



DAMAGE OF FALL ARMYWORM (*SPODOPTERA FRUGIPERDA* JE SMITH) ON QUALITY PROTEIN MAIZE VARIETIES AT SAMARU, ZARIA, NIGERIA

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ABSTRACT

Field experiments were conducted in 2019 and 2020 wet seasons to evaluate the effect of Fall Armyworm (FAW) damage on Quality Protein Maize (QPM) varieties. Six treatments consisting of five QPM varieties (SAMMAZ 14, SAMMAZ 17, SAMMAZ 32, SAMMAZ 33 and SAMMAZ 36) and a non-QPM variety (SAMMAZ 34) were laid out in a Randomized Complete Block Design (RCBD) with four replications. Percent pest incidence and Leaf (foliar) damage ratings were determined at four weeks after emergence. Percent cob damage and Cob damage ratings were determined and rated at harvest. Grain yield was also assessed for each maize variety. The combined years result showed that SAMMAZ 36 was the most tolerant variety to Fall Armyworm damage which had the least Fall Armyworm percent incidence (30.00 %), leaf damage rating (2.36), percent cob damage (21.25 %) and cob damage rating (2.60) while SAMMAZ 33 was the most susceptible variety with the highest percent cob damage (30.00 %) and cob damage rating (3.15) recorded among the QPM varieties. Furthermore, SAMMAZ 36 recorded the highest grain yield (2708.33 kg/ha) which was more than that of the non-QPM, SAMMAZ 34 (2562.50 kg/ha). In conclusion, SAMMAZ 36 variety, was therefore the most tolerant variety to FAW damage.

Keywords: Fall Armyworm; Quality Protein Maize; Non-Quality Protein Maize; Damage

INTRODUCTION

The Fall Armyworm (*Spodoptera frugiperda*) is a devastating insect pest that causes damage to economically important crops. It has several host plants (Goergen *et al.*, 2016; Roger *et al.*, 2017; Prassana *et al.*, 2018) but it appears to cause severe damage to maize in West and Central Africa than most other African *Spodoptera* species (IITA, 2016). Lower yields of maize have been attributed to a number of biotic and abiotic factors including insects, diseases, poor soil fertility and drought (Tufa and Ketema, 2016) but amongst them the loss caused by the insect pests is the major one. The fall armyworms have become the most destructive pest in reducing maize production in Africa (Abrahams *et al.*, 2017). Cereal farmers

across Sub-Saharan Africa are now experiencing heavy losses due to the devastation by this invasive pest. In January 2016, the Fall Armyworm (FAW) was reported for the first time causing damage to crops on the African continent (Goergen *et al.*, 2016). The presence of this new pest in West and Central Africa adds to the threat caused by native lepidopteran maize stalk/stemborers of economic importance, in particular the *Busseola fusca* (Fuller), *Sesamia calamistis* (Hampson), *Eldana saccharina* (Walker) and *Mussidia nigrivenella*. In Africa, maize yield losses of 20–50 % were estimated (Early *et al.*, 2018) due to FAW damage. Emerging threats from the insect has severe impact on the livelihoods of the farmers in terms of reduction of income as a result of grain yield loss or even

total crop failure if no management tactics are applied. Controlling *S. frugiperda* is a challenge because they reproduce fast and in large numbers, can migrate great distances, hide within growing leaves and have been reported to resist several pesticides. As a result of heavy infestation caused by *S. frugiperda* in the fields, farmers have been spraying indiscriminately various types of insecticides in the management of the insect to prevent yield losses. The use of synthetic chemical pesticides seems to be the most common practice that is currently the main option in use, which may seem to be detrimental to the environment and the user. Though often overlooked, there are other natural approaches such as manipulation of planting dates, use of inter-cropping technology, natural enemies, biopesticides and the use of resistant or tolerant varieties which have proven effective.

Maize contains all the ten essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine) in varying amounts. However, while maize may provide a rich source of some of these essential amino acids, it is a poor source of others. Non-Quality Protein Maize (Non-QPM) has poor nutritive value due to low concentration of two essential amino acids: lysine and tryptophan. Quality Protein Maize (QPM) confers the presence of high lysine and tryptophan, thus the use of QPM varieties helps to reduce nutritional related diseases and death among young children, pregnant and lactating mothers, the sickly and many low income families especially in developing countries including Nigeria (Bressani, 1992). Despite the importance of QPM amongst other Non-QPM maize varieties, there is little or no updated information known on the damage assessment of FAW on QPM prior to this study. There is therefore the need to assess the damage caused by FAW on QPM maize varieties since varietal resistance to insects are potential means of reducing yield losses of maize crop.

MATERIALS AND METHODS

Field experiments were conducted at the

research farm of Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru (11° 12' N, 07° 37' E) Zaria during 2019 and 2020 cropping seasons. Six maize varieties, comprising five Quality Protein Maize (QPM) varieties (SAMMAZ 14, SAMMAZ 17, SAMMAZ 32, SAMMAZ 33 and SAMMAZ 36) and 1 non-QPM variety (SAMMAZ 34) were obtained from the Maize Breeding Unit of IAR Samaru, Zaria.

Determination of Fall Armyworm Damage on Quality Protein Maize (QPM) Varieties

The experimental field was sprayed with Glyphosate at 4 L/ha and two weeks after, the land was ploughed, harrowed and ridged apart at 0.75 m inter row spacing. Gross plot size used was 12 m² (3 m x 4 m) consisting of 4 ridges, each 4.0 m long while the net plot was 6 m² (1.5 m x 4 m) consisting of 2 ridges each measuring 4.0 m long. The plots within each replication were separated by 1.5 m alley and replications were also separated by an alley of 2.0 m from each other. The treatments consist of six maize varieties (SAMMAZ 14, SAMMAZ 17, SAMMAZ 32, SAMMAZ 33, SAMMAZ 36 and SAMMAZ 34) laid out in a Randomized Complete Block Design (RCBD) with four replications making a total of 24 plots. Maize seeds of the different varieties were treated with seed dressing chemical Dress force (Imidacloprid 20 % + Metalaxyl-M 20 % + Tebuconazole 20 % WS active ingredients) at the rate of 10 g per 4 kg of maize seeds before sowing. Thereafter, the seeds were sown at the rate of three seeds per hole with 0.25 m intra row spacing. This was followed by application of pre-emergent Atrazine (290 g/l S-Metolachlor and 370 g/l Atrazine active ingredients) herbicide at the rate of 4 L/ha immediately after sowing. Emerged seedlings were thinned to two plants per stand at 3 weeks after sowing. Manual weeding was done at 3 weeks interval beginning from four weeks after sowing to manage weeds infestation. Fertilizer in two split doses was applied at recommended rates. The first dose of NPK 15:15:15 (120 N, 60 P₂O₅ and 60 K₂O kg/ha) was applied two weeks after

sowing. The second fertilizer dose of Nitrogen in the form of urea (46% N) at the rate of 100 kg/ha was applied at 5 weeks after sowing.

Damage and yield assessment

The following parameters were collected and recorded:

Percent incidence of FAW

This was determined at four weeks after plant emergence. Ten maize plants from the 2 middle ridges (net plots) were sampled, and the number of plants damaged by FAW larvae were recorded. The percent incidence was calculated using the formula sourced from Maruthadurai and Ramesh (2019).

$$\text{Incidence (\%)} = \frac{\text{Number of plants damaged}}{\text{Total number of plants sampled}} \times 100$$

Leaf (foliar) damage rating

Leave damage was rated four weeks after plant emergence and ten plants from the 2 middle ridges were rated individually according to Fernández and Expósito (2000) scale of 1-5 as presented in table below.

Table 1 Scale for Assessment of Foliar Damage due to Fall Armyworm in Maize

Score/Rating	Damage symptoms/description
1	No evident damage, or less than 1-3 pinhole type injuries
2	More than 3 pinhole injuries, and/or 1-3 injuries less than 10 mm each
3	More than 3 injuries less than 10 mm, and/or 1-3 injuries larger than 10 mm each (shothole type injuries)
4	3 to 6 shothole injuries, and/or at least 50% of the whorl destroyed
5	More than 6 shothole type injuries, and/or whorl totally destroyed

Harvesting

At maturity, harvesting was done manually for all the maize varieties by detaching the cobs of each plant from the stem. Maize cobs from the two middle ridges for each plot were harvested, bulked and dried. When the average moisture content was 12-14 %, the cobs were then threshed.

Percent cob damage

Percent cob damage was determined for each maize variety at harvest. Ten maize cobs from the two middle ridges already harvested and bulked were randomly selected and sampled for damage by FAW larvae. Each cob was assessed using the characteristics symptom of presence of holes and the number of cobs with these symptoms were counted. Percent cob damage was determined using the formula below as cited by Clovis *et al.* (2020).

$$\text{Cob damage (\%)} = \frac{\text{Number of damaged cobs}}{\text{Total number of cobs sampled per plot}} \times 100$$

Cob damage rating

Cob damage rating was determined for each maize variety. Ten cobs that were used in the determination of percent cob damage (above) were again used for the rating. The maize cobs were individually rated by the presence or

absence of boring holes on the cob using modified Davis and Williams (1992) cob damage scale of 1-5, where 1 signifies healthy cobs with no damage symptoms and 5 represent almost 100 % of the cobs were completely damaged.

Table 2 Modified scale for assessment of ear and kernel damage due to FAW in maize

Score/Rating	Damage symptoms/description	Response
1	No damage to the ear	Highly resistant
2	Damage to a few kernels (1 -15) or less than 10% damage to an ear	Resistant
3	Damage to 16-50 kernels or less than 25% damage to an ear	Moderately resistant
4	Damage to 51 -100 kernels or more than 50% but less than 60% damage to an ear	Susceptible
5	Damage to >100 kernels or more than 60% damage to an ear	Highly susceptible

One hundred seed weight per plot (g)

This was obtained from maize cobs of the plants in the two middle ridges of each plot that were harvested, bulked and dried (12-14 % moisture). The cobs were threshed and one hundred seeds were counted and weighed using an electric meter balance.

Grain yield (kg/ha)

This was determined from the already threshed cobs of the two middle ridges of each plot that was harvested and bulked. The maize varieties from each plot were weighed separately in kg per plot. Grain yield per hectare for each plot was calculated using the formula by Fleming and Retnakaran, 1985:

$$Yield (kg/ha) = \frac{Yield/plot \times 10,000m^2}{Plot size}$$

Statistical Analysis

Data obtained were subjected to Analysis of Variance (ANOVA) and the means were compared using Least Significant Difference (LSD). The analysis was carried out using Statistical Analysis System (SAS, 2003).

RESULTS

The results of the experiments when the seasons were combined, showed that SAMMAZ 34 followed by SAMMAZ 36 consistently had the least percent incidence, which differed

significantly from all the varieties (Table 1). Significant differences ($P \leq 0.05$) in leaf damage rating were recorded among the QPM varieties. SAMMAZ 34 had the least leaf damage rating (2.26), which differed significantly from the other varieties except SAMMAZ 36, while SAMMAZ 33 recorded significantly maximum leaf damage rating (Table 1). In terms of percent cob damage, SAMMAZ 36 recorded the least percent cob damage (21.25) while the maximum was recorded on SAMMAZ 33 (Table 2). There were significant differences

($P \leq 0.05$) in cob damage rating recorded among the varieties. SAMMAZ 34 (non-QPM) had the least damaged cob rating while SAMMAZ 33 had the maximum cob damage rating (3.15) which differed significantly ($P \leq 0.05$) from each other and all the other varieties (Table 2). One hundred (100) seed weight recorded indicated that SAMMAZ 33 had the lowest 100 seed weight (20.37 g) while the highest was recorded on SAMMAZ 36 (26.14 g) followed by the non-QPM, SAMMAZ 34 (24.33 g) (Table 3). The highest grain yield was recorded on SAMMAZ 36 (2708.33 kg/ha) followed by SAMMAZ 34 (non-QPM) which however differed significantly from each other. The lowest yield was obtained from SAMMAZ 33 (2083.33 kg/ha), which significantly differed from the yield obtained in the other varieties (Table 3).

Correlation analysis for damage parameters

The combined results for 2019 and 2020 wet seasons indicated that there was a highly significant positive correlation between percent incidence with leaf damage rating ($r = 0.60$, $p \leq 0.05$), percent cob damage ($r = 0.62$, $p \leq 0.05$)

and cob damage rating ($r = 0.71$, $p \leq 0.05$). Similarly, highly significant but negative correlation existed between percent incidence with seed weight ($r = -0.42$, $p \leq 0.05$) and grain yield ($r = -0.41$, $p \leq 0.05$). A highly significant positive correlation existed between leaf damage rating with percent cob damage ($r = 0.42$, $p \leq 0.05$) and cob damage rating ($r = 0.58$, $p \leq 0.05$) while there was a highly significant negative correlation between leaf damage rating with seed weight ($r = -0.48$, $p \leq 0.05$) and grain yield ($r = -0.57$, $p \leq 0.05$). The correlation between percent cob damage and cob damage rating ($r = 0.73$, $p \leq 0.05$) was highly significant and positively correlated. However, percent cob damage was highly significant and negatively correlated with seed weight ($r = -0.46$, $p \leq 0.05$) and grain yield ($r = -0.52$, $p \leq 0.05$). A highly significant negative correlation also existed between cob damage rating with seed weight ($r = -0.64$, $p \leq 0.05$) and grain yield ($r = -0.68$, $p \leq 0.05$). Seed weight was highly significant and positively correlated with grain yield ($r = 0.50$, $p \leq 0.05$) (Table 4).

Table 3 Effect of Quality Protein Maize Varieties on Fall Armyworm Incidence and Leaf Damage during 2019, 2020 and Combined Wet Seasons

Variety	Incidence (%)			Leaf damage rating		
	2019	2020	Combined	2019	2020	Combined
SAMMAZ 14	45.00a	27.50cd	36.25a	2.93a	2.50bc	2.71b
SAMMAZ 17	40.00b	32.50bc	36.25a	2.83ab	2.73ab	2.78b
SAMMAZ 32	37.50bc	42.50a	40.00a	2.75b	2.70ab	2.73b
SAMMAZ 33	45.00a	35.00b	40.00a	2.90ab	2.93a	2.91a
SAMMAZ 36	35.00c	25.00d	30.00b	2.43c	2.30cd	2.36c
SAMMAZ 34 (Non-QPM)	35.00c	22.50d	28.75b	2.30c	2.23d	2.26c
L.S.D	4.42	6.92	3.90	0.16	0.24	0.13
C.V	7.41	14.90	10.89	4.05	6.11	5.05

Means followed by the same letter (s) in a column are not significantly different at $P \leq 0.05$

Table 4 Effect of Quality Protein Maize Varieties on Fall Armyworm Damaged Cobs during 2019, 2020 and Combined Wet Seasons

Variety	2019	Cob damage (%)			Cob damage rating		
		2019	2020	Combined	2019	2020	Combined
SAMMAZ 14		32.50ab	22.50	27.50ab	3.25a	2.63b	2.94b
SAMMAZ 17		30.00ab	22.50	26.25abc	3.25a	2.63b	2.94b
SAMMAZ 32		27.50ab	20.00	23.75bc	2.90b	2.35c	2.63c
SAMMAZ 33		35.00a	25.00	30.00a	3.38a	2.93a	3.15a
SAMMAZ 36		25.00b	17.50	21.25c	2.85b	2.35c	2.60c
SAMMAZ 34 (Non-QPM)		27.50ab	17.50	22.50bc	2.75b	2.15d	2.45d
L.S.D		7.58	7.62	5.02	0.24	0.16	0.14
C.V		16.99	24.27	19.56	5.28	4.27	4.89

Means followed by the same letter (s) in a column are not significantly different at $P \leq 0.05$

Table 5 Effect of Quality Protein Maize Varieties on Fall Armyworm Damage on Yield Parameters during 2019, 2020 and Combined Wet Seasons

Variety	100 seed weight (g)			Grain yield (kg/ha)		
	2019	2020	Combined	2019	2020	Combined
SAMMAZ 14	21.49bc	23.91b	22.70bcd	2041.67de	2250.00c	2145.83cd
SAMMAZ 17	18.83cd	23.93b	21.38cd	2166.67d	2375.00bc	2270.83c
SAMMAZ 32	22.64ab	24.37b	23.50bc	2333.33c	2541.70ab	2437.50b
SAMMAZ 33	17.74d	22.99b	20.37d	2000.00e	2166.70c	2083.33d
SAMMAZ 36	24.97a	27.30a	26.14a	2666.67a	2750.00a	2708.33a
SAMMAZ 34 (Non-QPM)	23.54ab	25.11ab	24.33ab	2500.00b	2625.00a	2562.50ab
L.S.D	2.92	2.28	2.45	129.04	225.84	147.32
C.V	9.00	6.15	10.42	3.75	6.11	6.12

Means followed by the same letter (s) in a column are not significantly different at $P \leq 0.05$

Table 6 Correlation of Damage Parameters and Grain Yields of Quality Protein Maize Varieties to *Spodoptera frugiperda* Infestation

	PI	LDR	PCD	CDR	SEEDWT	YIELD
PI	1.00					
LDR	0.60**	1.00				
PCD	0.62**	0.42**	1.00			
CDR	0.71**	0.58**	0.73**	1.00		
SEEDWT	-0.42**	-0.48**	-0.46**	-0.64**	1.00	
YIELD	-0.41**	-0.57**	-0.52**	-0.68**	0.50**	1.00

PI= Percent Incidence

LDR=Leaf Damage Rating

PCD= Percent Cob Damage

CDR=Cob Damage Rating

SEEDWT= Seed Weight

*= Significant at 5%

**= Significant at 1%

DISCUSSION

The findings in percent incidence of FAW damage recorded among the varieties in this study for combined seasons (28.75 % - 40.00 %) were within the range recorded by Navik *et al.* (2021) that reported percent incidence caused by the invasive *S. frugiperda* ranged between 22.13 – 46.83 % in rainfed maize. In another study, Baudron *et al.* (2019) reported 26.4 – 55.9 % of FAW pest incidence in maize. Leaf damage rating (scale 1-5) recorded in this study for combined seasons (2.26 – 2.91) were within the range reported by Chouraddi and Mallapur (2017) in India, where the leaf feeding score varied from 0.49 – 7.91 and 0.58 – 8.09 during kharif and rabi season, respectively. Navik *et al.* (2021) reported leaf damage severity caused by the invasive *S. frugiperda* to range from 3.0 – 4.9 on 0-9 scale in rainfed maize and this was higher than the range obtained in the findings of this study in both years. The variation in leaf damage severity may be due to differences in varieties used, soil types and environmental conditions where the study was conducted. In the present study, cob damage rating (scale of 1-5) recorded varied among the varieties and was significantly low in

the two seasons (2.15 – 3.38). This probably could be due to the varietal susceptibility to the insect pest infestation (Houngbo *et al.*, 2020) as a result of differences in the genetic constitution of the maize varieties (Wiseman, 1994). The low damaged cobs recorded could however be attributed to the cannibalistic behavior of FAW larvae with only few larvae able to attack the cobs. This observation was supported by the findings of Prasanna *et al.* (2018) that reported the numbers of FAW larvae present within a given maize field decreases as they develop into later-instars due to unfavourable environmental conditions, presence of predatory insects, or competition and cannibalism among them. Also according to Britz (2020), FAW larval population remained consistent throughout vegetative phase but decline at beginning of reproductive stage of the plant. This might relate to reduced larval damage as the crop matures. Highest grain yield was recorded in SAMMAZ 36 in both years. The non-QPM (SAMMAZ 34), even-though recorded the least percent incidence and leaf damage rating, it had significantly lower yield than SAMMAZ 36. The observation in yield among the varieties was in accordance with findings by Kumar and Mihm (2002) that reported some maize hybrids,

even though presenting less FAW damage, had significantly lower yield than those having higher damage. This indicates that, in some genotypes, FAW damage does not lead to serious injury to the crop to the extent that yield is highly impacted, but severe yield losses usually occur when the leaf whorl is destroyed and photosynthetic area is reduced. A highly significant and positive correlation existed between FAW percent incidence and damage severity (leaf and cob damage ratings). Similar findings were reported by Kuate *et al.* (2019) that revealed positive and significant correlation between *S. frugiperda* incidence and damage severity. Generally, the non-QPM variety recorded the lowest damage parameters probably because it has poor nutritive value due to low concentration of two essential amino acids- lysine and tryptophan which makes it less attractive to FAW while the greatest damage

observed in the QPM varieties was probably due to their high concentration of lysine and tryptophan essential amino acids which makes them more nutritive and more attractive to FAW.

CONCLUSION

Quality Protein Maize (QPM) varieties significantly varied in their response to Fall Armyworm damage. SAMMAZ 36 had the least FAW percent incidence and leaf damage rating recorded among the QPM varieties. The same variety (SAMMAZ 36) suffered the least percent cob damage and cob damage rating as a result of feeding by FAW larvae, thus recorded the highest grain yield. It can therefore be concluded that SAMMAZ 36 QPM variety, was the most tolerant variety to FAW damage.

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