International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(5): 703-712
www.biochemjournal.com
Received: 02-03-2024
Accepted: 06-04-2024

G Sugeetha
Assistant Professor, Department of Entomology, College of Agriculture, V.C Farm, Mandya, Karnataka, India

MV Adwaith
M.Sc. student, Department of Entomology, College of Agriculture, V.C Farm, Mandya, Karnataka, India

KS Nikhil Reddy
M.Sc. student, Department of Entomology, College of Agriculture, V.C Farm, Mandya, Karnataka, India

P Mahadevu
Professor and Head, Department of Genetics and Plant Breeding, College of Agriculture, V.C Farm, Mandya, Karnataka, India

Corresponding Author:
G Sugeetha
Assistant Professor, Department of Entomology, College of Agriculture, V.C Farm, Mandya, Karnataka, India

Biochemical factors influencing fall armyworm damage in maize

G Sugeetha, MV Adwaith, KS Nikhil Reddy and P Mahadevu

DOI: https://doi.org/10.33545/26174693.2024.v8.i5i.1167

Abstract
The screening field experiment was conducted at Zonal Agricultural Research Station (ZARS), Mandya during *Kharif* 2020-21 against fall armyworm, *Spodoptera frugiperda* for 210 maize lines, out of which 18 inbreds were selected to study biochemical factors that influence fall armyworm damage. The biochemical parameters in plant sample like TSS (0.77** & 0.50*), TRS (0.52* & 0.64**), nitrogen (0.75** & 0.37), phosphorous (0.81** & 0.59**) and crude protein (0.61** & 0.40) had a positive correlation whereas, potassium (-0.86** & -0.73**), phenols (-0.69** & -0.65**), tannins (-0.81** & -0.77**), TFA (-0.52** & -0.75**) and peroxidases (-0.90** & -0.47*) showed a negative association at 30 and 60 DAS, respectively with leaf damage. Regression analysis stated that 95 percent ($R^2 = 0.95$) and 94 percent ($R^2 = 0.94$) of the whorl damage at the 30 and 60 days growth stage was controlled by these biochemical factors of the plant. In cob samples, TSS (0.49*), TRS (0.57*), nitrogen (0.78**), phosphorous (0.83**), crude protein (0.52*) had a positive association whereas, potassium (-0.92**), phenols (-0.73**), tannins (-0.51*), TFA (-0.70**) and peroxidases (-0.88**) had a negative association with leaf damage. Regression analysis states that 99 percent ($R^2 = 0.99$) of the ear and kernel damage was controlled by these biochemical factors of the plant.

Keywords: Fall armyworm, *Spodoptera frugiperda*, biochemical, TSS, TRS, correlation, regression

Introduction

In India, Maize is grown throughout the year predominantly as a *kharif* crop with 85 per cent of the area under cultivation in the season. Maize is the third most important cereal crop in India after rice and wheat. There are several pests recorded on maize, among them stem borer, cob worm, aphid, leaf hoppers, grasshoppers, armyworm, fall armyworm are considered as major insect pests (Kalleshwaraswamy *et al*., 2018) [10]. Among them, the fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) is one of the serious insect pests on maize which belongs to the family Noctuidae and the order Lepidoptera and known to cause significant yield losses. Management of this pest through chemical control by using insecticides for longer time period may cause insecticide resistance which also possess a residual effect making its way towards environmental pollution directly or indirectly affecting human health. The management of nutritional components to know the host plant resistance mechanism may be a key factor for its control. 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 biochemical parameters on the incidence of fall armyworm was studied.

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 hybrids against fall armyworm was taken up in the month of September 2020. The maize inbreds and hybrids 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, respectively in two replications. The maize crop was raised by following all the recommended practices except the plant protection measures. The maize inbreds were allowed for natural infestation of fall armyworm.

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 biochemical parameters on the incidence of fall armyworm: The uninfested whorl portions of selected maize genotypes were sampled at V5 stage and another tasseling stage of the crop (VT). The uninfested cob samples were collected after harvest separately in a butter paper for the estimation of the important biochemical components *viz*., total sugars, reducing sugars, total orthodoxy phenols, total free amino acids, tannins, crude proteins and enzymes. Further, the major nutrients *viz.*, N, P and K from the selected inbreds representing each resistant category were estimated by using standard procedure and protocols. The biochemical constituents in the test inbreds were linked with the incidence of FAW to establish the type of correlation. The fresh plant samples were used for the estimation of crude proteins, total free amino acids and enzyme like peroxidases. For the estimation of other nutritional and secondary metabolites like total sugars, reducing sugars, total orthodoxy phenols, tannins and major nutrients *viz.*, N, P and K dried samples were used.

The total and reducing sugars in each test genotype were estimated by the method suggested by Somogyi (1952) [19]. The nitrogen content in each test hybrid was estimated by the method suggested by Piper (1966) [13]. The phosphorous content in di-acid digested plant sample was determined by spectrophotometric method (UV) after appropriate dilution as suggested by Piper (1966) [13]. The potassium content in di-acid digested plant sample was determined by flame photometric method after appropriate dilution (Piper, 1966) [13]. The crude protein content in plant samples of various maize experimental lines were determined by using Bradford method. Estimation of total phenols from whorl samples of test inbreds was done by following Folin-Ciocalteau method suggested by Bray and Thorpe (1954) [3]. The estimation of Tannins from whorl samples of test inbreds was done by following Folin-Denis method suggested by Bray and Thorpe (1954) [3]. The amount of total free amino acids present in the leaf samples was estimated by following ninhydrin method developed by Moore and Stein (1948) [12]. The peroxidase enzyme activity was assayed through spectrophotometer method as described by Hartee (1955) [8].

Results and Discussion

Biochemical parameters in plant sample

Total soluble sugars (TSS)

In the early stage *i.e.*, 30 DAS, the total soluble sugars significantly varied from 0.41 to 1.41 mg g^{-1}. Less amount of TSS was recorded in case of least susceptible inbred lines, V 938-26 (0.41 mg g^{-1}) followed by MAI 285 (0.42 mg g^{-1}), MAI 210 (0.45 mg g^{-1}) and POP 1857 (0.50 mg g^{-1}) and were found to be statistically on par. Moderately high amount of TSS was recorded in case of moderately susceptible lines *i.e.*, 0.80- 1.22 mg g^{-1} (Table 1). In case of highly susceptible lines high amounts of TSS was recorded specifically on, PT 1877 (1.41 mg g^{-1}), SPS 23 (1.38 mg g^{-1}) and Z 490-24 (1.35 mg g^{-1}). Comparatively, in the inbreds higher amount of TSS was recorded in case of highly susceptible lines, while in the least susceptible lines the TSS content was less. A highly significant and positive correlation (0.77^{**}) was observed between the damage ratings induced by the larvae and TSS content (Table 5). An increasing trend of sugar content were recorded with increasing susceptibility.

At active crop growth stage *i.e.*, 60 DAS, the total soluble sugars significantly varied from 2.07 to 3.08 mg g^{-1}. An increasing trend of TSS was observed with susceptibility of the experimental lines towards the FAW. Less amount of the TSS was recorded in the least damaged inbreds *viz*., MAI 224 (2.07 mg g^{-1}), V 938 26 (2.08 mg g^{-1}), MAI 214 (2.33 mg g^{-1}), MAI 249 (2.35 mg g^{-1}), MAI 285 (2.35 mg g^{-1}), 4085 SC (2.42 mg g^{-1}), MAI 210 (2.44 mg g^{-1}), SPS 23 (2.44 mg g^{-1}) and MAI 142 (2.47 mg g^{-1}) and were found to be on par. A higher amount of TSS was recorded in the more damaged lines *i.e.*, MAI 298 (3.08 mg g^{-1}), MAI 755 (2.96 mg g^{-1}), PT 2217 (2.73 mg g^{-1}), NAI 207 (2.70 mg g^{-1}) and POP 1857 (2.65 mg g^{-1}) and were found to be statistically similar (Table 2). A significant positive correlation (0.50^{*}) was observed between TSS and damage score induced by FAW (Table 5).

An increased quantity of sugars in susceptible plants may act as feeding stimulants for the insects. Similar observations are reported by Praveen *et al*., (2013) [14] who stated that the TSS content raised as the growth advanced and they obtained low TSS in the resistant variety, Nithyashree (1.85%) than the susceptible variety, Basi- local (2.50%) at 60 days after sowing.

Total reducing sugars (TRS)

The amount of total reducing sugars at 30 DAS varied significantly from 3.49 mg g^{-1} to 10.44 mg g^{-1}. In the least susceptible inbreds, the TRS content varied between 3.49 to 6.93 mg g^{-1}. Less amount of TRS was recorded in Z 84-5 (3.49 mg g^{-1}) tracked by V 938-26 (3.57 mg g^{-1}), MAI 142 (3.90 mg g^{-1}) and PT 2217 (4.34 mg g^{-1}) and were found to be on par. In the moderately susceptible lines, the TRS content varied from 3.83 to 8.52 mg g^{-1}. A high amount of TRS were recorded in SPS 23 (10.44) which statistically differed from other inbred lines, while the inbreds, Z 490-24 and MAI 755 were found to be on par by recording 9.39 and 8.52 mg g^{-1}, respectively (Table 1). Comparatively, higher amount of TRS were observed in the highly susceptible inbred lines, while lower amount was recorded in case of moderately susceptible and less susceptible lines. A significant positive correlation (0.52^{*}) was observed between TRS and fall armyworm damage (Table 5).

At 60 DAS, the TRS content among the tested inbred lines significantly varied between 6.49 to 9.80 mg g^{-1}. The low TRS content was recorded of (6.49 mg g^{-1}) in the MAI 755, followed by V 938 26 (6.83 mg g^{-1}), MAI 224 (6.95 mg g^{-1}) and PT 1877 (7.08 mg g^{-1}) and the inbred lines were found to be on par with one another. Statistically, higher amount of TRS was recorded in the more damaged lines namely, POP 1857 (9.80 mg g^{-1}), MAI 8 (9.42 mg g^{-1}), Z 490 24 (9.01 mg g^{-1}), MAI 298 (8.95 mg g^{-1}), NAI 207 (8.85 mg g^{-1}) and PT 2217 (8.67 mg g^{-1}) and were statistically found to be on par (Table 2). Comparatively higher amount of TRS were observed in the more damaged inbreds. A positive relation

(0.64**) was observed between the TRS and fall armyworm damage (Table 5).

The results of present study were in line with the findings of Lokesh and Mehla (2017) [11] who reported that reducing sugar contents of resistant genotypes were found to be lesser as compared to susceptible ones. The lowest reducing sugar content of 5.08% was observed in resistant genotype 551-1 and highest of 7.10% was recorded in the susceptible genotype, 1015.

Nitrogen

An increasing trend in the infestation was observed with nitrogen content in selected lines leading to the susceptibility of hosts to fall armyworm. At 30 days of crop growth stage, the nitrogen content in various selected lines varied significantly between 1.23- 2.34 per cent. The low nitrogen content was recorded in the inbred lines belonging to least susceptible category namely, MAI 285 (1.23%), V 938 26 (1.26%), MAI 210 (1.42%) and MAI 142 (1.51%) and were found to be on par with one another (Table 1). The nitrogen content in the moderately susceptible lines varied between 1.78 to 2.21 per cent in case of MAI 8 and MAI 298. Comparatively, higher amount of nitrogen content was recorded in case of highly susceptible lines namely, SPS 23 (2.34%) trailed by PT 1877 (2.11%) and Z 490-24 (2.04%) wherein SPS 23 was found to be statistically different from other lines, whereas, PT 1877 and Z 490-24 were on par. A highly significant positive correlation (0.75**) was observed between plant nitrogen content and the damage induced by the fall armyworm larvae

At 60 DAS, the nitrogen content among the tested inbred lines varied significantly from 1.20 to 2.39 per cent. The minimum nitrogen content was recorded (1.20%) in V 938 26, followed by the other lines namely, MAI 285 (1.21%), MAI 224 (1.42%) and MAI 142 (1.43%) and were found to be statistically similar. The higher amount of nitrogen was recorded in the inbred lines which comparatively showed more damage by FAW (Table 2). The maximum nitrogen content was recorded in the genotypes namely, NAI 207 (2.39%), MAI 298 (1.94%), SPS 23 (1.94%), POP 1857 (1.89%) and MAI 249 (1.89%) and were found to be on par except the inbred NAI 207 which was statistically different from other inbreds. A positive relation (0.37) but non-significant was observed between nitrogen content and FAW damage (Table 5).

These results are in accordance with the observations of Ali *et al.*, (2015) [1] who reported that positive and significant correlation between nitrogen and infestation by the *Chilo partellus* (Swinhoe). The maximum nitrogen content (2.80%) was recorded in the susceptible genotype com 6625, while lower amount of nitrogen (1.77%) content was recorded in the resistant genotype FH 949.

Phosphorous

Among the inbred lines, the phosphorus content was varied significantly between 0.30 to 0.82 per cent. The Low amount of phosphorus was recorded in the inbreds namely, MAI 249 (0.30%), V 938-26 (0.34%), MAI 210 (0.35%), MAI 142 (0.39%) and MAI 224 (0.39%) and these genotypes were statistically on par and belonged to the least susceptible category, except MAI 249 which was moderately susceptible. In the moderately susceptible lines, the phosphorus content varied between 0.30 to 0.68 per cent (Table 2). A High amount of phosphorus was recorded in the highly susceptible lines namely, SPS 23 (0.82%), Z 490 24 (0.76%) and PT 1877 (0.71%) in which SPS 23 and Z 490 24 and was found to be on par. A highly significant and positive correlation (0.81**) between the phosphorus content and damage induced by the FAW was observed (Table 5).

The phosphorus content among the various inbred lines varied significantly from 0.2 to 0.42 percentage, at active crop growth stage *i.e.,* 60 DAS. The low amount of phosphorus was recorded in the least damaged inbreds namely, MAI 224 (0.20%), 4085 SC (0.21%) and MAI 210 (0.21%) were found to be statistically on par. The maximum phosphorus content was recorded (0.46%) in MAI 755, followed by MAI 8 (0.43%) and NAI 207 (0.42%) and were found to be on par with one another and the same inbred lines recorded comparatively more damage at 60 days crop growth stage. The relation between the phosphorus content and fall armyworm damage was found to be positive and highly significant (0.59**) (Table 5).

The results obtained in the present study was in contrast with the findings of Lokesh and Mehla (2017) [11] who observed that phosphorus content of resistant genotypes are lower compared to the susceptible genotypes, which indicated phosphorus playing negative role with the total life span of maize stem borer.

Potassium

Amount of potassium content in selected experimental lines significantly varied between 1.76 to 2.91 per cent. The per cent potassium content was statistically higher in least susceptible lines than the moderately and highly susceptible ones (Table 1). The Low amount of potassium was recorded in the highly susceptible and moderately susceptible inbreds namely, PT 1877 (1.76%), SPS 23 (1.82%), Z 490 24 (1.97%), MAI 214 (1.92%), MAI 298 (1.98%) and MAI 755 (2.04%) and were found to be on par with one another. The high amount of potassium was recorded in the least susceptible lines, MAH 14 5 (2.91%), MAI 224 (2.79%), V 938 26 (2.72%), MAI 210 (2.71%), POP 1857 (2.63%) and in a moderately susceptible line MAI 249 (2.74%) which was found on par with one another. The correlation between the potassium content and the damage induced by the larvae in the different inbreds were highly significant and negative (-0.86**).

At 60 DAS, the potassium content varied significantly among the various inbreds and ranged between 1.27 to 2.47 percentage. Statistically, low amount of potassium was recorded in the more damaged lines namely, MAI 755 (1.27%), MAI 298 (1.27%), Z 490 24 (1.32%), MAI 8 (1.34%) and POP 1857 (1.39%) and were found to be on par (Table 2). The high amount of potassium was recorded in the least damaged lines *i.e.,* MAH 14 5 (2.47%), MAI 224 (2.43%) and MAI 249 (2.36%) and were found to be at par. A decreasing trend in the potassium content was recorded with increasing susceptibility of inbreds against FAW (r=-0.73**).

Potassium is essential to the performance of multiple plant enzyme functions and permits plants to develop stronger cell walls for preventing pathogen infection and insect attack and to obtain more nutrients to be used for plant defence and damage repair. Also, it plays an important role in increasing the phenol concentrations, which play a critical role in plant resistance (Wang *et al.,* 2013) [20]. Sharma and Chatterji (1971) [18] reported that plants of resistant genotypes of maize had lower potassium content as compared to susceptible ones. The results of present study was in agreement with earlier studies conducted by Lokesh and Mehla (2017) [11] who reported that significant negative correlation was observed between the potassium content and damage caused by the *Chilo partellus* (Swinhoe) larvae. The highly susceptible genotypes *i.e.,* 295 and 1015 (2+3) recorded low amount of potassium whereas the higher potassium content was recorded in the resistant genotypes, 551-5 and 335.

Crude protein

An increasing trend of crude proteins in selected inbred lines was observed with an increase in susceptibility of hosts to FAW and the values ranged from 9.89 to 14.20 mg g^{-1}. The inbred lines belonging to least susceptible category recorded low crude protein content of 9.89, 10.07, 10.47 and 10.84 mg g^{-1} in MAI 210, MAI 224, MAI 285 and V 938 26, respectively and these inbreds were found to be statistically on par (Table 1). In the moderately susceptible category, the protein content varied between 11.18 to 14.20 mg g^{-1}. The high amount of crude protein was observed in a moderately susceptible line, MAI 298 (14.20 mg g^{-1}) trailed by the two highly susceptible lines namely, PT 1877 (13.82 mg g^{-1}), SPS 23 (13.53 mg g^{-1}) and were found to be on par with one another. A highly significant positive correlation (0.61**) was observed between the crude protein content and damage induced by the larvae (Table 5).

At 60 DAS, crude protein content among the various experimental lines significantly varied between, 11.15 and 16.14 mg g^{-1}. The low amount of crude protein was recorded (11.15 mg g^{-1}) in MAI 214, trailed by V 938 26 (11.24 mg g-1), SPS 23 (11.61 mg g-1), 4085 (12.27 mg g^{-1}), MAI 142 (12.36 mg g^{-1}) and MAI 285 (12.43 mg g^{-1}) and were on par with one another (Table 2). The maximum crude protein content was recorded in more damaged lines of maize namely, POP 1857 (16.64 mg g^{-1}), PT 2217 (16.37 mg g^{-1}) and NAI 207 (15.91 mg g^{-1}) and were statistically similar with one another. A positive correlation (0.40) was observed between the damage caused by the fall armyworm and crude protein but non-significant (Table 5).

The results obtained are in conformity with the findings of Chen *et al.*, (2009) [5] who reported that the fall armyworm susceptible genotypes Ab24E and FAW7050 had greater constitutive foliar total soluble protein than the resistant one *i.e.,* Mp708. Also, similar results were observed by Kabre and Ghorapde (1999) [9] who reported positive correlation between protein content and susceptibility of maize varieties to the stem borer.

Secondary metabolites in plant sample

Total phenols

At 30 DAS, the minimum phenol content was recorded in MAI 298 (0.43 mg g^{-1}), a moderately susceptible line, followed by highly susceptible inbreds, Z 490 24 (0.51 mg g^{-1}) and SPS 23 (0.56 mg g^{-1}) and were found to be on par. The maximum phenol content was recorded in the least susceptible lines namely, MAH 14 5 (1.95 mg g^{-1}), V 938 26 (1.77 mg g^{-1}) MAI 285 (1.71 mg g^{-1}), 4085 SC (1.04 mg g^{-1}), MAI 224 (1.04 mg g^{-1}), MAI 142 (0.99 mg g^{-1}) and MAI 210 (0.92 mg g^{-1}) (Table 3). The relation between the phenol content and fall armyworm damage was highly significant but negative (-0.69**) (Table 5).

The minimum phenol content at 60 DAS was recorded in more damaged lines namely, Z 84 5 (1.15 mg g^{-1}), NAI 207 (1.16 mg g^{-1}), MAI 8 (1.17 mg g^{-1}) POP 1857 (1.19 mg g^{-1}), MAI 210 (1.23 mg g^{-1}), Z 490 24 (1.24 mg g^{-1}), MAI 298 (1.26 mg g^{-1}), PT 2217 (1.28 mg g^{-1}) and were found to be statistically at par. A high amount of phenol was recorded in the least damaged inbreds specifically in, MAI 224 (2.13), MAI 285 (2.12) and 4085 (2.06) and were statistically similar with one another (Table 4). A decreasing trend of phenol was observed with the susceptibility of inbred lines and hybrid against FAW and a highly significant negative correlation (-0.65**) was observed between damage scale and phenol content (Table 5).

Phenolic compounds prevent the insect oviposition on the host plant and effect the larval growth. The low amount of phenolic compounds are detoxified by prophenoloxidase present in the insect gut, however, intensive feeding may result in insufficiency performance of prophenoloxidase to catalyse the phenols which pose detrimental towards the insects (Caretto *et al.*, 2015) [4]. The present findings are in agreement with Santiago *et al.* (2005) [16] and Rasool *et al.* (2017) [15] who revealed that total phenol content was found to be significantly and negatively correlated with the damage caused by *C. partellus* (r= -0.812*). They reported significantly lowest concentrations of total phenols in extremely susceptible genotype, Basi- local (117.97 μg/g) while in highly resistant genotypes *viz*., CM- 123 (238.05 μg/g) and CM- 133 (234.76 μg/g), high content of total phenols were reported.

Tannins

Lower amount of tannins were recorded in case of highly susceptible lines namely, SPS 23 (1.02 mg g^{-1}), Z 490 24 (1.14 mg g^{-1}) and PT 1877 (1.25 mg g^{-1}) were found to be on par (Table 3). In the moderately susceptible inbreds, the tannin content varied from 1.37 to 1.76 mg g^{-1}. Comparatively, higher amount of tannin content was recorded in the least susceptible lines namely, MAI 285 (2.83 mg g^{-1}), MAI 142 (2.76 mg g^{-1}), V 938 26 (2.71 mg g^{-1}), MAH 14 5 (2.64 mg g^{-1}) and MAI 224 (2.58 mg g^{-1}) and were found to be statistically on par. The tannin content showed a highly significant but negative correlation (-0.81**) with the damage caused by the larvae of FAW (Table 5).

The low tannin content was recorded in case of more damaged inbred lines explicitly in, NAI 207 (1.53 mg g^{-1}), MAI 8 (1.61 mg g^{-1}), MAI 755 (1.69 mg g^{-1}), Z 84 5(1.75 mg g^{-1}), POP 1857 (1.76 mg g^{-1}) and PT 2217 (1.78 mg g^{-1}) and were found to be on par at 60 DAS. A higher tannin content was recorded (4.51 mg g^{-1}) in MAI 224 followed by MAH 14 5 (3.25 mg g^{-1}), PT 1877 (2.83 mg g^{-1}) and MAI 285 (2.68 mg g^{-1}) in which MAI 224 and MAH 14 5 was statistically differed from all other inbred lines whereas PT 1877 and MAI 285 were found to be on par with each other. A decreasing trend of tannin content was observed with increase in susceptibility towards FAW with a negative relation (-0.77**) (Table 5).

Table 1: Influence of nutritional factors of maize inbreds on the incidence of fall armyworm at 30 DAS

Sl. No.	Inbred lines	Category	Damage score	TSS ($mg\ g^{-1}$)	TRS ($mg\ g^{-1}$)	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)	Crude Protein ($mg\ g^{-1}$)
1	MAH 14 5	Least susceptible	1.20	0.79^{cd}	6.93^{def}	$1.94(8.01)^{cdefg}$	$0.62(4.52)^{def}$	$2.91(9.82)^{i}$	13.24^{bcde}
2	V 938 26		1.20	0.41^{a}	3.57^{ab}	$1.26(6.45)^{a}$	$0.34(3.34)^{ab}$	$2.72(9.49)^{ghi}$	10.84^{abcd}
3	MAI 285		1.30	0.42^{a}	6.47^{cde}	$1.23(6.37)^{a}$	$0.41(3.67)^{abc}$	$2.64(9.35)^{ghi}$	10.47^{abc}
4	MAI 210		1.30	0.45^{a}	6.36^{cde}	$1.42(6.84)^{ab}$	$0.35(3.39)^{ab}$	$2.71(9.48)^{ghi}$	9.89^{a}
5	MAI 142		1.40	0.96^{cde}	3.90^{ab}	$1.51(7.06)^{abc}$	$0.39(3.58)^{abc}$	$2.53(9.15)^{defghi}$	12.25abcde
6	MAI 224		1.40	0.95^{cde}	6.36^{cde}	$1.63(7.34)^{abcde}$	$0.39(3.58)^{abc}$	$2.79(9.62)^{hi}$	10.07^{ab}
7	4085 SC		1.50	1.12^{efg}	6.90^{def}	$1.54(7.13)^{abcd}$	$0.41(3.67)^{abc}$	$2.41(8.93)^{bcdefghi}$	11.60abcde
8	POP 1857		1.50	0.50^{ab}	4.77^{abc}	$1.98(8.09)^{cdefg}$	$0.45(3.85)^{abc}$	$2.63(9.33)^{fghi}$	13.02abcde
9	PT 2217		3.20	0.71^{bc}	4.34^{ab}	$1.91(7.95)^{bcdefg}$	$0.49(4.01)^{bcd}$	$2.57(9.23)^{efghi}$	12.54abcde
10	Z 84 5		3.40	0.84^{cd}	3.49^{a}	$1.86(7.84)^{bcdefg}$	$0.53(4.18)^{cde}$	$2.16(8.45)^{abcdefg}$	12.00abcde
11	MAI 249	Moderately susceptible	4.00	1.14efgh	3.83^{ab}	$1.94(8.01)^{cdefg}$	$0.30(3.14)^{a}$	$2.74(9.53)^{ghi}$	11.76abcde
12	NAI 207		4.10	0.80^{cd}	5.34^{bcd}	$2.06(8.25)^{efg}$	$0.63(4.55)^{def}$	$2.43(8.97)^{cdefghi}$	13.00abcde
13	MAI 8		4.20	1.00^{def}	4.85^{abc}	$1.78(7.67)^{bcdef}$	$0.64(4.59)^{def}$	$2.27(8.67)^{abcdefgh}$	12.35abcde
14	MAI 214		4.20	0.81^{cd}	4.90^{abc}	$1.96(8.05)^{cdefg}$	$0.68(4.73)^{efg}$	$1.92(7.97)^{abc}$	12.50abcde
15	MAI 755		4.40	0.92^{cde}	8.52^{fg}	$1.69(7.47)^{abcde}$	$0.61(4.48)^{def}$	$2.04(8.21)^{abcdef}$	11.18abcde
16	MAI 298		5.30	1.22fghi	5.34^{bcd}	$2.21(8.55)^{fg}$	$0.68(4.73)^{efg}$	$1.98(8.09)^{abcde}$	14.20^{e}
17	PT 1877	Highly susceptible	7.00	1.41^{i}	7.90^{efg}	$2.11(8.35)^{efg}$	$0.71(4.83)^{fg}$	$1.76(7.62)^{a}$	13.82^{de}
18	SPS 23		7.10	1.38^{hi}	10.44^{h}	$2.34(8.80)^{g}$	$0.82(5.20)^{g}$	$1.82(7.75)^{ab}$	13.53^{cde}
19	Z 490 24		7.30	1.35^{ghi}	9.39^{gh}	$2.04(8.21)^{defg}$	$0.76(5.00)^{fg}$	$1.97(8.07)^{abcd}$	12.70abcde
SE m ± CD @p=0.05			0.25 0.76	0.03 0.10	0.20 0.59	0.21 0.61	0.13 0.40	0.12 0.36	0.54 1.60

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TSS-Total soluble sugar; TRS-Total reducing sugar.

Table 2: Influence of nutritional factors of maize inbreds on the incidence of fall armyworm at 60 DAS

Sl. No.	Inbred lines	Damage score	TSS ($mg\ g^{-1}$)	TRS ($mg\ g^{-1}$)	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)	Crude protein ($mg\ g^{-1}$)
1	MAH 14 5	0.40	2.70^{abc}	7.90^{abc}	1.81(7.73)	$0.29(3.09)^{bcde}$	$2.47(9.04)^{h}$	15.26^{bcde}
2	MAI 224	0.40	2.07^{a}	6.95^{ab}	1.42(6.84)	$0.20(2.56)^{a}$	$2.43(8.97)^{gh}$	13.68abcde
3	4085 SC	0.70	2.42^{abc}	7.62^{abc}	1.47(6.96)	$0.21(2.63)^{ab}$	$2.16(8.45)^{fgh}$	12.27^{abc}
4	PT 1877	0.80	2.66^{abc}	7.08^{ab}	1.82(7.75)	$0.40(3.63)^{fg}$	$1.43(6.87)^{abcd}$	13.53abcde
5	MAI 285	0.90	2.35^{ab}	7.83^{abc}	1.21(6.32)	$0.28(3.03)^{abcd}$	$1.98(8.09)^{efg}$	12.43^{abc}
6	V 938 26	1.00	2.08^{a}	6.83^{ab}	1.2(6.29)	$0.25(2.87)^{abc}$	$2.04(8.21)^{efg}$	11.24^{a}
7	MAI 249	1.10	2.35^{ab}	7.62^{abc}	1.89(7.90)	$0.24(2.81)^{abc}$	$2.36(8.84)^{gh}$	13.37abcde
8	SPS 23	1.10	2.47^{abc}	7.75^{abc}	1.94(8.01)	$0.41(3.67)^{fg}$	$1.47(6.96)^{abcd}$	11.61^{ab}
9	MAI 214	1.20	2.33^{ab}	7.83^{abc}	1.75(7.60)	$0.37(3.49)^{ef}$	$1.68(7.45)^{abcde}$	11.15^{a}
10	MAI 142	1.20	2.47^{abc}	8.62^{abc}	1.43(6.87)	$0.25(2.87)^{abc}$	$1.74(7.58)^{bcdef}$	12.36^{abc}
11	MAI 210	1.30	2.44^{abc}	8.26^{abc}	1.48(6.99)	$0.21(2.63)^{ab}$	$1.83(7.78)^{def}$	13.64abcde
12	Z 490 24	1.50	2.99^{bc}	9.01^{bc}	1.83(7.78)	$0.43(3.76)^{fg}$	$1.32(6.60)^{ab}$	12.62^{abcd}
13	Z 84 5	1.60	2.62^{abc}	8.42^{abc}	1.64(7.36)	$0.28(3.03)^{abcd}$	$1.73(7.56)^{bcdef}$	13.24abcde
14	MAI 298	1.60	3.08^{c}	8.95^{bc}	1.94(8.01)	$0.36(3.44)^{def}$	$1.27(6.47)^{a}$	14.91abcde
15	PT 2217	1.80	2.73^{abc}	8.67^{abc}	1.83(7.78)	$0.31(3.19)^{cde}$	$1.79(7.69)^{cdef}$	16.37^{de}
16	NAI 207	1.80	2.70^{abc}	8.85^{bc}	2.39(8.89)	$0.42(3.72)^{fg}$	$1.48(6.99)^{abcd}$	15.91^{cde}
17	MAI 755	1.90	2.96^{bc}	6.49^{a}	1.57(7.20)	$0.46(3.89)^{g}$	$1.27(6.47)^{a}$	15.54^{cde}
18	POP 1857	2.20	2.65^{abc}	9.80^{c}	1.89(7.90)	$0.37(3.49)^{ef}$	$1.39(6.77)^{abcd}$	16.64^{e}
19	MAI 8	2.70	2.62^{abc}	9.42^{c}	1.74(7.58)	$0.43(3.76)^{fg}$	$1.34(6.65)^{abc}$	13.32abcde
SE m ± CD @p=0.05		0.07 0.19	0.11 0.33	0.27 0.81	0.30 0.90	0.13 0.40	0.29 0.86	0.46 1.36

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TSS-Total soluble sugar; TRS-Total reducing sugar

Tannins have a prolonged deleterious effect on plant feeding insects and affect the insect growth and development by binding to the proteins which reduces nutrient absorption efficiency. They precipitate proteins which inhibits the digestive enzymes and affect the utilization of vitamins and minerals. Tannins are caustic bitter polyphenols and act as feeding deterrents to many insect pests (Sharma *et al.* 2009) [17]. The present findings are in accordance with Praveen *et al.* (2013) [14] who reported maximum concentrations of total tannins in maize resistant variety, NAC-6004 and minimum in the susceptible variety, CM- 300 at all the growth stages and conferred resistance against *Chilo partellus*.

Total free amino acids (TFA)

The low amount of TFA at 30 DAS was recorded in the moderately susceptible and highly susceptible inbreds namely, MAI 298 (1.41 mg g^{-1}), MAI 214 (1.41 mg g^{-1}), MAI 249 (1.54 mg g^{-1}), MAI 755 (1.60 mg g^{-1}), SPS 23 (1.82 mg g^{-1}) and PT 1877 (1.89 mg g^{-1}) and were found to be statistically on par (Table 3). A high amount of TFA was recorded in the least susceptible lines V 938 26 (6.34 mg g^{-1}) and MAH 14 5 (6.05 mg g^{-1}) and were on par with each other. The TFA showed significant and negative relation (-0.52^{*}) with the damage caused by the FAW larvae.

The minimum TFA content at 60 DAS were recorded in the more damaged lines *viz*., MAI 298 (0.68 mg g^{-1}), MAI 755 (0.71 mg g^{-1}), PT 2217 (0.84 mg g^{-1}) and Z 84 5 (0.85 mg g^{-1}) and were statistically on par with one another. Whereas high amount of TFA was recorded (1.86 mg g^{-1}) in MAH 14 5, followed by MAI 224 (1.75 mg g^{-1}) and PT 1877 (1.57 mg g^{-1}) in which MAH 14 5 and MAI 224 were found to be on par with each other. A highly significant and negative correlation (-0.75^{**}) was recorded between the TFA and fall armyworm damage (Table 5).

The outcome of the present study was in accordance with the findings of Chen *et al.*, (2009) [5] where they reported the greater amino acid levels in the FAW resistant genotypes FAW7050 and Mp708 than the susceptible one, Ab24E.

Peroxidases (POX)

At 30 DAS, a low amount of peroxidases enzymes were recorded in case of highly susceptible inbred, Z 490 24 (1.39 min^{-1} g^{-1}) and statistically differs from other inbreds, followed by PT 1877 (1.78 min^{-1} g^{-1}). In case of moderately susceptible inbred lines, the peroxidases activity varied from 2.12 to 2.81 min^{-1} g^{-1}. A high peroxidases activity of 3.62 min^{-1} g^{-1} was observed in case of, V 938 26 followed by MAI 285 (3.45 min^{-1} g^{-1}), MAI 210 (3.43 min^{-1} g^{-1}), MAI 224 (3.42 min^{-1} g^{-1}) and MAH 14-5 (3.38 min^{-1} g^{-1}) and were statistically on par. Significant but negative correlation (-0.90^{**}) observed between the damage ratings induced by the larvae and peroxidase activity (Table 5).

At 60 DAS, the peroxidases activity was low (2.00 min^{-1} g^{-1}) in the Z 490 24, tracked by MAI 755 (2.38 min^{-1} g^{-1}) and NAI 207 (2.45 min^{-1} g^{-1}) and were found to be statistically similar (Table 4). However maximum peroxidases activity was recorded in the lines namely, V 938 26 (3.62 min^{-1} g^{-1}), MAH 14 5 (3.59 min^{-1} g^{-1}) and MAI 224 (3.45 min^{-1} g^{-1}) and found to be statistically on par and the FAW damage recorded in these lines were comparatively less. The relation between peroxidase activity and damage induced by the FAW larvae was highly significant and negative (-0.90^{**}).

Peroxidase catalyses lignin synthesis and thereby protects the plant tissues when affected by herbivores and microorganisms (Han *et al.* 2009) [7]. The outcome of the present study were in line with findings of Chen *et al.*, (2009) [5] who reported that constitutive peroxidase activity of fall armyworm resistant genotype Mp708 was higher than the susceptible genotype Ab24E and local control FAW7050. Also, they revealed that *S. frugiperda* damage increased peroxidase activity of susceptible genotype Ab24E which helped the plant to overcome the oxidative stress.

Table 3: Influence of secondary metabolites and defensive enzyme on the infestation of fall armyworm at 30 DAS

Sl. No.	Inbred lines	Category	Damage score	Total phenols (mg g^{-1})	Total tannins (mg g^{-1})	TFA (mg g^{-1})	Peroxidase's activity (min^{-1} g^{-1})
1	MAH 14 5	Least susceptible	1.20	1.95g	2.64e	6.05e	3.38ghi
2	V 938 26		1.20	1.77g	2.71e	6.34e	3.62i
3	MAI 285		1.30	1.71g	2.83e	3.91d	3.45hi
4	MAI 210		1.30	0.92def	1.80fg	2.85c	3.43hi
5	MAI 142		1.40	0.99ef	2.76e	2.22bc	2.74cdefg
6	MAI 224		1.40	1.04f	2.58e	2.45bc	3.42ghi
7	4085 SC		1.50	1.04f	1.90d	1.94ab	3.09fghi
8	POP 1857		1.50	0.72bcde	1.51bcd	1.88ab	2.80defgh
9	PT 2217		3.20	0.63abc	1.80cd	1.78ab	2.47cdef
10	Z 84 5		3.40	0.58abc	1.47abcd	1.85ab	2.40bcde
11	MAI 249	Moderately susceptible	4.00	0.81cdef	1.58bcd	1.54a	2.81efgh
12	NAI 207		4.10	0.75bcde	1.39abc	1.78ab	2.31bcde
13	MAI 8		4.20	0.72bcde	1.61bcd	1.86ab	2.42bcdef
14	MAI 214		4.20	0.63abc	1.47abcd	1.41a	2.31bcde
15	MAI 755		4.40	0.69abcd	1.76cd	1.60a	2.12bcd
16	MAI 298		5.30	0.43a	1.37abc	1.41a	2.38bcde
17	PT 1877	Highly susceptible	7.00	0.63abc	1.25ab	1.89ab	1.78ab
18	SPS 23		7.10	0.56abc	1.02a	1.82ab	2.09bc
19	Z 490 24		7.30	0.51ab	1.14ab	2.13abc	1.39a
SE m ±			0.25	0.04	0.10	0.07	0.12
CD @p=0.05			0.76	0.13	0.30	0.20	0.35

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TFA-Total free amino acid.

Table 4: Influence of secondary metabolites and defensive enzyme on the infestation of fall armyworm at 60 DAS

Sl. No.	Inbred lines	Damage score	Total phenols (mg g^{-1})	Total tannins (mg g^{-1})	TFA (mg g^{-1})	Pe Peroxidases activity (min^{-1} g^{-1})
1	MAH 14 5	0.40	1.45^{abc}	3.25^{f}	1.86^{i}	3.59^{e}
2	MAI 224	0.40	2.13^{d}	4.51^{g}	1.75^{hi}	3.45^{de}
3	4085 SC	0.70	2.06^{d}	2.19bcde	1.38^{efg}	3.32^{cde}
4	PT 1877	0.80	1.41^{abc}	2.83^{ef}	1.57^{ghi}	2.64abcd
5	MAI 285	0.90	2.12^{d}	2.68^{ef}	1.10^{cde}	3.41^{cde}
6	V 938 26	1.00	1.16^{ab}	2.58^{de}	1.43^{fg}	3.62^{e}
7	MAI 249	1.10	1.52^{c}	2.29^{cde}	1.20^{def}	3.30^{cde}
8	SPS 23	1.10	1.51^{bc}	2.25bcde	1.52^{gh}	2.61^{abc}
9	MAI 214	1.20	1.52^{c}	1.98abcd	1.12^{cde}	2.91bcde
10	MAI 142	1.20	1.31^{abc}	1.97abcd	0.95abcd	3.09bcde
11	MAI 210	1.30	1.23^{abc}	2.83^{ef}	0.99^{bcd}	3.45^{de}
12	Z 490 24	1.50	1.24^{abc}	1.95abcd	1.43^{fg}	2.00^{a}
13	Z 84 5	1.60	1.15^{a}	1.75^{abc}	0.85^{abc}	2.82abcde
14	MAI 298	1.60	1.26^{abc}	1.81^{abc}	0.68^{a}	2.87bcde
15	PT 2217	1.80	1.28^{abc}	1.78^{abc}	0.84^{abc}	3.08bcde
16	NAI 207	1.80	1.16^{ab}	1.53^{a}	1.01^{bcd}	2.45^{ab}
17	MAI 755	1.90	1.37abcd	1.69^{abc}	0.71^{ab}	2.38^{ab}
18	POP 1857	2.20	1.19^{abc}	1.76^{abc}	0.89^{abc}	3.08bcde
19	MAI 8	2.70	1.17^{abc}	1.61^{ab}	0.92abcd	2.90bcde
SE m ± CD @p=0.05		0.07 0.19	0.06 0.19	0.10 0.31	0.04 0.12	0.15 0.44

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TFA-Total free amino acid.

Table 5: Impact of biochemical constituents of maize inbreds on resistance and susceptibility to fall armyworm

		Correlation coefficient (r) value	
Sl. No.	Category	Damage score at 30 DAS	Damage score at 60 DAS
1	TSS	0.77**	0.50*
2	TRS	0.52*	0.64**
3	Nitrogen	0.75**	0.37
4	Phosphorus	0.81**	0.59**
5	Potassium	-0.86**	-0.73**
6	Crude protein	0.61**	0.40
7	Phenols	-0.69**	-0.65**
8	Tannins	-0.81**	-0.77**
9	TFA	-0.52*	-0.75**
10	Peroxidases	-0.90**	-0.47*
11	Coefficient of determination (R^2)	0.95	0.94

*Correlation is significant at 5% (p = 0.05) level; **correlation is significant at 1% (p = 0.01) level; N= 19; r = correlation coefficient; R2 = coefficient of determination.

Biochemical parameters in cob samples

Total soluble sugars (TSS)

The low amount of TSS were recorded in the grains of moderately susceptible line SPS 23 (2.24 mg g^{-1}), followed by the least susceptible lines namely, MAI 8 (2.27 mg g^{-1}), MAI 285 (2.33 mg g^{-1}), MAI 224 (2.40 mg g^{-1}), V 938 26 (2.45 mg g^{-1}) and MAI 142 (2.46 mg g^{-1}) and were found to be statistically on par. A higher TSS content were recorded in case of 4085 SC (3.22) followed by Z 84 5 (3.10 mg g^{-1}) which belongs to the moderately susceptible category. While the highly susceptible inbreds POP 1857 and PT 2217 recorded the TSS content of 2.91 and 2.86 mg g^{-1} respectively, which was on par with each other (Table 6). Comparatively lower amount of TSS recorded in case of least susceptible lines, while in case of moderately and highly susceptible lines, the TSS content was higher. This showed a significant positive relation (0.49*) between the damage induced by the FAW larvae and TSS content (Table 8).

The results of present study were in line with the findings of Garcia-lara *et al.* (2004) [6] as they reported that greater amount of sugars in the maize weevil susceptible genotypes whereas in the resistant genotypes the sugar content recorded was minimum.

Total reducing sugars (TRS)

The minimum TRS content was recorded in the kernels of least susceptible inbred lines namely, PT 1877 (5.42 mg g^{-1}), MAI 8 (5.44 mg g^{-1}), Z 490-24 (5.54 mg g^{-1}), MAI 224 (5.54 mg g^{-1}), MAI 298 (5.70 mg g^{-1}), MAI 285 (5.83 mg g^{-1}) and MAI 142 (5.98 mg g^{-1}) and were found to be statistically on par with one another (Table 6). Whereas in case of moderately susceptible inbreds, the TRS content varied from 6.03 to 6.83 mg g^{-1}. Comparatively higher TRS content were recorded in case of highly susceptible lines and showed an increasing trend of TRS with susceptibility towards FAW. The Maximum The inbred lines were statistically on par with each other.

Nitrogen

The low nitrogen content was recorded in the grains of inbred lines belonging to least susceptible category namely, Z 490 24 (1.74%), MAI 298 (1.81%), MAI 224 (1.82%), V 938 26 (1.82%) and MAI 8 (1.84%) and were found to be on par with one another. Whereas, nitrogen content varied from 1.86 to 2.88 per cent in case of moderately susceptible category (Table 6). The maximum nitrogen content recorded in the grains of inbred lines that include PT 2217 (2.98%) trailed by MAI 249 (2.94%) and POP 1857 (2.91%) and were statistically similar. There is a significant positive relation (0.78**) between nitrogen content and cob damage by fall armyworm larvae (Table 8).

Phosphorous

Among the inbreds, the phosphorous content in the grains, varied significantly between 0.34 to 0.71 per cent. A low amount of phosphorus was recorded with 0.34 per cent in case of Z 490 24, followed by V 938 26 (0.35%), MAI 142

(0.36%), MAI 224 (0.37%), MAI 8 (0.41%) and MAI 298 (0.41%) and were statistically similar with one another. In case of moderately susceptible category, among the inbreds the phosphorus content varied from 0.43 to 0.68 per cent (Table 6). A higher phosphorus content was recorded in the highly susceptible and moderately susceptible inbred lines namely, PT 2217 (0.71%), MAI 249 (0.69%), Z 84 5 (0.68%), 4085 SC (0.67%) and POP 1857 (0.65%), however these lines were on par with one another.

Potassium

A low amount of potassium was recorded in the highly susceptible and moderately susceptible lines *viz*., MAI 249 (1.84%), Z 84 5 (1.86%), PT 2217 (1.92%), POP 1857 (1.94%), 4085 SC (1.98%) and NAI 207 (2.16%) and were found to be statistically on par (Table 6). The higher amount of potassium was recorded (3.04%) in the genotype, MAH 14 5 followed by PT 1877 (2.98), V 938 26 (2.91), MAI 8 (2.88), Z 490 24 (2.84), MAI 298 (2.74) and MAI 210 (2.64) and were found to be statistically similar. A highly significant but negative correlation (-0.92**) was found between the potassium content and ear and kernel damage induced by the FAW larvae (Table 8).

Crude protein

A significantly low crude protein content (14.15 mg g^{-1}) was observed in MAI 224, followed by Z 490 24 (14.27 mg g^{-1}), MAI 214 (14.36 mg g^{-1}), V 938 26 (14.65 mg g^{-1}), MAI 8 (15.31 mg g^{-1}), MAI 755 (15.37 mg g^{-1}) and NAI 207 (15.48 mg g^{-1}) where the inbreds belonged to least and moderately susceptible category. However, they were statistically similar with one another (Table 6). Comparatively high amount of crude protein was observed in the highly susceptible inbreds specifically, PT 2217 (19.43 mg g^{-1}), POP 1857 (19.26 mg g^{-1}) and MAI 249 (18.53 mg g^{-1}) were found to be statistically on par. A significant positive relation (0.52*) was recorded between the crude protein and cob damage caused by FAW larvae.
Similar results were observed by Ngom *et al.* (2020) as they reported non- significant positive correlation between the protein content in the maize grains and susceptibility of various genotypes against the larger grain borer, *Prostephanus truncatus* (Horn).

Table 6: Influence of nutritional factors in the grains of maize inbreds on the fall armyworm incidence

Sl. No.	Inbred lines	Category	Ear and kernel damage score	TSS (mg g^{-1})	TRS (mg g^{-1})	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)	Crude protein (mg g^{-1})
1	MAI 8	Least susceptible	1.10	2.27^{ab}	5.44^{a}	1.84(7.80)^{ab}	0.41(3.67)^{abc}	2.88(9.77)^{fg}	15.31^{ab}
2	MAH 14 5		1.10	2.72abcd	6.88^{ab}	2.64(9.35)^{cd}	0.61(4.48)^{def}	3.04(10.04)^{g}	18.62^{ab}
3	V 938 26		1.10	2.45^{abc}	6.65^{ab}	1.82(7.75)^{a}	0.35(3.39)^{ab}	2.91(9.82)^{g}	14.65^{a}
4	Z 490 24		1.10	2.52^{abc}	5.54^{a}	1.74(7.58)^{a}	0.34(3.34)^{a}	2.84(9.70)^{fg}	14.27^{a}
5	PT 1877		1.20	2.74abcd	5.42^{a}	1.97(8.07)^{ab}	0.46(3.89)^{abc}	2.98(9.94)^{g}	16.27^{ab}
6	MAI 298		1.30	2.62abcd	5.70^{ab}	1.81(7.73)^{a}	0.41(3.67)^{abc}	2.74(9.53)^{efg}	15.75^{ab}
7	MAI 142		1.30	2.46^{abc}	5.98^{ab}	1.93(7.99)^{ab}	0.36(3.44)^{ab}	2.62(9.32)^{defg}	16.73^{ab}
8	MAI 224		1.40	2.40^{ab}	5.54^{a}	1.82(7.75)^{a}	0.37(3.49)^{ab}	2.78(9.60)^{efg}	14.15^{a}
9	MAI 285		2.10	2.33^{ab}	5.83^{ab}	2.09(8.31)^{abc}	0.48(3.97)^{bcd}	2.53(9.15)^{bcdefg}	17.62^{ab}
10	MAI 210		2.20	2.83abcd	7.08^{ab}	1.94(8.01)^{ab}	0.46(3.89)^{abc}	2.64(9.35)^{efg}	16.24^{ab}
11	SPS 23	Moderately susceptible	4.30	2.24^{a}	6.03^{ab}	1.86(7.84)^{ab}	0.54(4.21)^{cde}	2.58(9.24)^{cdefg}	15.83^{ab}
12	MAI 214		4.70	2.53^{abc}	6.83^{ab}	1.98(8.09)^{ab}	0.43(3.76)^{abc}	2.63(9.33)^{defg}	14.36^{a}
13	MAI 755		5.10	2.52^{abc}	6.11^{ab}	2.04(8.21)^{abc}	0.62(4.52)^{ef}	2.24(8.61)^{abcdef}	15.37^{ab}
14	NAI 207		5.30	2.62abcd	6.72^{ab}	2.46(9.03)^{bcd}	0.54(4.21)^{cde}	2.16(8.45)^{abcde}	15.48^{ab}
15	4085 SC		5.40	3.22^{d}	6.80^{ab}	2.74(9.53)^{d}	0.67(4.70)^{ef}	1.98(8.09)^{abcd}	17.32^{ab}
16	Z 84 5		5.70	3.10^{cd}	6.36^{ab}	2.88(9.77)^{d}	0.68(4.73)^{f}	1.86(7.84)^{a}	18.34^{ab}
17	POP 1857	Highly susceptible	7.00	2.91^{bcd}	7.11^{ab}	2.91(9.82)^{d}	0.65(4.63)^{ef}	1.94(8.01)^{abc}	19.26^{b}
18	PT 2217		7.30	2.86abcd	6.16^{ab}	2.98(9.94)^{d}	0.71(4.83)^{f}	1.92(7.97)^{ab}	19.43^{b}
19	MAI 249		7.60	2.68abcd	7.39^{b}	2.94(9.87)^{d}	0.69(4.77)^{f}	1.84(7.80)^{a}	18.53^{ab}
SE m ±			0.15	0.10	0.23	0.26	0.17	0.13	0.59
CD @p=0.05			0.45	0.31	0.67	0.76	0.50	0.37	1.76

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TSS-Total soluble sugar; TRS-Total reducing sugar

Secondary metabolites in cob samples

Total phenols

A minimum phenol content was recorded in the grains of highly susceptible inbred lines *viz*., MAI 249 (0.45 mg g^{-1}), PT 2217 (0.51 mg g^{-1}), POP 1857 (0.52 mg g^{-1}) and were statistically on par (Table 7). In the moderately susceptible inbreds, the phenol content varied from 0.54 to 0.81 mg g^{-1}. Statistically, higher phenol content was recorded in case of least susceptible lines specifically, Z 490 24 (0.92 mg g^{-1}), MAH 14 5 (0.91 mg g^{-1}), PT 1877 (0.87 mg g^{-1}), V 938 26 (0.86 mg g^{-1}) and MAI 8 (0.85 mg g^{-1}) and were found to be on par with one another. The relation between the cob damage caused by the fall armyworm and phenol content was found to be negative and highly significant (-0.73**).

The outcome of the present study was in line with findings of Ngom *et al.* (2020) who reported significant but negative correlation between the phenols and grain damage caused by the larger grain borer, *Prostephanus truncatus* (Horn).

Tannins

The low amount of tannins was recorded in the grains of highly susceptible as well as in the moderately susceptible inbreds namely, PT 2217 (0.69 mg g^{-1}), 4085 SC (0.73 mg g^{-1}), MAI 249 (0.78 mg g^{-1}), Z 84 5 (0.81 mg g^{-1}) and NAI 207 (0.85 mg g^{-1}) and were found to be statistically at par (Table 7). Comparatively high amount of tannins were recorded in the grains harvested from least susceptible inbred lines. The maximum tannin content recorded (1.88

mg g^{-1}) was in MAH 14 5, followed by PT 1877 (1.80), MAI 142 (1.69 mg g^{-1}) and MAI 298 (1.58 mg g^{-1}) and were MAH 14 5 and PT 1877 found to be on par with each other, while MAI 142 and MAI 298 were statistically similar. A significant and negative relation (-0.51^{*}) was found between the tannin content and cob damage caused by the FAW larvae (Table 8).

Total free amino acids

Among the tested lines, low amounts of TFA were recorded in the grains of moderately susceptible and highly susceptible inbreds including, PT 2217 (0.90 mg g^{-1}), MAI 249 (0.99 mg g^{-1}), MAI 214 (0.99 mg g^{-1}), Z 84 5 (1.10 mg g^{-1}), POP 1857 (1.12 mg g^{-1}) and MAI 755 (1.16 mg g^{-1}) and were found to be statistically on par. The high TFA content was recorded in the least susceptible lines *viz.*, MAH 14 5 (3.23 mg g^{-1}), MAI 8 (2.50 mg g^{-1}) and V 938 26 (2.20 mg g^{-1}) and were statistically differing from one another. A highly significant but negative relation (-0.70^{**}) was observed between the cob damage and TFA content (Table 8).

Praveen *et al*. (2013) [14] revealed that the grains of resistant group recorded higher amount of Starch, total protein and free amino acid compared to the susceptible ones after the infestation by maize stem borer *Chilo partellus*. In the present study it was found that greater amount of TFA was recorded in the least susceptible lines which imparted resistance against FAW.

Peroxidases (POX)

The low amount of peroxidase enzymes was recorded in the kernels of highly susceptible as well as moderately susceptible inbred lines specifically in PT 2217 (0.80 min^{-1} g^{-1}), MAI 249 (0.82 min^{-1} g^{-1}), 4085 SC (0.82 min^{-1} g^{-1}), Z 84 5 (0.94 min^{-1} g^{-1}) and POP 1857 (0.98) and were found to be on par (Table 6). The high amount of peroxidase activity was recorded in case of least susceptible lines namely, MAH 14 5 (2.30), V 938-26 (2.16 min^{-1} g^{-1}), MAI 8 (2.14 min^{-1} g^{-1}) and MAI 142 (2.04 min^{-1} g^{-1}) and were found to be statistically similar except MAI 142. The peroxidases activity showed a highly significant but negative correlation (-0.88^{**}) with the susceptibility of the genotypes.

A similar results were observed by Garcia-lara *et al.* (2004) [6] where they reported that significant correlations were found between endosperm POD activity and maize weevil resistance (r = 0.89, p<0.001) which supported the present study.

Table 7: Influence of secondary metabolites and defensive enzyme in grains of maize inbreds on the fall armyworm incidence

Sl. No.	Inbred lines	Category	Ear and kernel damage score	Total phenols (mg g^{-1})	Total tannins (mg g^{-1})	TFA (mg g^{-1})	Peroxidase's activity (min^{-1} g^{-1})
1	MAI 8	Least susceptible	1.10	0.85^{de}	0.95abcd	2.50^{f}	2.14^{ij}
2	MAH 14 5		1.10	0.91^{de}	1.88^{j}	3.23^{g}	2.30^{j}
3	V 938 26		1.10	0.86^{de}	1.31^{fgh}	2.20^{def}	2.16^{ij}
4	Z 490 24		1.10	0.92^{e}	1.25defg	1.80^{bcd}	1.42cdef
5	PT 1877		1.20	0.87^{de}	1.80^{ij}	1.85bcde	1.97ghij
6	MAI 298		1.30	0.59^{ab}	1.58^{hij}	1.72^{bc}	1.81fghi
7	MAI 142		1.30	0.74bcde	1.69^{ij}	1.64^{b}	2.04^{hij}
8	MAI 224		1.40	0.74bcde	1.12cdef	1.80^{bcd}	1.66defgh
9	MAI 285		2.10	0.73^{bcd}	0.90^{abc}	1.63^{b}	1.72efgh
10	MAI 210		2.20	0.59^{ab}	0.98abcde	2.08cdef	1.39^{cde}
11	SPS 23	Moderately susceptible	4.30	0.64^{abc}	1.54^{ghi}	1.92bcde	1.31^{bcd}
12	MAI 214		4.70	0.58^{ab}	1.07bcdef	0.99^{a}	1.61cdefg
13	MAI 755		5.10	0.54^{a}	1.27defgh	1.16^{a}	1.24^{bc}
14	NAI 207		5.30	0.74^{bcd}	0.85^{abc}	1.71^{bc}	1.30^{bcd}
15	4085 SC		5.40	0.81^{cde}	0.73^{a}	2.25^{ef}	0.82^{a}
16	Z 84 5		5.70	0.61^{ab}	0.81^{abc}	1.10^{a}	0.94^{ab}
17	POP 1857	Highly susceptible	7.00	0.52^{a}	1.29efgh	1.12^{a}	0.98^{ab}
18	PT 2217		7.30	0.51^{a}	0.69^{a}	0.90^{a}	0.80^{a}
19	MAI 249		7.60	0.45^{a}	0.78^{ab}	0.99^{a}	0.82^{a}
SE m ±			0.15	0.03	0.06	0.05	0.09
CD @p=0.05			0.45	0.10	0.17	0.16	0.26

Values in the column followed by common letters are non-significant at p = 0.05 as per Tukey's HSD; TFA-Total free amino acid.

Table 8: Impact of biochemical constituents in cob and kernels of maize genotypes on fall armyworm incidence

Correlation coefficient (r) value		
Sl. No.	**Biochemical traits**	**Ear and kernel damage score**
1	TSS	0.49*
2	TRS	0.57*
3	Nitrogen	0.78**
4	Phosphorus	0.83**
5	Potassium	-0.92**
6	Crude protein	0.52*
7	Phenols	-0.73**
8	Tannins	-0.51*
9	TFA	-0.70**
10	Peroxidases	-0.88**
11	Coefficient of determination (R^2)	0.99

*Correlation is significant at 5% (p = 0.05) level; **correlation is significant at 1% (p = 0.01) level; N= 19; r = correlation coefficient; R2 = coefficient of determination

Conclusion

Among the biochemical constituents in 18 selected maize inbreds, a higher amount of TSS, TRS, nitrogen, phosphorus and crude protein was recorded in the inbred lines which comparatively showed more damage by FAW. A decreasing trend in the potassium content was recorded with increasing susceptibility of inbreds against FAW. Secondary metabolites, a high amount of total phenols, tannin content, TFA and peroxidases activity was recorded in the least susceptible inbreds.

References

1. Ali A, Khalil N, Abbas M, Tariq R, Zia-ullah HD. Plant traits as resistance influencing factors in maize against *Chilo partellus* (Swinhoe). J Entomol Zool Stud. 2015;3(2):246-250.
2. Bradford MM. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal Biochem. 1976;72:248-254.
3. Bray HG, Thorpe WV. Analysis of phenolic compounds of interest in metabolism. Meth Biochem Anal. 1954;1:27-52.
4. Caretto S, Linsalata V, Colella G, Mita G, Lattanzio V. Carbon fluxes between primary metabolism and phenolic pathway in plant tissues under stress. Int J Mol Sci. 2015;16(11):26378-26394.
5. Chen Y, Ni X, Buntin GD. Physiological, nutritional, and biochemical bases of corn resistance to foliage-feeding fall armyworm. J Chem Ecol. 2009;35(3):297-306.
6. García-Lara S, Bergvinson DJ, Burt AJ, Ramputh AI, Díaz-Pontones DM, Arnason JT. The role of pericarp cell wall components in maize weevil resistance. Crop Sci. 2004;44(5):1546-1552.
7. Han Y, Wang Y, Yang XQ, Huang Y, Zhao X. Constitutive and induced resistance in aphid-resistant and aphid-susceptible cultivars of wheat. J Chem Ecol. 2009;35:176-182.
8. Hartee EF. Modern methods of plant analysis. 1st ed. New Delhi: CBS Publishers and Distributors; c1955. p. 106-116.
9. Kabre GB, Ghorpade SA. Susceptibility to maize stem borer, *Chilo partellus* (Swinhoe), in relation to sugars, proteins, and free amino acids content of maize germplasm and F1 hybrids. J Insect Sci. 1999;12(1):37-40.
10. Kalleshwaraswamy CM, Asokan R, Swamy HM, Maruthi MS, Pavithra HB, Hegbe K, *et al*. First report of the fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Indian J Entomol. 2018;80(3):540-43.
11. Lokesh, Mehla JC. Study on morphological and biochemical features associated with maize (*Zea mays* L.) resistance against C. partellus. Int J Pure App Biosci. 2017;5(4):1011-1021.
12. Moor S, Stein WH. Photometric ninhydrin method for use in the chromatography of amino acids. J Biol Chem. 1948;176:367-388.
13. Piper CS. Soil and plant analysis. New York: Interscience Publishers; c1966. p. 368.
14. Praveen HD, Ugalat J, Singh H. Biochemical changes during crop growth period of resistant and susceptible varieties of maize against stem borer. Environ Ecol. 2013;31(4):1621-26.
15. Rasool I, Wani AR, Nisar M, Dar ZA, Nehru RK, Hussain B. Antixenosis and antibiosis as a resistance mechanism to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in some maize genotypes. J Entomol Zool Stud. 2017;5(2):22-7.
16. Santiago R, Malvar RA, Baamonde MD, Revilla P, Souto XC. Free phenols in maize pith and their relationship with resistance to *Sesamia nonagrioides* (Lepidoptera: Noctuidae) attack. J Econ Entomol. 2005;98(9):1349-56.
17. Sharma HC, Sujana G, Rao DM. Morphological and chemical components of resistance to pod borer, Helicoverpa armigera, in wild relatives of pigeon pea. Arthropod Plant Interact. 2009;3(3):151-61.
18. Sharma VK, Chatterji SM. Studies on some chemical constituents in relation to differential susceptibility of some maize germplasm to *Chilo zonellus* (Swinhoe). Indian J Entomol. 1971;33(4):419-424.
19. Somogyi M. Estimation of sugars by colorimetric method. J Biol Chem. 1952;200:245-250.
20. Wang M, Zheng Q, Shen Q, Guo S. The critical role of potassium in plant stress response. Int J Mol Sci. 2013;14(4):7370-7390.