworm. i.e. major yield losses of 17 per cent were incurred when more than 20 percent of plants received larval infestation [8]. Similar results were observed by [6] where they reported that, the percent reduction in grain yield was increased with larval density rise. The maximum yield loss was observed when 9 larva per plant were released. The results of the present study are in similar with the outcomes of [17] as they also reported that, increase in number of borers (*Busseola fusca*) leads to decrease in biomass yield, here different number of borers for different treatments are very much similar to different levels of infestation of fall armyworm in our study. Similar findings were recorded by [12] where they revealed that yield impact of larval infestation of *C. partellus* in maize. The yield difference in untreated and treated maize was assessed. Untreated maize showed that, weight of 100 kernels was decreased by 8.5 % compare to treated maize and yield of maize was substantially lower by 28 percent compared to treated maize. [1] also found similar pattern in test weight of maize in Chitwan condition but with different tested varieties than that is reported in our study. We observed that fall armyworm damage parameters showed negative impact on test weight. Similar findings were recorded by [12] where they revealed that crop loss assessment methods followed in maize for stem borer. Plant height was significantly affected by its level of economic injury and thresholds for intervention. The results of the present investigations on yield loss assessment in maize due to fall armyworm infestation at various levels of infestation are in accordance with studies made by [18], who reported larval infestations of fall armyworm at sixth leaf stages of plant growth at levels 10 percent level and 20 percent causes significant yield loss. Likewise, outcomes of experiments on yield loss due to fall armyworm was similar with reports of [4] who reported that, the yield loss was assessed based on correlation between percent infestation and number of sustained plant population and his results are found that maximum yield loss was correlated with highest rate of infestation. [6] reported that crop loss estimation of fall armyworm, he recommended that action threshold for controlling fall armyworm should be within the 20 percent level of infestation for early whorl growth stages. If level of infestation crosses 20 percent, there is a significant yield loss could be occurred, which is almost on par with the present study.

Conclusion

From the results of present study, we can conclude that as the per cent infestation increased yield also decreases significantly up to certain level. there was no significant reduction in yield up to 20 percent of infestation of fall armyworm, when infestation level crossed 20 percent significant yield reduction was noticed. Here in this case maximum yield loss was observed in 25-30% level of infestation whereas, minimum yield loss was observed at protected treatment.

Table 2: Mean of two seasons (*Kharif* and *Rabi*) observations on yield attributes influenced by different levels of infestation of fall armyworm

S. No	Treatments (% infestation)	Grain yield (q ha^{-1})			Straw yield (t ha^{-1})			Test weight (g)		
		Kharif	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean
1	0-5	73.66^{c}	75.00^{c}	74.33	11.33^{c}	12.30^{c}	11.81	28.34^{c}	29.05^{c}	28.69
2	5-10	69.66^{bc}	73.00^{bc}	71.33	11.07^{bc}	11.86^{bc}	11.46	27.12^{bc}	28.18^{c}	27.65
3	10-15	68.66^{bc}	72.00^{b}	70.33	10.83^{b}	11.63^{bc}	11.23	26.67^{bc}	27.43^{c}	27.05
4	15-20	67.00^{b}	69.67^{b}	68.33	10.53^{b}	11.40^{bc}	10.96	26.01^{bc}	26.97^{bc}	26.49
5	20-25	64.00^{a}	60.67^{a}	62.33	10.08ab	10.33^{ab}	10.21	23.19^{ab}	22.16^{ab}	22.67
6	25-30	61.00^{a}	54.67^{a}	57.83	9.70^{a}	9.76^{a}	9.73	20.15^{a}	18.81^{a}	19.48

7	Protected	75.00^{d}	77.00^{d}	76.00	12.00^{c}	12.70^{d}	12.35	30.89^{d}	31.67^{d}	31.28
SE m ±		2.30	2.31	2.31	0.35	0.38	0.37	0.87	0.88	0.88
CD @ p=0.05		7.09	7.31	7.11	1.08	1.18	1.13	2.65	2.73	2.71

Values in the colomn followed by common letters are non-significant p=0.05 as per Tukey's HSD (Tukey, 1965)

Table 3: Mean of two season (*Kharif* and *Rabi*) observations on growth and yield attributes influenced by different levels of infestation of fall armyworm

Treatments	Plant height (m)			Cob length (cm)			Cob diameter (cm)			No. of kernel rows			No. of kernels per row		
	Kharif	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean
0-5	1.99^{bc}	2.17^{cd}	2.08	20.05^{c}	20.11^{bc}	20.08	5.12^{cd}	5.17^{c}	5.14	16.21^{b}	16.93^{c}	16.57	40.81^{cd}	42.16^{b}	41.48
5-10	1.96^{bc}	2.15^{cd}	2.05	19.19^{c}	19.92^{bc}	19.55	5.09^{c}	5.13^{c}	5.11	16.01^{b}	16.87^{bc}	16.44	39.76^{cd}	40.37^{ab}	40.06
10-15	1.93^{b}	2.09^{bcd}	2.01	19.88^{bc}	19.87^{bc}	19.87	5.07^{c}	5.10^{c}	5.08	15.90^{b}	16.81^{bc}	16.35	38.91^{c}	39.92^{ab}	39.41
15-20	1.92^{b}	2.01^{bc}	1.96	19.79^{bc}	19.82^{bc}	19.80	5.03^{bc}	5.06^{bc}	5.04	15.87^{b}	16.79^{bc}	16.33	38.71^{bc}	39.47^{ab}	39.09
20-25	1.75^{a}	1.89^{ab}	1.82	18.13^{b}	18.01^{ab}	18.07	4.45^{ab}	4.57^{ab}	4.51	14.31^{a}	15.05^{ab}	14.68	36.01^{ab}	37.97^{a}	36.99
25-30	1.69^{a}	1.74^{a}	1.71	16.19^{a}	17.32^{a}	16.75	4.35^{a}	4.45^{a}	4.40	13.81^{a}	14.93^{a}	14.37	35.13^{a}	37.45^{a}	36.29
Protected	2.10^{c}	2.23^{d}	2.16	20.23^{d}	20.21^{c}	20.29	5.16^{d}	5.28^{c}	5.22	16.29^{c}	17.21^{c}	16.8	42.02^{d}	44.21^{c}	43.11
SE m ±	0.06	0.07	0.07	0.64	0.69	0.60	0.16	0.17	0.16	0.52	0.55	0.53	1.30	1.35	1.32
CD @ p=0.05	0.20	0.21	0.20	1.96	1.99	1.86	0.50	0.51	0.51	1.60	1.69	1.64	4.00	4.15	4.07

Values in the colomn letters are non-significant p= 0.05 as per Tukeys HSD (Tukey, 1965)

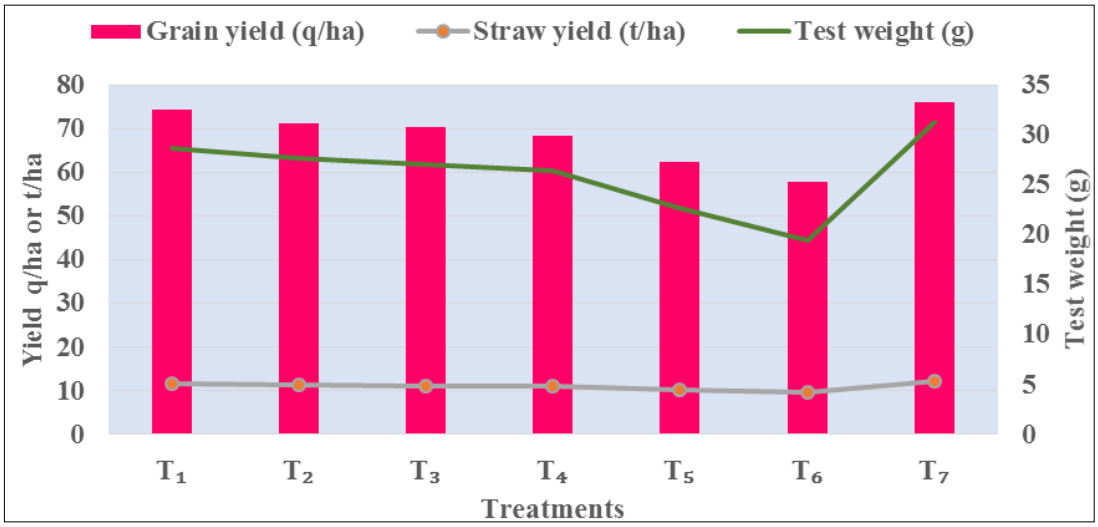
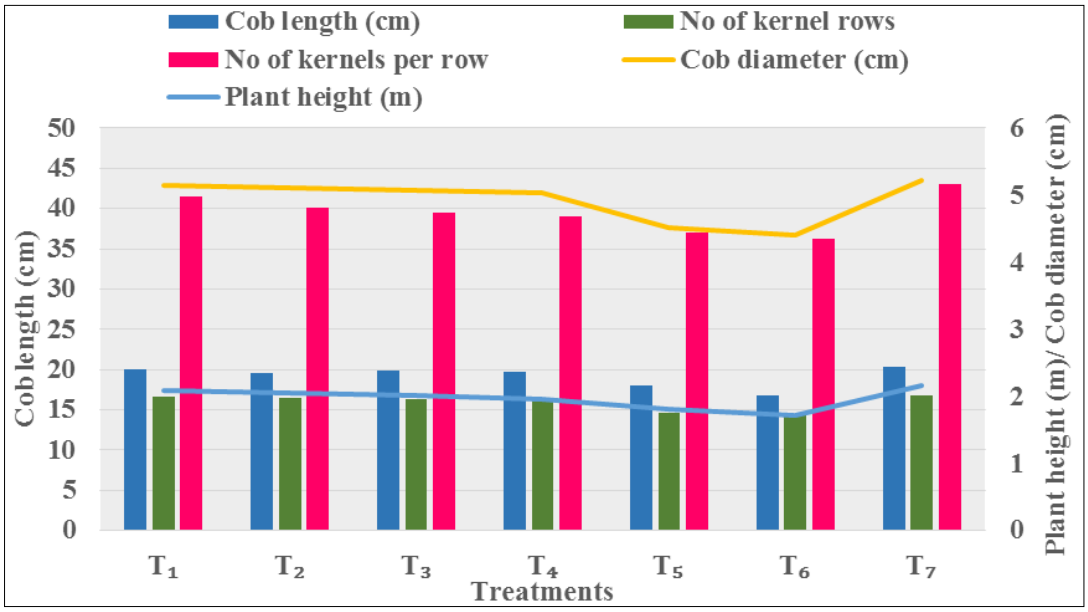


Fig 1: Yield performance at different levels of infestation by *S. frugiperda* on maize during 2019-20



T_1- 0-5% infestation
T_2- 5-10% infestation
T_3- 10-15% infestation
T_4- 15-20% infestation
T_5- 20-25% infestation
T_6-25-30% infestation
T_7- protected

Fig 2: Effect of different levels of infestation on plant morphology and yield attributes in maize during 2019-20

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