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Influence of macro and micro nutrients on the incidence of fall armyworm, *Spodoptera frugiperda*infesting maize hybrids

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Abstract
A research study was conducted on the role of nutritional components in inducing resistance against fall armyworm, *Spodoptera frugiperda* in maize. Nutrition encompasses the essential compounds required by organisms to support growth, maintain tissues, facilitate reproduction, and sustain vital functions. These elements also play a role in determining an organism's vulnerability or resistance to pests. Nine elements were analysed to know their resistance mechanism. The nutrient components like nitrogen, phosphorous, magnesium and sulphur may influence the attack of fall armyworm with greater damage, whereas, potassium, calcium, zinc, manganese and iron may induce resistance against fall armyworm. Among the nutrients analysed in highly susceptible hybrids *viz.,* JHS 666, MAH 21-577 and ADV 9293, the macronutrients like nitrogen, phosphorous, magnesium and sulphur were found in higher amounts and nitrogen (r = 0.941**), phosphorous (r = 0.901**), magnesium (r = 0.874**) and sulphur (r = 0.799*) showed positive correlation with the incidence of fall armyworm. In contrast, potassium and calcium were found higher in least susceptible hybrids *viz.,* JP 2007, MAH 20-40 and PAC 741 where potassium (r = -0.810**) and calcium (r = -0.837*) showed negative correlation with the incidence of fall armyworm. The micronutrients like zinc, manganese and iron were higher in least susceptible hybrids *viz.,* JP 2007, MAH 20-40 and PAC 741 where zinc (r = -0.774**), manganese (r = -0.845**) and iron (r = -0.831**) showed negative correlation with the incidence of fall armyworm.

Keywords: Fall armyworm, *Spodoptera frugiperda*, maize, positive correlation, negative correlation

Introduction
In India, maize (*Zea mays* L.) is the third most important food crops after rice and wheat.Maize is known as "Queen of cereals" as it possesses the high yielding capacity and also, it possesses great genetic diversity compare to the other crops, because of this, it can be cultivated under different agro-ecological zones. Maize faces biotic stresses primarily from weeds, insects, and diseases. Over 250 insect species have been documented to attack maize, with significant ones including stemborers like *Chilo partellus* and *Sesamiainferens*, sorghum shoot fly *Atherigona* spp., and the fall armyworm *Spodoptera frugiperda*. Notably, *Chilo partellus* and *Sesamiainferens* were responsible for a 35% yield loss (Pradhan 1969) [11]. 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), *Spodoptera frugiperda* (J. E. Smith.) responsible for causing significant yield reduction in maize crop.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. This present investigation aims at studying the macro and micro-nutrients associated with resistance in maize hybrids against fall armyworm.

Materials and Methods
Screening of maize hybrids
A total number of 30 hybrids were screened against FAW in Zonal Agricultural Research Station, V. C. Farm, Mandya.

The experiment was laid down by using Randomized Block Design (RBD) during *rabi* 2022. The hybrids used for screening were:MAH21-581, MAH21-596, MAH21-592, GK 3122, MAH 19-2, NAH 2049-II, NAH 1137, Byrava Super, MAH 4271, GK 3264, MAH21-627, KMH 517, MAH 15-84, MAH 14-5, MAH 20-40, NAH 2049-I, MAH21-616, TOP 28, MAH 14-138, ADV 9293, PAC 741, Apsa 91, JHS 666, MAH21-588, MAH21-577, MAH21-580, MAH21-585, JP 2007, MAH21-548, KMH 244. The experimental plot was applied with recommended dose of fertilizer *i.e.*, 100, 75, 40 kg ha^{-1} at the time of sowing and split application of 50 kg ha^{-1} of nitrogen was applied at 30 DAS. Later on, based on leaf damage score the hybrids were grouped into least susceptible, moderately susceptible and highly susceptible categories.

Nutritional components

The plant leaf samples were collected from selected 11 hybrids *i.e.,*three hybrids belonging to least susceptible category namely, JP 2007 (1.23), MAH-20-40 (1.28), PAC 741 (2.98), four hybrids belonging to moderately susceptible category namely, Apsa 91(4.18), GK 3122(4.45), MAH-19-2 (4.75), MAH 21-580 (6.38) and three hybrids belonging to highly susceptible category namely, JHS 666 (7.05), MAH 21-577 (7.05), ADV 9293 (7.10) along with standard check MAH-14-5 (3.15) and analysed for nutritional elements like N, P, K, Ca, Mg, S, Zn, Mn and Fe. The leaf samples were collected at 30 and 60 DAS for analysis of different nutrient components. The nutrient content in each hybrid was correlated with the leaf damage caused by FAW. The samples of leaf were dried at 35 ℃ in hot air oven for 24 to 48 hrs. The dried samples were ground using mixer grinder. The powdered leaf samples were stored in plastic covers until analysis. The nutrient analysis was done in the department of Soil Science and Agricultural Chemistry, College of Agriculture, Mandya. Nitrogen, phosphorous and potassium were analyzed using the standard procedure given by Piper, 1966 [10]. Whereas, other elements like calcium, magnesium, sulphur, zinc, manganese and iron were analyzed using the standard procedure given by Page *et al.*, 1982 [9].

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 (Gomez and Gomez, 1984; Hoshmand, 1988) [3, 5] and means were separated by Tukey's HSD (Tukey, 1965) [16]. The correlation studies were done with mean leaf damage score upto 60 DAS and nutrient content using statistical analysis program software (SPSS).

Results and discussion

Nitrogen

At 30 DAS, nitrogen content was higher in highly susceptible hybrids, ADV 9293 had 2.14% followed by JHS 666 (2.11%) and MAH 21-577 (2.07%). Whereas, lower nitrogen was recorded in least susceptible hybrid, JP 2007 (1.34%) (Table 1).At 60 DAS, the nitrogen content was found to be high in highly susceptible hybrids *viz.*, ADV 9293 (2.35%) followed by MAH 21-577 (2.34%) and JHS 666 (2.20%). Among the moderately susceptible hybrids, the nitrogen content was found to be 1.73, 1.80, 1.88 1.90 percent in GK 3122, MAH-19-2, Apsa 91 and MAH 21-580, respectively (Table 2). The correlation studies reveal that nitrogen content is positively correlated with the leaf damage caused by fall armyworm (r = 0.941**) (Table 3).

The key enzymes of phenol metabolism, the concentration of phenolics, and the deposition of lignin may be reduced during a high supply of nitrogen. And also decrease the concentration of silicon in plants. The various biochemical changes, together with the increase in the concentration of low molecular weight organic nitrogenous compounds, are the main factors responsible for the close correlation between nitrogen supply and susceptibility. This effect of high nitrogen supply is further enhanced by high membrane permeability induced by boron, calcium, and zinc deficiency (which causes increased membrane permeability) and potassium deficiency (which impairs polymer synthesis) (Huber *et al.*, 2012) [6]. Similar results were obtained by Rao and Parwar (2002) [12], who reported that low nitrogen was noticed in resistant varieties as compared to susceptible ones against *Chilo partellus* in maize. Arabjafari and Jalali (2007) [2] revealed that high percentage of nitrogen in the susceptible variety of maize to *Chilo partellus*. Sharma and Chatterji (1971) [14] also reported that susceptible germplasm had higher nitrogen content compared to resistant ones against *Chilo zonellus* in maize. In other similar studies, Ali *et al.*, 2015 [1] reported that positive and significant correlation between nitrogen and infestation by the *Chilo partellus* (Swinhoe). The susceptible genotype com 6625 recorded maximum nitrogen content (2.80%), while the resistant genotype FH 949 recorded lower amount of nitrogen (1.77%) content.

Phosphorous

At 30 DAS, the phosphorous content was found to be high in highly susceptible hybrids *viz.*, JHS 666 (0.32%), MAH 21-577 (0.34%) and ADV 9293 (0.37%). The phosphorous content in least susceptible hybrids *viz.*, JP 2007 (0.21%), MAH-20-40 (0.20%) and PAC 741 (0.20%) was found to be on par with standard check, MAH-14-5 (0.20%) (Table 1). At 60 DAS, the phosphorus content was found to be high in highly susceptible hybrids *viz.*,JHS 666 (0.48%), MAH 21-577 (0.52%) and ADV 9293(0.54%) and low phosphorous content was recorded in least susceptible hybrids, JP 2007 (0.21%), MAH-20-40 (0.23%) and PAC 741 (0.30%)(Table 2). An increasing trend of phosphorus in tested maize hybrids showed a significant positive impact on per cent leaf damage due to fall armyworm (r = 0.901**)(Table 3).

The results obtained are in conformity with Shah 2017[13], who reported that, higher levels of phosphorous are associated with higher incidence of insect pests. The results obtained in the present study was in contrast with the findings of Lokesh and Mehla (2017) [7] who observed that phosphorus content of resistant genotypes was lower compared to the susceptible genotypes, which indicated phosphorus playing negative role with the total life span of maize stem borer. Similarly, Thakur *et al.*, 2019[15], reported that phosphorous content did not favor the fruit borer attack in tomato.

Potassium

At 30 DAS, the potassium content was found to be high in least susceptible hybrids (JP 2007, PAC 741, MAH 20-40) and low potassium content in highly susceptible hybrids (ADV 9293 JHS 666, MAH 21-577). It was seen that among least susceptible hybrids, the potassium content was high in

JP 2007 (2.4%). Among the moderately susceptible hybrids, the potassium content was found to be 1.33, 1.40, 1.43, 1.6 percent in MAH-19-2, GK 3122, Apsa 91 and MAH 21-580 respectively. Whereas, standard check recorded the potassium content of 1.35 percent. The highly susceptible hybrids *viz.*,JHS 666, ADV 9293, MAH 21-577 recorded 1.20, 1.26 and 1.35 percent of potassium respectively(Table 1).At 60 DAS, the potassium content was found to be high in least susceptible hybrids (JP 2007, MAH-20-40, PAC 741) and low potassium content in highly susceptible hybrids (JHS 666, MAH 21-577 and ADV 9293). It was seen that among least susceptible hybrids, the potassium content was high in JP 2007 (2.76%). Among the moderately susceptible hybrids, the potassium content was found to be 1.60, 1.88, 2.0, 2.0 percent in MAH-19-2, GK 3122, Apsa 91 and MAH 21-580 respectively. Whereas, standard check recorded the potassium content of 1.69 percent. The highly susceptible hybrids *viz.*, JHS 666, MAH 21-577, ADV 9293 recorded 1.40, 1.60 and 1.65 percent of potassium respectively (Table 2). From the correlation studies, it was found that the per cent potassium had a negative significant influence on the infestation of fall armyworm (r = -0.810*) (Table 3).

These results are in conformity with Lokesh and Mehla (2017) [7] who reported that significant negative correlation was observed between the potassium content and damage caused by the *Chilo partellus* (Swinhoe) larvae. The resistant genotypes, 551-5 and 335 recorded higher potassium content whereas, highly susceptible genotypes *i.e.*, 295 and 1015 (2+3) recorded low amount of potassium. In contrast, Sharma and Chatterji (1971) [14] reported that resistant genotypes recorded lower potassium content as compared to susceptible ones.

In potassium deficit plants, there is an accumulation of low-molecularweight organic compounds (amino acids, soluble sugars, organic acids) which act as source of nutrients for parasites, in turn such plants reduce the synthesis of high-molecular-weight compounds (proteins, starch and cellulose) in the plant tissues.This attracts many insects (Marschner, 2011) [8]. When potassium is sufficient, there is an increase in the synthesis of high-molecular weight compounds such as proteins, starches and cellulose and depressed concentrations of low-molecular weight compounds such as soluble sugars, organic acids, amino acids and amides in the plant tissue. Adequate levels of potassium increase phenol concentrations which play a role in plant resistance. The synthesis of other defensive compounds in K-sufficient plants resulted in higher pest mortality (Wang *et al.*, 2013) [17].

Calcium

At 30 DAS, the calcium content was found to be high in least susceptible hybrids PAC 741 (0.68%), JP 2007 (0.60%), MAH-20-40 (0.60%) and low calcium content in highly susceptible hybrids ADV 9293 (0.32%), MAH 21-577 (0.36%) and JHS 666 (0.40%). The standard check, MAH-14-5 recorded 0.44 percent of calcium. In the moderately susceptible hybrids, GK 3122 (0.48%), Apsa 91 (0.48%) and MAH 21-580 (0.48%) the calcium content was found to be on par with each other except MAH-19-2 (0.52%) (Table 1). Amount of calcium content in selected hybrids significantly varied between 0.44 to 0.88 per cent at 60 DAS. The high amount of calcium was recorded in the least susceptible hybrids, MAH-20-40 (0.88%), PAC741 (0.80%), JP 2007 (0.76%) and in moderately susceptible hybrids, Apsa 91 (0.70%), MAH-19-2 (0.72%) and MAH 21-580 (0.72%) were found to be on par with one another, whereas, GK 3122 recorded 0.75% of calcium. The standard check, MAH-14-5 recorded 0.69 percent of calcium. The low amount of calcium was recorded in the highly susceptible hybrids namely, ADV 9293 (0.44%), MAH 21-577 (0.56%) and JHS 666 (0.60%) (Table 2). The correlation coefficient studies showed that fall armyworm incidence was negatively correlated with the calcium content (r = -0.837**) of all the selected hybrids (Table 3).

Calcium is important for the stability and function of plant membranes and when there is calcium deficiency it results in membrane leakage of low-molecular weight compounds, *e.g.*, sugars and amino acids, from the cytoplasm to the apoplast, which stimulate the infection by the pathogens (Marschner, 2011) [8]. Calcium is also an important component of the cell wall structure as calcium polygalacturonates are required in the middle lamella for cell wall stability. When calcium concentration drops, there is an increased susceptibility to infestation which results in easy feeding by the defoliators. In addition, plant tissues that are low in Ca are also much more susceptible than tissues with normal calcium levels. Calcium plays an important role in the formation of rigid cell walls and adequate calcium also impedes the formation of pectolytic enzymes produced upon infection. Calcium deficiency triggers the buildup of sugars and amino acids in the apoplast, which attract insects and lowers pest resistance (Gupta *et al.*, 2017) [4].

Magnesium

At 30 DAS, the magnesium content was found to be high in highly susceptible hybrids *viz.*, MAH 21-577 (0.46%), ADV 9293 (0.46%), JHS 666 (0.40%). In moderately susceptible hybrids *viz.*, MAH-19-2, GK 3122, MAH 21-580, Apsa 91, the percent magnesium was 0.22, 0.26, 0.34 and 0.36. The standard check, MAH-14-5 recorded 0.28 percent magnesium. The magnesium content in least susceptible hybrids *viz.*, PAC 741 (0.17%), MAH-20-40 (0.19%) and JP 2007 (0.22%) (Table 1). At 60 DAS, the magnesium content was found to be high in highly susceptible hybrids (JHS 666, MAH 21-577 and ADV 9293) and low magnesium content in least susceptible hybrids (JP 2007, MAH-20-40 and PAC 741). It was seen that among highly susceptible hybrids, the magnesium content was high in JHS 666 (0.56%). Among the moderately susceptible hybrids, the magnesium content was found to be 0.32, 0.40, 0.43, 0.44 percent in MAH-19-2, MAH 21-580, GK 3122 and Apsa 91 respectively. Whereas, in standard check, MAH-14-5 the percent magnesium is 0.38.

The least susceptible hybrid, MAH-20-40 recorded lowest magnesium content of 0.23 percent in the leaf samples (Table 2). The correlation studies revealed a positive relationship between fall armyworm damage and per cent magnesium ($r = 0.874^{**}$) (Table 3).

Magnesium when applied alone or applied along with nitrogen and phosphorous, it causes nutrient imbalance leading to potassium deficiency which in turn increases soluble nitrogen concentration consequently making the plants more susceptible to pest infestation. It has a major role in plant photosynthesis as it is central atom of chlorophyll that captures light energy. Apart from this, it is also involved in transport of photosynthates, which creates a favorable condition for various pest attacks (Huber *et al.*, 2012) [6].

Table 1: Influence of macro and micro-nutrients on the incidence of fall armyworm in maize hybrids at 30 DAS

Sl. No	Hybrids	Category	LDS	Macro nutrients (%) *						Micronutrients (mg kg^{-1}) *		
				N	P	K	Ca	Mg	S	Zn	Mn	Fe
1	JP 2007	LS	1.15	1.34^{c}	0.21^{d}	2.40^{a}	0.60^{ab}	0.22^{ef}	0.18^{bc}	68.10^{a}	28.3^{abc}	163.9^{a}
2	MAH 20-40		1.05	1.37^{c}	0.20^{d}	2.00^{ab}	0.60^{ab}	0.19^{ef}	0.17^{c}	62.34^{ab}	30.2^{ab}	160.8^{a}
3	PAC 741		2.65	1.49^{c}	0.20^{d}	2.20^{a}	0.68^{a}	0.17^{f}	0.19^{abc}	60.25^{abc}	31.6^{a}	156.4^{ab}
4	Apsa 91	MS	4.45	1.70^{abc}	0.23^{cd}	1.43^{c}	0.48^{bcd}	0.36^{bc}	0.23^{abc}	55.36^{abcd}	23.7^{bcde}	143.7^{ab}
5	GK 3122		5.95	1.58^{bc}	0.22^{d}	1.40^{c}	0.48^{bcd}	0.26^{def}	0.27^{ab}	52.80^{bcd}	26.2^{abcd}	139.1^{ab}
6	MAH 19-2		5.65	1.65^{abc}	0.25^{bcd}	1.33^{c}	0.52^{bc}	0.22^{ef}	0.21^{abc}	47.60^{cd}	24.6^{abcde}	132.5^{ab}
7	MAH 21-580		6.90	1.78^{abc}	0.25^{bcd}	1.60^{bc}	0.48^{bcd}	0.34^{bcd}	0.22^{abc}	57.10^{abc}	24.8^{abcde}	150.3^{ab}
8	JHS 666	HS	7.40	2.11^{a}	0.32^{abc}	1.20^{c}	0.40^{cde}	0.40^{ab}	0.25^{abc}	46.81^{cd}	21.5^{cde}	122.5^{b}
9	MAH 21-577		7.90	2.07^{ab}	0.34^{ab}	1.35^{c}	0.36^{de}	0.46^{a}	0.28^{a}	50.20^{bcd}	18.9^{de}	130.3^{ab}
10	ADV 9293		7.55	2.14^{a}	0.37^{a}	1.26^{c}	0.32^{e}	0.46^{a}	0.26^{abc}	41.62^{d}	17.4^{e}	136.1^{ab}
11	MAH 14-5	SC	3.90	1.55^{c}	0.20^{d}	1.35^{c}	0.44^{cde}	0.28^{cde}	0.17^{c}	57.30^{abc}	25.1^{abcd}	149.5^{ab}
	SE m ±		0.65	0.098	0.0142	0.084	0.028	0.015	0.015	2.74	1.49	3.41
	CD @ p=0.05		2.04	0.291	0.042	0.25	0.082	0.045	0.045	8.08	4.39	10.26

Table 2: Influence of macro and micro-nutrients on the incidence of fall armyworm in maize hybrids at 60 DAS

Sl. No	Hybrids	Category	LDS	Macro nutrients (%) *						Micronutrients (mg kg^{-1}) *		
				N	P	K	Ca	Mg	S	Zn	Mn	Fe
1	JP 2007	LS	1.23	1.45^{e}	0.21^{f}	2.76^{a}	0.76^{abc}	0.28^{f}	0.15^{ab}	70.48^{a}	30.4^{ab}	168.1^{a}
2	MAH 20-40		1.28	1.56^{de}	0.23^{ef}	2.70^{a}	0.88^{a}	0.23^{f}	0.13^{b}	65.8^{ab}	32^{a}	167.2^{ab}
3	PAC 741		2.98	1.66^{de}	0.30^{def}	2.50^{ab}	0.80^{ab}	0.26^{f}	0.18^{ab}	63.4^{abc}	32.4^{a}	160.7^{ab}
4	Apsa 91	MS	4.18	1.88^{cde}	0.29^{def}	2.00^{bc}	0.70^{abcd}	0.44^{bcd}	0.17^{ab}	57.8^{abcd}	24.1^{bcd}	149.5^{ab}
5	GK 3122		4.45	1.73^{de}	0.32^{cde}	1.88^{cd}	0.75^{abc}	0.43^{bcd}	0.21^{ab}	53.54^{bcd}	28.4^{abc}	144.5^{ab}
6	MAH 19-2		4.75	1.80^{cde}	0.41^{bc}	1.60^{cd}	0.72^{abcd}	0.32^{ef}	0.19^{ab}	49.2^{cd}	28.7^{abc}	137.6^{ab}
7	MAH 21-580		6.38	1.90^{bcd}	0.38^{cd}	2.00^{bc}	0.72^{abcd}	0.40^{cde}	0.16^{ab}	59.4^{abc}	28.2^{abc}	158.4^{ab}
8	JHS 666	HS	7.05	2.20^{abc}	0.48^{ab}	1.4^{d}	0.60^{cde}	0.56^{a}	0.20^{ab}	49.4^{cd}	22.3^{cd}	142.6^{ab}
9	MAH 21-577		7.05	2.34^{ab}	0.52^{a}	1.60^{cd}	0.56^{de}	0.48^{abc}	0.23^{a}	52.1^{bcd}	21.9^{cd}	136.9^{ab}
10	ADV 9293		7.1	2.35^{a}	0.54^{a}	1.65^{cd}	0.44^{e}	0.52^{ab}	0.21^{ab}	44.3^{d}	19.9^{d}	131.2^{b}
11	MAH 14-5	SC	3.15	1.75^{de}	0.40^{bc}	1.69^{cd}	0.69^{bcd}	0.38^{de}	0.14^{ab}	58.6^{abcd}	28.5^{abc}	153.8^{ab}
	SE m ±		0.188	0.087	0.02	0.102	0.034	0.019	0.008	2.83	1.401	3.69
	CD @ p=0.05		0.593	0.259	0.06	0.301	0.102	0.058	0.025	8.42	4.161	10.7

Sulphur

At 30 DAS, low sulphur content was recorded in least susceptible hybrids, MAH-20-40 (0.17%), JP 2007 (0.18%) and PAC 741(0.19%). Moderately susceptible hybrids *viz.*, MAH-19-2, MAH 21-580, Apsa 91recorded 0.21, 0.22 and 0.23 percent respectively which are on par with standard check, MAH-14-5 (0.20%). Whereas, 0.25, 0.26, 0.28 percent sulphur was recorded by JHS 666, ADV 9293 and MAH 21-577 respectively (Table 1). Sulphur content among the selected hybrids varied significantly from 0.13 to 0.23 percent at 60 DAS. In least susceptible hybrids, *viz.*, JHS 666, ADV 9293 and MAH 21-577, the sulphur content was found to be 0.20, 0.21 and 0.23 percent, respectively. The moderately susceptible hybrids, *viz.*, MAH 21-580, Apsa 91, MAH-19-2, GK 3122 recorded 0.16, 0.17, 0.19 and 0.21 percent respectively. The sulphur content of 0.13, 0.15 and 0.18 percent wasobserved by MAH-20-40, JP 2007 and PAC 741 respectively (Table 2). The sulphur content among different selected hybrids was positively correlated with fall armyworm damage (r = 0.799**) (Table 3).

Sulphur is an important component of plant proteins as it is a prime element present in the cysteine, cystine and methionine amino acids. It acts as a coenzyme during photosynthesis and is vital for the synthesis of nucleic acid proteins. The deficiency of Sulphur results in reduced protein synthesis and reduced phenol content. The reduced phenol content will affect the defence system of the plants. Sulphur is a constituent of a nitrogen-uptake enzyme and its absence can disturb nitrogen metabolism. Sulphur, when combined with nitrogen, allows for the creation of essential amino acids for protein synthesis.

Zinc

At 30 DAS, the zinc content was found to be high in least susceptible hybrids PAC 741 (60.25 mg kg^{-1}), MAH-20-40 (62.34 mg kg^{-1}) and JP 2007 (68.10 mg kg^{-1}) and low zinc content in highly susceptible hybrids ADV 9293 (41.62 mg kg^{-1}), JHS 666 (46.81 mg kg^{-1}) and MAH 21-577 (50.20 mg kg^{-1}). The standard check, MAH-14-5 recorded 57.3 mg kg^{-1} of calcium. In the moderately susceptible hybrids, *viz.*, MAH-19-2, GK 3122, Apsa 91 and MAH 21-580 the calcium content was found to be 47.6, 52.8, 55.36, 57.10 mg kg^{-1}(Table 1).Amount of zinc content in selected hybrids significantly varied between 44.30 to 70.48 at 60 DAS. The high amount of zinc was recorded in the least susceptible hybrids, JP 2007 (70.48 mg kg^{-1}), MAH-20-40 (65.80 mg kg^{-1}), PAC 741 (63.40 mg kg^{-1}) and in moderately susceptible hybrids, MAH-19-2, GK 3122 and MAH 21-580 recorded 49.20, 53.54, 59.40 mg kg^{-1} of zinc content. Whereas, other moderately susceptible hybrid, Apsa 91 (57.80 mg kg^{-1}) found to be on par with standard check, MAH-14-5 (58.60 mg kg^{-1}). The low amount of zinc was recorded in the highly susceptible hybrids namely, ADV 9293 (44.30 mg kg^{-1}), JHS 666 (49.40 mg kg^{-1}) and MAH 21-577 (52.10 mg kg^{-1}) (Table 2). The correlation studies revealed a significant and negative relationship between fall armyworm damage and the amount of zinc (r = -0.774**) (Table 3).

The most fundamental role of zinc is RNA synthesis and protein metabolism. With zinc deficiency, protein synthesis is significantly inhibited and high concentrations of non-protein nitrogen, including amino acids, build up. This results in unpalatability for the insect feeding. Zinc plays an important role in energizing enzymes involved in various metabolic pathways, especially in protein and starch synthesis, and therefore, a low zinc concentration induces accumulation of amino acids in plant tissue makes the plant vulnerable for insect infestation. (Marschner, 2011) [8]. Zinc is also involved in the maintenance of the integrity of bio membranes (Marschner 2011; Huber *et al.* 2012) [8, 6]. Zn deficiency might lead to increased membrane leakage of low-molecular-weight compounds into apoplast region, the presence of which becomes more suitable feeding substrate for the insects (Marschner 2011; Huber *et al.*, 2012) [8, 6].

Manganese

At 30 DAS, the highest amount of manganese was recorded in least susceptible hybrid PAC 741 (31.6 mg kg^{-1}) followed by MAH-20-40 (30.02 mg kg^{-1}) and JP 2007 (28.3 mg kg^{-1}), whereas, least was observed in highly susceptible hybrid, ADV 9293 (17.4 mg kg^{-1}) which was followed by MAH 21-577 (18.9 mg kg-1) and JHS 666 (21.5mg kg^{-1}). In moderately susceptible hybrids *viz.*, Apsa 91, MAH-19-2 and MAH 21-580 recorded 23.7, 24.6 and 24.8 mg kg^{-1} of manganese respectively. However, the standard check, MAH-14-5 recorded 25.1 mg kg^{-1} which is on par with GK 3122 (26.2 mg kg^{-1}) (Table 1). At 60 DAS, the greater manganese content was observed in least susceptible hybrid PAC 741 (32.4 mg kg^{-1}) followed by MAH-20-40 (32.0 mg kg^{-1}) and JP 2007 (30.4 mg kg^{-1}). The manganese content of 24.1, 28.2, 28.4, 28.7 was recorded in Apsa 91, MAH 21-580, GK 3122 and MAH-19-2 respectively. Whereas, the manganese content of 28.5 mg $kg^{-1}$was observed in standard check, MAH-14-5. Likewise, in highly susceptible hybrids namely, ADV 9293, MAH 21-577 and JHS 666 recorded 19.9, 21.9 and 22.3 mg kg^{-1} of manganese content respectively (Table 2). The correlation studies revealed a negative relationship between fall armyworm damage and the amount of manganese(r = -0.845**) (Table 3).

Mn plays a significant role in biogenesis of lignin and phenol compounds (Marschner 2011) [8]. Mn acts as a cofactor and activates the enzymes phenol oxidases and peroxidases responsible for conversion of phenol compounds into quinones which increases unpalatability (Huber *et al.*, 2012) [6]. It is also lignification of cell wall that serve as a barrier for infestation/infection.

Iron

At 30 DAS, the highest amount of iron content was recorded in case of least susceptible hybrids, JP 2007 (163.9 mg kg^{-1}) followed by MAH 20-40 (160.8 mg kg^{-1}) and PAC 741 (156.4 kg mg^{-1}). Whereas, the least was observed in highly susceptible hybrids, JHS 666 (122.5 mg kg^{-1}), MAH 21-577 (130.3 mg kg^{-1}) and ADV 9293 (136.1 mg kg^{-1}). The standard check, MAH-14-5, recorded 149.5 mg kg^{-1} of iron content. The moderately susceptible hybrids, MAH-19-2, GK 3122, MAH 21-580 and Apsa 91 recorded 132.5, 139.1, 150.3, 143.7 and mg kg^{-1}, respectively (Table 1). At 60 DAS, among the different maize hybrids that were analyzed for nutrient factors, iron content ranged from 131.2 to 168.1 mg kg^{-1}. The highest amount of iron was recorded in case of least susceptible hybrid, JP 2007 (168.1 mg kg^{-1}) followed by MAH 20-40 (167.2 mg kg^{-1}) and PAC 741 (160.7 mg kg^{-1}). Whereas, the least was observed in highly susceptible hybrids, ADV 9293 (131.2 mg kg^{-1}), MAH 21-577 (136.9 mg kg^{-1}) and JHS 666 (142.6 mg kg^{-1}). The moderately susceptible hybrids *viz.*, MAH-19-2, GK 3122, MAH 21-580 and Apsa 91 recorded 137.6, 144.5, 158.4 and 149.5 mg kg^{-1}, respectively. The standard check, MAH-14-5, recorded 153.8 mg kg^{-1} of iron content (Table 2). The correlation studies revealed a negative relationship between fall armyworm damage and the amount of iron (r = -0.844**) (Table 3).

The results obtained were in conformity with Arabjafari and Jalali, 2007 [2] who reported that susceptible variety HY-4642 recorded less quantity of iron compared to resistant variety CM-137 indicating positive correlation between the quantity of iron and the degree of resistance to *C. partellus*. Similarly, Sharma and Chatterji, 1971 [14] also reported higher concentration of iron was found in resistant germplasms compared to susceptible ones.

Table 3: Coefficient of correlation between maize leaf nutrient contents and FAW leaf damage score

	N	P	K	Ca	Mg	S	Zn	Mn	Fe
Leaf damage score	0.941**	0.901**	-0.810**	-0.837**	0.874**	0.799**	-0.774**	-0.845**	-0.844**

* Correlation is significant at p= 0.05 (2- tailed); ** Correlation is significant at p=0.01 (2- tailed)

Conclusion

Upon screening, 6 hybrids were grouped under least susceptible group and 19 under moderately susceptible group and the remaining 5 hybrids were grouped under highly susceptible category. The studies on nutrient components reveal that the amount of potassium, calcium, zinc, manganese and iron was higher in least susceptible hybrids compared to highly susceptible hybrids. The correlation studies between leaf damage score and nutrient components were positive with nitrogen (r = 0.941**), phosphorous (r = 0.901**), magnesium (r = 0.874**) and sulphur (r = 0.799*). While potassium (r = -0.810**) and calcium (r = -0.837*) showed a negative association with leaf damage score. All the micronutrients, zinc (r = -0.774**), manganese (r = -0.845**) and iron (r = -0.831**) showed negative association with leaf damage score. The nutrient components like nitrogen, phosphorous, magnesium and sulphur may influence the attack of fall armyworm with greater damage, whereas, potassium, calcium, zinc, manganese and iron may induce resistance against fall armyworm.

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