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Biophysical Factors Influencing Fall Armyworm Damage in Maize: Insights from Morphological Traits and Cob Characteristics

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GS and PM conceptualized and designed the study. Author MVA supervised the study. Author KSNR wrote and prepared the original draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Influence of different morphological (biophysical) parameters on the incidence of fall armyworm.
Sample: All the observations on plant morphological traits and collection of plant samples for biochemical analysis were made at two respective crop growth stages of maize *i.e.,* five leaf stage (V5) and at tasseling stage (VT) which coincides at 30 and 60 days after sowing respectively. Whereas, cob samples were collected at reproductive stage of the crop.

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Study Design: Randomized Complete Block Design (RCBD).
Place and Duration of Study: Zonal Agricultural Research Station (ZARS), V. C. Farm, Mandya during*Kharif*2020-21.
Methodology: The plant height, leaf length and leaf width of the crop was recorded with the help of a measuring tape. The stem diameter of the crop was recorded using Vernier. The trichomes of a leaf were counted under a binocular microscope from 1 cm^2 area of a leaf. The number of stomata on leaves was counted by using compound microscope from an area of 1 mm^2 of a leaf. The leaf colour was recorded using 1 to 4 colour index. The length of central spike of a tassel was recorded with the help of measuring tape. The height of the cob above the soil level was recorded with the help of measuring tape up to the node position of cob at silking stage. The cob length and cob diameter were measured using measuring tape and vernier calipers respectively and then the mean was calculated.
Results: The morphological traits like plant height (0.56* & 0.10) and leaf length (0.46* & 0.04) are positively correlated, whereas, leaf width had a positive (0.63**) and negative correlation (-0.23) with leaf damage at 30 and 60 DAS, respectively. Stem girth (-0.33 & -0.67**) and trichome no. (-0.71** & -0.60**) were negatively correlated, leaf color had a negative (-0.05) and positive (0.32) correlation, no. of leaves had a positive (0.43) and negative correlation (-0.06) at 30 and 60 DAS, respectively, whereas, stomatal density on upper (-0.33) and lower (-0.32) leaves was negatively correlated with leaf damage at 30 DAS. The biophysical parameters in cob samples like tassel length (-0.144) had negative, cob length (0.561*) had positive, cob diameter (-0.47*) had positive and ear height (-0.161) had negative association with leaf damage rating.
Conclusion: Morphological traits of maize inbreds influence fall armyworm infestation. At 30 DAS, infestation positively correlated with plant height, leaf length, leaf width, but negatively with trichomes. At 60 DAS, infestation correlated negatively with trichomes and stem girth positively with leaf color.

Keywords: Fall armyworm; spodoptera frugiperda; screening; maize; biophysical.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile emerging crop sharing wider adaptability under varied agro-climatic conditions. Maize is staple food crop in sub-Saharan Africa, Southeast Asia and Latin America [1] but it faces both biotic and abiotic stresses hindering it to produce the essential quantity to meet the food requirements. Among these, biotic stresses primarily include weeds, insects and diseases. Over 250 insect species have been documented to attack maize [2] with significant ones including stemborers like *Chilo partellus* and *Sesamia inferens*, sorghum shoot fly *Atherigona* spp. and the fall armyworm *Spodoptera frugiperda*. Notably, *Chilo partellus* and *Sesamia inferens* were responsible for a 35% yield loss [3]. Occasional yield reductions are also attributed to pests like termites, corn earworm and chaffer beetles. Among the insect pests attacking maize, recently introduced pest, fall armyworm (FAW) *S. frugiperda* responsible for causing significant yield reduction in maize crop [4].

FAW completes several overlapping generations in a year and capable of building pestiferous proportions in the place where it occurs. The eggs are laid in mass inside the whorls or on undersurface of leaf or on stem when the pest population is more. The eggs are cream colored covered with anal tuft of hairs or sometimes without hair covers. The developing larvae eat different parts of the host plant, depending on the stage of crop which usually feed on leaves, creating a characteristic “windowing” effect and moist sawdust-like frass near the tunnel and upper leaves [5]. In the older plants the grown-up larvae bore and feed into the developing reproductive structures, such as tassel, maize cobs, thereby reducing yield quantity and quality. In the present investigation, an attempt was made to explore the sources of host plant resistance using maize inbreds to combat the infestation of fall army worm. Hence, the influence of different morphological (biophysical) parameters on the incidence of fall armyworm was studied. This research is crucial as it sheds light on how the physical traits of maize plants, such as their morphology and cob characteristics, affect their vulnerability to fall armyworm infestations. Understanding these biophysical factors can help in developing more resistant maize varieties, thereby improving crop yields and food security. Additionally, the insights gained could guide targeted pest management strategies, reducing

the economic impact of fall armyworms on agriculture.

2. MATERIALS AND METHODS

Screening of maize genotypes: A field experiment was conducted at Zonal Agricultural Research Station (ZARS), V.C. farm, Mandya during *Kharif* 2020-21. The field evaluation of 210 maize inbred lines, private and public sector inbreds against fall armyworm was taken up in the month of September 2020. The maize inbreds were sown in a plot containing 3 m row of single line in the field with a spacing of 60X20 cm between rows and plants. The maize crop was raised by following all the recommended package of practices except the plant protection measures. The maize inbreds were allowed for natural infestation of fall armyworm. Then the damage score was recorded according to Davis and Willilams [6] scale.

Observations and collection of samples at different stages of maize crop: For the study, 18 maize inbreds were selected based upon categorization of resistance and along with the hybrid MAH 14-5 were re-sown. All the observations on plant morphological traits and collection of plant samples for biochemical analysis were made at two respective crop growth stages of maize *i.e.,* five leaf stage (V5) and at tasseling stage (VT) which coincides at 30 and 60 days after sowing respectively. Whereas, cob samples were collected at reproductive stage of the crop.

Influence of morphological/biophysical parameters on the incidence of fall armyworm: The plant morphological parameters including plant height, leaf length, leaf width, trichome density (No. of macro hairs per cm square or leaf area), leaf colour, stomatal density and stem diameter were measured. The observations were recorded twice *i.e.,* on 30 and 60 days after sowing. During the reproductive phase of the crop, the length of central spike of tassel, cob height, cob length and cob diameter were recorded. The morphological parameters were recorded on five randomly selected plants in each inbred. The biophysical parameters of the tested inbreds were correlated with the damage score to establish positive or negative relationship with the incidence of fall armyworm.

The plant height of the crop above the ground level was recorded from five randomly selected plants in each inbred with the help of a measuring tape. The stem diameter of the crop was recorded using Vernier caliper and measured from the center of the third inter node of the plant. The Leaf length and leaf width of the crop were recorded with the help of a measuring tape. The trichomes of a leaf were counted under a binocular microscope from 1 cm^2 area of a leaf. The number of stomata on leaves was counted by using compound microscope from an area of 1 mm^2 of a leaf. The procedure to examine the stomata was done by applying xylene thermacol solution on the leaf surface. The leaf was left for drying and later, the upper layer of the leaf surface was removed. Then the stomatal density on both upper and lower surface of the leaves was counted. The leaf colour was recorded using 1 to 4 colour index. The Length of central spike of a tassel was recorded with the help of measuring tape at reproductive stage *i.e.,* tasseling stage approximately 65 to 70 days after sowing. Then, the length of the central spike was averaged to get mean length for each inbred. The height of the cob above the soil level was recorded with the help of measuring tape up to the node position of cob upon attainment of the reproductive stage *i.e.,* silking stage approximately 75 to 80 days after sowing. Then average of cob height was calculated. The cob length and cob diameter were measured after the harvest of the crop by using measuring tape and vernier calipers respectively and then the mean was calculated.

Statistical analysis: All the statistical analysis were done using opstat software. The data on the nutrient constituents of the selected maize hybrids was subjected for ANOVA [7] and means were separated by Tukey's HSD [8]. The correlation studies were done with mean leaf damage score upto 60 DAS and nutrient content using statistical analysis program software (SPSS).

3. RESULTS AND DISCUSSION

3.1 Morphological/Biophysical Factors

Plant height: At 30 DAS, the minimum plant height recorded was 28.5 cm in the sweet corn line 4085 SC, followed by MAI 142 (29.90 cm), MAI 224 (30.90 cm), MAI 210 (31.40 cm), POP 1857 (32.00 cm), MAI 285 (32.20 cm) and Z 84 5 (33.40 cm) and these inbred lines belong to least susceptible group and found to be on par among themselves. Whereas, the maximum plant height recorded was 47.6 cm in case of a fodder inbred line SPS 23, trailed by MAI 298 (45.00 cm), MAI 8 (43.10 cm), PT 2217 (43.00 cm) and MAH 14 5 (42.20cm) and were found to be statistically on par with one another (Table 1). The plant height

of evaluated lines showed significant positive correlation with the damage score (0.56*) (Table 3).

At 60 DAS, the highest plant height was observed in case of Z 84-5 (160.00 cm), followed by PT 2217 (140.80 cm), MAI 8 (142.40 cm), NAI 207 (140.80 cm), MAI 249 (134.20 cm) and MAI 298 (134.00 cm) and were found to be on par with one another except Z 84-5 which statistically differed from others. Whereas, the lowest plant height recorded was 89.50 cm in the inbred line MAI 755, tracked by POP 1857 (105.40 cm) and which was found to be statistically on par (Table 2). At active crop growth stage, there was no correlation observed between the plant height and FAW damage. A non-significant positive correlation (r = 0.100) was observed between the plant height and damage score (Table 3).

Ali et al. [9] reported genotypes namely, Com 6625 (252.93cm) and Agaiti- 2002 (247.53cm) categorized under resistant group were found to be taller than susceptible genotypes, FH- 949 (226.43cm) and FH- 963 (229.40cm). They have also reported that a non-significant negative correlation between plant height and the infestation of *C. partellus* (r = -0.294). Rasool et al. [10] also found a negative correlation of plant height with leaf damage caused by *C. partellus* (r = -0.293). The present findings are in contrast with the studies done by Rasool et al. [10] which might be because of difference in genotypic traits or because of the variation in insect biology. Fall armyworm is a whorl feeder and the plant volatiles released from the taller and healthy plants will attract the moths to lay eggs on them.

Leaf length: At 30 DAS, Z 84 5 showed short leaves and recorded the minimum leaf length of 23.5 cm followed by the other least susceptible lines specifically, MAI 210 (25.6 cm), MAI 142 (26 cm), 4085 (27.70 cm), MAI 224 (28.20cm), MAI 285 (28.20cm) and POP 1857 (28.80cm) and were found to be statistically on par. The maximum leaf length was observed in highly susceptible lines SPS 23 (42.9 cm) followed by others namely, MAH 14-5 (41.45 cm), MAI 8 (41.4 cm) and MAI 298 (41.3 cm) and were found to be on par (Table 1). Significant, positive correlation (r = 0.460*) was observed between leaf length and damage score at the 30 days crop growth stage (Table 3).

At 60 DAS, the minimum leaf length observed was 55.3 cm in POP 1857, followed by MAI 214 (58.5 cm), MAI 285 (59.8 cm) and 4085 SC (60.50 cm) and were found to be statistically on par with one another. While statistically, higher leaf length (96.3 cm) was observed in PT 2217, followed by PT 1877 (88.3 cm). The experimental lines MAI 755 and MAH 14-5 recorded leaf length of 82.7 and 80.8 cm respectively and were found to be on par. At 60 DAS prominence between the leaf length and damage was not observed. A non-significant positive relation was observed (r = 0.040) between the leaf length and FAW damage (Table 3).

The results obtained are in conformity with the findings of Paul and Deole [11] who reported highest leaf area (732.45 cm^2) in the highly susceptible genotype INDAM-1122. Whereas, the lowest leaf area observed in least susceptible lines against fall armyworm *i.e.,* Pro-DKC-9182 (298.67cm^2) followed by ADV-9293 (345.76cm^2), MOTI-155 (345.87cm^2).

Leaf width: At 30 DAS, the maximum leaf width was recorded in highly susceptible inbreds PT 1877 (5.75 cm) and SPS 23 (5.15 cm) followed by the moderately susceptible one MAI 298 (5.07 cm) and were found to be on par. Whereas, minimum leaf width was recorded in case of least susceptible inbred lines namely, POP 1857 (3.6 cm), MAI 210 (3.7 cm), MAI 285 (3.7 cm), 4085 (3.95 cm), Z 84 5 (3.95 cm) and MAI 142 (4.00 cm) and found to be statistically on par (Table 1). A highly significant and positive correlation (r = 0.630**) was observed between leaf width and damage score (Table 3).

The lowest leaf width at 60 DAS was recorded in the inbreds MAI 142 (5.91 cm) followed by Z 490-24 (5.94 cm), V 938 26 (6.42 cm) and Z 84 5 (6.45 cm) and were found to be statistically on par (Table 3). Whereas the highest leaf width was recorded in MAH 14-5 (11.10 cm), trailed by, MAI 8 (7.80 cm), MAI 755 (7.5 cm), PT 2217 (7.45 cm) and PT 1877 (7.40 cm) were found to be statistically on par. A non-significant negative correlation (r = -0.230) was observed between the leaf width and FAW damage (Table 3).

The findings of present studies were in agreement with the findings of Paul and Deole [11] who reported significant positive correlation between leaf area and leaf damage rating of fall armyworm where they stated that with increase in leaf area there will be increase in infestation level. In the present studies it was recorded that, narrow leaves confer resistance against fall armyworm larvae. The reason might be due to the wider leaves produce a compact whorl when it furls. Moreover, fall armyworm larvae chooses to feed in the closed or darker areas of the plant preferably the whorls than the exposed leaf area.

Table 1. Morphological traits of maize inbreds in relation to the infestation of *S. frugiperda* recorded at 30 DAS

Sl. No.	Inbreds	Category	Damage score	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Stem girth (mm)	Leaf colour	No. of leaves	No. of trichomes per cm²	No. of stomata per mm²	
											LS	US
1	MAH14 5	Least susceptible	1.20	42.30^{defg}	41.45^{d}	4.95^{cde}	15.31^{d}	3.00	5.60	48.00^{fg}	148.00^{fg}	131.00^{g}
2	V 938 26		1.20	39.40bcdefg	31.70^{abc}	4.13^{abcd}	15.09^{cd}	2.00	6.00	51.00^{g}	86.00^{abc}	67.30^{abc}
3	MAI 285		1.30	32.20^{abc}	28.20^{abc}	3.70^{ab}	13.56^{abcd}	3.00	5.00	41.00^{def}	108.30^{cde}	87.00^{cdef}
4	MAI 210		1.30	31.40^{abc}	25.60^{ab}	3.70^{ab}	12.81^{abcd}	3.00	5.60	27.00^{b}	105.00^{bcde}	83.00^{bcd}
5	MAI 142		1.40	29.90^{ab}	26.00^{ab}	4.00^{abcd}	11.80^{abcd}	3.00	5.80	30.00^{bc}	117.30^{de}	98.00^{def}
6	MAI 224		1.40	30.90^{ab}	28.20^{abc}	4.10^{abcd}	14.92^{cd}	3.00	5.80	42.00^{defg}	119.00^{de}	102.00^{ef}
7	4085 SC		1.50	28.50^{a}	27.70^{abc}	3.95^{abc}	11.60^{abc}	2.00	5.40	69.00^{h}	116.00^{de}	99.50^{ef}
8	POP 1857		1.50	32.00^{abc}	28.80^{abc}	3.60^{a}	10.74^{a}	2.00	6.20	29.00^{bc}	100.00^{abcde}	83.00^{bcde}
9	PT 2217		3.20	43.00^{defg}	36.50^{cd}	4.19abcd	13.07^{abcd}	3.00	6.20	37.00^{cde}	119.20^{de}	94.70^{def}
10	Z 84 5		3.40	33.40^{abcd}	23.50^{a}	3.95^{abc}	13.51^{abcd}	2.00	5.20	33.00^{bcd}	97.70abcde	81.70abcde
11	MAI 249	Moderately susceptible	4.00	41.00^{cdefg}	36.60^{cd}	4.10^{abcd}	14.53^{bcd}	2.00	5.60	27.00^{b}	78.70^{ab}	62.30^{ab}
12	NAI 207		4.10	40.90^{cdefg}	35.10^{bcd}	4.30^{abcd}	13.50^{abcd}	2.00	6.40	46.00^{efg}	122.30^{ef}	108.30^{f}
13	MAI 8		4.20	43.10^{efg}	41.40^{d}	4.05^{abcd}	13.48^{abcd}	2.00	5.60	30.00^{bc}	153.30^{g}	147.00^{g}
14	MAI 214		4.20	39.30^{bcdefg}	35.70^{cd}	4.81^{bcde}	13.47^{abcd}	2.00	6.00	30.00^{bc}	77.30^{a}	59.70^{a}
15	MAI 755		4.40	33.80^{abcde}	29.80^{abc}	4.75^{abcde}	10.70^{a}	3.00	5.80	10.00^{a}	109.00^{cde}	94.30^{def}
16	MAI 298		5.30	45.00^{fg}	41.30^{d}	5.07^{cde}	12.70^{abcd}	3.00	5.40	10.00^{a}	98.00^{abcde}	83.30^{defg}
17	PT 1877	Highly susceptible	7.00	36.70^{abcdef}	31.20^{abc}	5.75^{e}	13.65^{abcd}	3.00	6.20	15.00^{a}	95.70^{abcde}	70.00^{abc}
18	SPS 23		7.10	47.60^{g}	42.90^{d}	5.15^{de}	11.02^{ab}	3.00	6.40	12.00^{a}	95.30^{abcd}	76.00^{abcd}
19	Z 490 24		7.30	38.50bcdefg	34.30^{bcd}	4.15abcd	10.97^{ab}	2.00	6.00	10.00^{a}	86.00^{abc}	67.70^{abc}
SE m ±			0.25	1.62	1.51	0.20	0.55	NS	NS	1.70	2.19	2.16
CD @p=0.05			0.76	4.82	4.50	0.58	1.65			5.07	6.50	6.43

NS: Non-Significant, Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; LS: Lower surface, US: Upper surface.

Table 2. Morphological traits of maize inbreds in relation to the infestation of *S. frugiperda* recorded at 60 DAS

Sl. No.	Inbreds	Damage score	Plant height(cm)	Leaf length(cm)	Leaf width(cm)	Stem girth(mm)	Leaf colour	No. of leaves	No. of trichomesper cm²
1	MAH 14 5	0.40	133.00^{bcd}	80.80^{defg}	11.10^{b}	30.20^{e}	4.00	12.10^{d}	83.00^{fg}
2	MAI 224	0.40	122.90^{bc}	62.30^{abcd}	7.40^{a}	18.20^{abcd}	3.00	7.80^{ab}	78.00^{efg}
3	4085 SC	0.70	118.20^{abc}	60.50^{abc}	7.35^{a}	18.30^{abcd}	3.00	7.40^{ab}	94.00^{g}
4	PT 1877	0.80	119.20^{abc}	88.30^{fg}	7.40^{a}	22.10^{d}	4.00	8.60^{bcd}	45.00^{bc}
5	MAI 285	0.90	130.30^{bcd}	59.80^{ab}	6.95^{a}	18.30^{abcd}	3.00	8.00^{ab}	68.00^{def}

Sl. No.	Inbreds	Damage score	Plant height(cm)	Leaf length(cm)	Leaf width(cm)	Stem girth(mm)	Leaf colour	No. of leaves	No. of trichomesper cm^2
6	V 938 26	1.00	119.10^{abc}	71.60^{abcdef}	6.42^{a}	16.60^{abc}	4.00	8.10^{abc}	83.00^{fg}
7	MAI 249	1.10	134.20^{bcd}	64.70^{abcde}	6.95^{a}	19.00^{bcd}	3.00	8.10^{abc}	55.00^{cd}
8	SPS 23	1.10	124.90^{bc}	71.30^{abcdef}	7.10^{a}	17.50^{abcd}	3.00	6.30^{a}	41.00^{abc}
9	MAI 214	1.20	108.90^{ab}	58.50^{ab}	6.63^{a}	16.20^{abc}	3.00	8.00^{ab}	45.00^{bc}
10	MAI 142	1.20	131.00^{bcd}	63.30^{abcd}	5.91^{a}	15.20^{ab}	3.00	8.10^{abc}	63.00^{de}
11	MAI 210	1.30	121.20^{bc}	74.20^{bcdef}	6.90^{a}	15.00^{abc}	4.00	7.80^{ab}	30.00^{ab}
12	Z 490 24	1.50	128.80^{bc}	66.00^{abcde}	5.94^{a}	16.40^{abc}	3.00	8.20^{abc}	26.00^{a}
13	Z 84 5	1.60	160.00^{d}	67.30^{abcde}	6.45^{a}	18.30^{cd}	3.00	8.60^{abc}	46.00^{bc}
14	MAI 298	1.60	134.00^{bcd}	78.70^{cdefg}	7.20^{a}	19.80^{cd}	4.00	10.50^{cd}	28.00^{a}
15	PT 2217	1.80	140.80^{cd}	96.30^{g}	7.45^{a}	18.20^{abcd}	4.00	9.20^{bc}	56.00^{cd}
16	NAI 207	1.80	134.70^{bcd}	73.80^{abcdef}	7.20^{a}	15.00^{abc}	3.00	8.20^{abc}	65.00^{de}
17	MAI 755	1.90	89.50^{a}	82.70^{efg}	7.50^{a}	14.70^{ab}	4.00	9.00^{bc}	26.00^{a}
18	POP 1857	2.20	105.40^{ab}	55.30^{a}	7.20^{a}	15.00^{abc}	4.00	7.60^{ab}	46.00^{bc}
19	MAI 8	2.70	134.80^{bcd}	66.40^{abcde}	7.80^{a}	13.80^{a}	4.00	8.50^{abc}	38.00^{ab}
SE m ±		0.07	4.68	3.04	0.31	0.80	NS	0.39	2.85
CD @p=0.05		0.19	13.90	9.04	0.93	2.36		1.16	8.47

NS: Non-Significant, Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD.

Table 3. Impact of biophysical plant traits on the whorl damage of maize inbredsdue to fall armyworm at different growth stages

		Correlation coefficient (r) value	
Sl. No.	**Category**	**Damage scoreat 30 DAS**	**Damage scoreat 60 DAS**
1	Plant height	0.56*	0.10
2	Leaf length	0.46*	0.04
3	Leaf width	0.63**	-0.23
4	Stem girth	-0.33	-0.67**
5	Leaf colour	-0.05	0.32
6	No. of leaves	0.43	-0.06
7	No. of trichomes	-0.71**	-0.60**
8	No. of stomata on lower surface of leaves	-0.33	-
9	No. of stomata on upper surface of leaves	-0.32	-
10	Coefficient of determination (R^2)	0.850	0.840

**Correlation is significant at 5% (p = 0.05) level; **correlation is significant at 1% (p = 0.01) level;N= 19; r = correlation coefficient; R^2 = coefficient of determination.*

Stem girth: The maximum stem girth at 30 DAS was recorded in least susceptible lines namely, MAH 14-5 (15.31 mm), V 938 26 (15.09 mm) and MAI 224 (14.92 mm) and were found to be on par. The minimum stem girth was recorded in the moderately susceptible line MAI 755 (10.70 mm) and in a least susceptible line POP 1857 (10.74 mm) followed by the highly susceptible lines Z 49024 (10.97 mm) and SPS 23 (11.02 mm). The results were found to be statistically on par. A decreasing trend between stem girth and susceptibility of the host towards FAW was observed (Table 1). A non-significant but negative correlation was observed in case of stem girth and damage score (r = -0.332) (Table 3).

The lowest stem girth recorded was 13.8 mm in MAI 8 trailed by MAI 755 (14.7 mm), POP 1857 (15.0 mm), NAI 207 (15.0 mm), MAI 210 (15.0 mm) and MAI 142 (15.20 mm) were found to be on par with one another and these lines recorded maximum damage at 60 DAS comparing with the others (Table 2). While the higher stem girth was observed in comparatively least damaged lines *i.e.,*MAH 14-5 (30.2 mm) followed by PT 1877 (22.1 mm) and MAI 298 (19.80 mm). A commercial hybrid MAH 14-5 was found statistically different from other inbred lines, whereas, PT 1877 and MAI 298 found to be on par with each other. A significant negative correlation (-0.670**) was observed between the damage score and stem girth (Table 3).

The present results are in confirmation with the findings of Afzal et al. [12] who reported that the resistant genotypes, EV 6098 (23.23mm) and DK 6525 (21.73mm) had the maximum stem diameter than that of the susceptible genotype, Sahiwal- 2002 (18.80mm). The stem diameter alone contributed 32.7 per cent resistance of maize genotypes towards the stem borer, *C. partellus.* Stem girth had a significant negative association with the infestation of *C. partellus* (r = -0.572). In the present studies, it was found that larger stem diameter contributes to the resistance against the fall armyworm, the reason might be the plant having minimum stem girth will have tight and compact whorl, that facilitates easy feeding of FAW and helps escaping from the natural enemies like predators and parasitoids.

Leaf color: At 30 DAS, the leaf colour recorded was non-significant. There was no significant difference observed in the leaf colour of various inbred lines. The maximum leaf colour score recorded was 3 and minimum score recorded was 2 (Table 1).

At 60-days growth stage of the crop there was no significant variation in leaf colour of different inbred lines, which influences the fall armyworm damage (Table 2). The lowest leaf colour score recorded was 3 and highest score recorded was 4. The findings were clear that there was no relationship between the leaf colour and fall armyworm incidence.

No. of leaves: Among the various inbreds, no of leaves ranged from 5 to 6.4 and were found to be non-significant. There was no significant difference among the different experimental lines in case of leaf count, also there was no relationship with leaf count and resistance or susceptibility of maize inbreds against the infestation of fall armyworm at 30 DAS (Table 1). At 60 DAS, the number of leaves recorded on the various inbreds significantly varied from 6.30

to 12.10. Less number of leaves were observed in case of SPS 23 (6.30) followed by 4085 SC (7.40) and POP 1857 (7.60) and were found to be on par. While more no. of leaves was recorded in MAH 14-5 (12.1) trailed by MAI 298 (10.5), PT 2217 (9.2) and MAI 755 (9.0) and were statistically differed from one another except PT 2217 and MAI 755 which was found to be on par (Table 2). The exact relation between the number of leaves on susceptibility and resistance of inbred lines against the fall armyworm larval damage was not observed.

No. of trichomes: The minimum number of trichomes per unit area observed in the inbred lines Z 490 24 (10), MAI 298 (10), MAI 755 (10), SPS 23 (12) and PT 1877 (15) and these were the experimental lines belonged to the moderately susceptible and highly susceptible categories and found to be on par with one another (Table 1). The maximum number of 69 trichomes per cm^2 was recorded in the least susceptible inbred line 4085 SC followed by V 938-26 (51), MAH 14-5 (48) and NAI 207 (46.00) in which 4085 SC statistically differs from other lines, whereas V 938-26, MAH 14-5 and NAI 207 was statistically at par. Comparatively less number of trichomes per unit leaf area was observed in case of highly susceptible lines, whereas pubescent leaves were observed in case of least susceptible lines. A decreasing trend was observed between the leaf hairiness and susceptibility of the inbreds with significant negative correlation (r = -0.708**).

The minimum no. of trichomes observed (26 per cm^2) was in case of Z 490 24 and MAI 755, followed by MAI 298 (28) and MAI 210 (30) and were found to be on par with one another at 60 DAS. Whereas the highest number of trichomes per unit leaf area was recorded in 4085 SC (94) tracked by MAH 14-5 (83), V 938-26 (83) and MAI 224 (78) where in the inbred line 4085 SC found to be statistically different among the inbred lines, while MAH 14-5, V 938-26 and MAI 224 were found to be on par with one another (Table 2). Comparatively higher number of trichomes per unit area was observed in least damaged lines and lesser number of trichomes were counted at highly damaged lines at 60 DAS. Significant, but negative correlation (-0.600**) was observed between the damage score and leaf hairiness (Table 3).

The trichome density negatively affects the ovipositional behavior as well as feeding and larval nutrition of insect pests. The present results are in agreement with the findings of Paul and Deole who reported that at 45 days after sowing the highest leaf trichomes (73.68 cm^2) observed in the genotype ADV-9293. Whereas, the lowest leaf trichomes observed in LG-34.06 (27.98 cm^2) followed by NK-30 (29.06cm^2), LG-35.02 (29.09 cm^2), INDAM-1122 (34.98 cm^2), S-6217 (34.98 cm^2), DKC-9182 (39.87 cm^2), I-CORN-369 (42.98 cm^2) and Penna gold-1188 (44.36 cm^2). The *S. frugiperda* incidence had highly significant negative correlation between trichome density at 45 DAS and leaf damage rating (-0.61**). Moya-Raygoza [13] also reported that trichomes offer a physical defense in minimizing the chewing damage by the fall armyworm associated with maize, which support the present findings.

Stomatal density: Stomatal count on both upper and lower surface of the leaves were recorded at the most susceptible crop growth stage against the fall armyworm *i.e.,* 30 DAS. The lowest no. of stomata per mm^2 leaf area observed was in MAI 214 (77.30) followed by MAI 249 (78.70), V 938-26 and Z 490 24 (86.00) and were scattered in all the damaged categories and found to be statistically on par (Table 1). The highest number of stomata recorded was 153.3 per mm^2 leaf area in MAI 8, trailed by MAH 14-5 (148.00) and NAI 207 (122.30) that differed statistically, while inbred lines MAI 8 and MAH 14-5 were found to be on par. Non-significant negative correlation (-0.329) was observed between the no. of stomata on the lower surface of the leaves and damage score (Table 3).

The minimum no. of stomata recorded on the upper surface of the leaves was 59.7 per mm^2 in case of MAI 214 followed by MAI 249 (62.3), V 938 26 (67.3), Z 490 24 (67.7) and PT 1877 (70.00) and were found to be statistically on par. The highest number of 147.0 stomata per mm^2 was recorded on the upper surface of MAI 8, trailed by MAH 14-5 (131.0), NAI 207(108.3), MAI 224 (102.0) and MAI 142 (98.00) that statistically differed from one another, except MAI 224 and MAI 142 found to be on par. The number of stomata on upper surface of leaves showed negative relation (-0.320) but non-significant towards the FAW damage (Table 3).

The present findings are in conformity with Prasad et al [14] who reported significant variations for stomatal density, stomatal length and width on adaxial and abaxial leaf surface of various maize genotypes. In the present study, a significant variation in stomatal density among the genotypes were observed, but a statistical

relation with the insect damage was not observed.

Tassel length: The minimum tassel length was recorded (25.80 cm) in case of POP 1857 and PT 1877, followed by MAI 224 (27.00 cm), MAI 142 (27.10 cm), MAI 755 (30.60 cm) and 4085 SC (30.80 cm) and were found to be statistically on par. Whereas, the maximum tassel length recorded was 40.70 cm in case of V 938-26, tracked by SPS 23 (39.70 cm), MAI 298 (39.20 cm), MAH 14-5 (38.80 cm), MAI 214 (38.70 cm) and MAI 285 (38.20 cm) and were found to be on par, except V 938-26 which statistically differed from other inbreds. The exact relation with the variation in the tassel length on susceptibility and resistance were not observed (Table 5).

Paul and Deole [11] reported significant positive correlation (0.450*) between central spike and ear damage by the FAW indicating that, increase in central spike there was increase in infestation. But contradictory findings were observed in the present experiment that, a non-significant negative correlation (-0.14^{NS}) between the ear damage & length of central spike.

Ear height: Low ear height was recorded in MAI 224 (35.70 cm) followed by the inbreds namely, MAI 298 (59.90 cm), MAI 755 (65.30 cm) and POP 1857 (65.30 cm) and were found to be statistically on par with one another. While the maximum ear height was observed in SPS 23 (128.30 cm), trailed by V 938-26 (120.30 cm) and MAH 14-5 (120.0 cm) and were found to be on par. There was a negative relationship (-0.16^{NS}) between the ear height and susceptibility or resistance of the inbred lines against fall armyworm but it was non-significant (Table 5).

Paul and Deole [11] reported significant but negative correlation (-0.410*) between cob height and kernel damage rating, indicating that with increase in cob height there was decrease in infestation level. In the present study, statistically a non-significant relation was observed between the ear height and cob damage rating. However, it was negatively correlated.

Cob length: The lowest cob length was recorded in case of least susceptible lines namely, MAI 224 (8.17 cm) and V 938 26 (8.90 cm) and were statistically on par followed by MAI 210 (10.3 cm) and MAI 298 (10.5 cm) which found to be on par with one another. Whereas, the maximum cob length was observed in case of highly susceptible inbred POP 1857 (17.83 cm), followed by a moderately susceptible line Z 84 5 (17.45 cm) and also in the least susceptible lines MAI 142 (16.80 cm) and MAH 14 5 (16.50 cm) the data was found to be statistically on par. Comparatively lesser cob length was recorded in case of least susceptible lines while in the highly susceptible lines longer cobs were observed. A significant positive correlation (0.560*) was observed between cob length and cob damage by the fall armyworm.

The results of present findings are in agreement with earlier findings by Paul and Deole [11] who reported significant correlation between cob length and kernel damage rating. However, it was positive (0.40*) indicating that with increase in cob length there was increase in infestation level.

Cob diameter: Comparatively minimum cob diameter recorded was in the moderately and highly susceptible lines namely, 4085 SC (32.82 cm), PT 2217 (33.31 cm) and MAI 755 (35.27 cm) and were found to be on par with one another (Table 4). Whereas, maximum cob diameter was recorded in the least susceptible lines namely, MAH 14-5 (47.16 cm), MAI 142 (47.13 cm) and MAI 285 (45.16 cm) and were found to be statistically on par. In case of moderately susceptible inbreds the cob diameter varied from 32.82 to 44.11 cm. Comparatively minimum cob diameter recorded in case of highly susceptible lines while in case of least susceptible lines the cob diameter recorded was maximum. A significant negative correlation (-0.470*) between cob damage and cob diameter was observed (Table 5).

Table 4. Morphological traits of maize inbreds in relation to the infestation of fall armyworm at reproductive stage of the crop

Sl. No.	Inbred lines	Category	Ear and kernel damage score	Length of central spike (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (mm)
1	MAI 8		1.10	31.80^{abcde}	83.30^{cd}	11.67^{abc}	41.95^{bcdef}
2	MAH 14 5		1.10	38.80^{def}	120.00^{e}	16.50^{efg}	47.16^{f}

Sl. No.	Inbred lines	Category	Ear and kernel damage score	Length of central spike (cm)	Ear height (cm)	Cob length (cm)	Cob diameter (mm)
3	V 938 26	Least susceptible	1.10	40.70^{e}	120.30^{e}	8.90^{a}	38.47^{abcde}
4	Z 490 24		1.10	37.80^{cde}	78.00^{bcd}	11.33^{abc}	37.91^{abcde}
5	PT 1877		1.20	25.80^{a}	75.00^{bc}	11.00^{abc}	39.70^{abcde}
6	MAI 298		1.30	39.20^{cde}	59.90^{b}	10.50^{ab}	43.10^{cdef}
7	MAI 142		1.30	27.10^{ab}	98.30^{d}	16.80^{efg}	47.13^{f}
8	MAI 224		1.40	27.00^{ab}	35.70^{a}	8.17^{a}	35.93^{abc}
9	MAI 285		2.10	38.20^{cde}	70.30^{bc}	13.67^{bcde}	45.16^{ef}
10	MAI 210		2.20	34.40^{abcde}	80.70^{bcd}	10.30^{ab}	37.87^{abcd}
11	SPS 23	Moderately susceptible	4.30	39.70^{de}	128.30^{e}	15.67^{defg}	44.11^{def}
12	MAI 214		4.70	38.70^{cde}	98.00^{d}	13.50^{bcde}	42.29^{bcdef}
13	MAI 755		5.10	30.60^{abc}	65.30^{bc}	14.50cdefg	35.27^{ab}
14	NAI 207		5.30	35.10^{bcde}	80.00^{bcd}	13.66^{bcde}	42.22^{bcdef}
15	4085 SC		5.40	30.80^{abcd}	68.00^{bc}	14.17^{cdef}	32.82^{a}
16	Z 84 5		5.70	33.70^{abcde}	78.30^{cde}	17.45^{fg}	39.38^{abcde}
17	POP 1857	Highly susceptible	7.00	25.80^{a}	65.30^{bc}	17.83^{g}	37.98^{abcde}
18	PT 2217		7.30	35.60^{bcde}	80.30^{bcd}	12.83^{bcd}	33.31^{a}
19	MAI 249		7.60	32.00^{abcde}	68.70^{bc}	16.25^{defg}	37.17^{abcd}
SE m ± CD @p=0.05			0.15 0.45	0.41 1.20	5.19 15.43	0.68 2.03	1.19 3.54

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD.

Table 5. Impact of biophysical constituents in cob and kernels of maize genotypes on fall armyworm incidence

Correlation coefficient (r) value		
Sl. No.	**Morphological traits**	**Ear and kernel damage score**
1	Length of central spike	-0.144
2	Cob length	0.561*
3	Cob diameter	-0.470*
4	Ear height	-0.161
5	Coefficient of determination (R^2)	0.772

4. CONCLUSION

Morphological traits of various maize inbreds on the incidence of fall armyworm at the 30 DAS revealed that the infestation was significant and correlated positively with plant height (0.560*), leaf length (0.460*) and leaf width (0.630**). While significant negative correlation was observed (-0.710**) in case of number of trichomes per unit area of leaves. At the same time non-significant but positive correlation was observed between the damage and number of leaves (0.43). Whereas, non-significant negative correlation was observed in case of stem girth (-0.33), leaf colour (-0.05), number of stomata on the lower surface of the leaves (-0.33) and in the upper surface of the leaves (-0.32). Morphological traits of various maize inbreds on the incidence of fall armyworm at the 60 DAS revealed that the infestation was significant and correlated negatively with of number of trichomes per unit area of leaves (-0.60**) and stem girth (-0.67**). Whereas, non-significant but positive correlation recorded in case of plant height (0.10), leaf length (0.04) and leaf colour (0.32). While a non-significant negative correlation was recorded in case of leaf width (-0.23) and number of leaves (-0.06).

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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