*Moor Journal of Agricultural Research 17, 71 - 79, 2016*

# Contribution of Stem Borer Damage Parameters and Agronomic Traits to Grain Yield Reduction in Maize (*Zea mays* L.)

**[1]Oloyede-Kamiyo Q. O. and [2]Ajala S. O..**
*[1]Institute of Agricultural Research and Training (IAR&T), P.M.B. 5029, Moor Plantation, Apata*
*[2] International Institute of Tropical Agriculture (IITA), Ibadan*
*Corresponding author: Oloyede-Kamiyo Q.O. Ph.D.*
*Email: olaqpublication@yahoo.co.uk*
*Mobile no.: 08060993930*

## Abstract

A study was conducted at IITA Ibadan in 2009 and 2010 to determine the contributions of agronomic and damage parameters to grain yield reduction due to infestation by two stem borer species (*Sesamia calamistis* and *Eldana saccharina*) in a yellow maize population, DMR ESR-Y. This aims at identifying the most important damage parameter(s) contributing to grain yield reduction in maize.

The result of analysis of variance revealed significant difference among the maize entries for days to 50% silking, plant height, grain yield, stalk breakage and stem tunneling. Mean square of entry by environment was significant for cob damage. Damage parameters had negative correlations with most agronomic traits. Grain yield was also negatively correlated with damage parameters with the highest being between grain yield and stem tunneling (rp = -0.25*, rg = -0.52**), followed by cob damage (rp = -0.20*). Correlations among damage parameters were however positive.

Path coefficient analysis revealed that plant height and ears per plant had relatively high negative direct effect on grain yield reduction. Stem tunneling had the highest positive direct effect on grain yield loss (0.106) among damage parameters, followed by cob damage (0.028). This indicates that the direct contribution of stem tunneling and cob damage accounted for about 85% and 68% of the total correlation between stem tunneling and grain yield reduction, and cob damage and grain yield reduction respectively. When the effects of only the damage parameters were considered, stem tunneling also had the highest direct effect (0.094) accounting for over 90% of the total correlation, followed by cob damage (**0.033**) which accounts for 80.5% of the total correlation. The results of this study indicated that both stem tunneling and cob damage due to stem borer infestation are the most important damage parameters contributing to grain yield reduction in maize and could therefore be used as selection criteria in breeding for stem borer resistance.

**Keywords:** Stem borers; Grain yield reduction; Damage parameters; Correlation; Path analysis

## Introduction

The pink stem borer, *Sesamia calamistis (Hampson) and* the sugarcane borer, *Eldana saccharina* (Walker) are the most damaging and widespread pest in West Africa (Bosque-Perez and Mareck, 1990; Polaszek 1998).*S. calamistis* attack maize at early stages of its growthcausing leaf feeding damage, dead heart and stem tunneling which later result in stalk breakage, while *E. saccharina* attacks maize at flowering stage causing cob damage. The 3-4$^{th}$ instar larvae bore into the stem of maize plant where they continue to feed and cause extensive tunneling. This disrupts the translocation of nutrients, resulting in stunted growth, weakening of the stalk and lodging under intense wind. *Eldana* infests maize plant at flowering by feeding on developing cobs thereby reducing the quality and quantity of grains which eventually results in grain yield reduction, because yield is a function of cob number and weight. Defoliation of leaves due to leaf feeding reduces the photosynthetic capacity of the plant and consequently leads to stunted growth. However, as maize plants mature, many of them overcome the effect of leaf feeding damage because the leaves become too strong for the larvae to chew.

The overall effect of the damage is grain yield reduction. Ajala *et al.* (2001) estimated grain yield losses due to stem borer attack to vary between 20-70%, depending on the severity and the stage of plant development when attacked. Total crop failure has also been reported in some instances (Girling, 1980; Bosque-Perez and Mareck, 1991; Gounou *et al*., 1994; Schulthess and Ajala, 1999).

Opinions differ as to the most important stem borer damage parameter causing grain yield reduction which can be used to classify maize germplasm for resistance. Starks and Doggett (1970), Mohyuddin and Attique (1978), and Pathak and Othieno (1990) from independent studies reported that yield reduction was mostly due to deadheart, which according to other studies (Kaufmann 1983; Bosque-Perez and Mareck, 1990) may be up to 50% of entire plant population. Ampofo (1986) identified foliar damage as the most significant damage parameter that influence grain yield of maize while. Ajala (1992) reported that the extent of stem tunneling could be used to estimate level of tolerance. In separate studies, Ajala and Saxena (1994) and Odiyi (2007) reported that stem tunneling was the most important parameter contributing to grain yield reduction under stem borer infestation in maize. Munyiri *et al*., (2015) reported that either number of exit holes or stem tunnel length could be used to evaluate germplasm for resistance to stem borer. Except for the study conducted by Odiyi (2007) which focused on combined resistance to *S. calamistis* and *E. saccharina,* all these reports and most others in the literature reported on resistance to the spotted stem borer, *Chilo partellus alone*.

Identification of the most important stem borer damage parameter causing grain yield reduction will help to determine criteria to estimate level of tolerance and/or resistance of any maize population to stem borers, and hence aid breeding programme. This study was therefore carried out to identify the most important damage parameter(s) of *S. calamistis* and *E. saccharina* causing grain yield reduction in maize for easy classification of maize varieties into either resistance or susceptibility.

**Materials and Methods**

An early-maturing maize population, DMR ESR-Y, which to downy mildew and streak disease of maize, was used for this study.The study was conducted at the International Institute of Tropical Agriculture (IITA), Ibadan in 2009 and 2010. Two hundred and fiftyfull-sib progenies of the maize population were generated and evaluated along with six checks. The experimental design was a randomized incomplete block with two replications.The evaluation was carried out under artificially infested and non-infested (control) conditions. Each row plot was 3m long. Row and hill spacing was 0.75m x 0.25m. On the artificially infested plots, each plant was infested with egg mass of stem borers (containing about 40 eggs) reared on artificial diet in laboratory.Eggs of *S.calamistis* were introduced at three weeks after planting, while eggs of *E.saccharina* were introduced at flowering. Plants were thinned to one stand per hill at three weeks after planting. N.P.K 15:15:15 and urea were applied at 10 days and six weeks after planting respectively at 60 kg N/ha. Manual weeding was carried out two weeks and six weeks after planting.

***Data collection***

Data collected included plant height measured from five competitive plants per plot as distance from base of the plant to base of the tassel. Plant aspect was rated per plot after anthesis on a scale 1-9 with 1 representing vigorous and appealing plants without defoliation, disease symptoms, or lodging, and with the first ear neither too close to the tassel nor to the base of the plant, while 9 represents lodged, diseased and defoliated plants with their first ear closer to the soil surface or to the tassel. Days to 50% silking was estimated as days from planting to the day when half of the plants in a plot had silk extrusion. Number of ears per plant was calculated as number of ears at harvest divided by number of plants at harvest. Leaf feeding damage, stalk breakage, cob damage and stem tunneling were measured per plot only on the infested plots. Leaf feeding damage was scored at three weeks after infestation (WAI) based on a visual rating on a scale of 1-9 with 1 = clean plant without leaf defoliation and 9 = 80-100% defoliation of the entire leaf area. Stalk breakage was taken as number of broken stalks above the first ear and expressed as percentage of plant stand. Number of damaged cobs was also expressed as percentage of number of ears at harvest. Stem tunneling was taken after harvesting on average of five stalks per plot. The length of each stalk was first measured, and then split longitudinally. The length tunneled by the stem borer larvae was measured and expressed as a percentage of the plant height. Grain yield (t/ha) adjusted to 14% moisture content, was calculated from ear field weight (FWT) per plot, assuming 80% shelling percentage. Percentage grain yield reduction was estimated as:

$$YLS = \{(YNI-YI)/YNI\}*100$$

Where YNI= Grain yield on the non-infested plot, YI = Grain yield on infested plot.

***Data analyses***

Data were analysed using Proc GLM procedure from SAS statistical software Version 9.2 (SAS Institute Inc., 2003). Combined analysis of variance was performed for both seasons. Phenotypic and genotypic correlation coefficients were computed using variance-covariance matrix and estimates of genetic and phenotypic variances as described by Falconer (1996). Genotypic correlation was calculated as follows:

$$r_G = \sigma_{G(X,Y)} / \sqrt{\sigma^2_{G(X)}, \sigma^2_{G(Y)}}$$

where $r_G$ is genotypic correlation between traits X and Y, $\sigma_{G(X,Y)}$ is genotypic covariance between trait X and Y, $\sigma^2_{G(X)}$ is genotypic variance of trait X, $\sigma^2_{G(Y)}$ is genotypic variance of trait Y.

Path analysis was used to partition the significant correlation coefficients into direct and indirect effects. The partial regression coefficient gave the direct effect of each trait, while indirect effect was estimated as product of correlation and path coefficient of each trait.

## Results

Mean square estimates from combined analysis of variance for the agronomic and resistant traits

Mean square of environment was highly significant for all the traits except plant aspect (Table 1). Mean square of entries was highly significant for days to 50% silking, plant height, grain yield, stalk breakage and stem tunneling. However, mean square for entry by environment was significant for plant aspect, number of ears per plant, stalk breakage and cob damage.

### Correlation among traits studied

Grain yield had highly significant genotypic correlation with days to 50% silking and number of ears per plant (Table 2). Phenotypic correlationswere low but significant between grain yield and most damage parameters. Stem tunneling had the highest genotypic correlation with grain yield (-0.52*) among damage parameters. Genotypic correlation was not estimated for leaf feeding damage because of negative genetic variance. Low phenotypic correlations were observed among damage parameters.

### Contribution of agronomic and damage parameters to grain yield reduction

When the significant correlation coefficients of traits were further partitioned into direct and indirect effects, plant height showed the highest negative direct effect (-0.074) among agronomic traits (Table3). Number of ears per plant followed plant height in order of importance among agronomic traits with direct effect of -0.019. Stem tunneling had the highest direct effect (0.106) among damage parameters, followed by cob damage (0.028), while leaf feeding had the least (0.005). Total indirect effect of stem tunneling and cob damage on yield loss accounted for only 15% and 32% respectively of the total correlation. When effect of only the damage parameters on yield reduction was considered (Table 4), stem tunneling consistently had the highest direct effect (0.094) followed by cob damage (0.033).

## Discussion

The significant mean squares of entries for stem tunneling and stalk breakage indicate that there is a considerable level of variation in the maize population for combined resistance to stem borers. The negative correlations between grain yield and damage parameters suggest possible improvement for resistance to stem borers with increased grain yield. Similar results were reported by Ajala (1994) as well as Ajala and Saxena (1994) for the spotted stem borer and by Gounou *et al*. (1994) for stem and ear borers. The high negative genotypic correlation between grain yield and stem tunneling suggests its reliability as selection criterion for improvement of stem borer resistance and grain yield. The positive relationship between grain yield and number of ears per plant is expected since grain yield is a function of cob number and weight.

The negative relationship between plant height and stem tunneling in this study tends to suggest that the taller the plant, the lower the tunneling. This contrasts the report of Sandoya *et al.* (2010) who observed positive and significant association between tunnel length and plant height. However, extensive damage on vascular bundle results in stunted growth of the plant. Therefore, reduced level of damage on

**Table 1. Mean squares for agronomic and resistance parameters for the maize population under stem borer infestation in 2009 and 2010 season**

| Source | df | Days to 50% silking | Plant height (cm) | Plant aspect | Ears per plant | Grain yield (t/ha) | Leaf feeding damage | +Stalk breakage (%) | Stem tunneling (%) | Cob damage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Env | 1 | 120.28** | 450351.08** | 0.31 | 17.58** | 1319.85** | 111.44** | 1.30** | 0.083** | 4.25** |
| Rep(Env) | 2 | 1.57 | 97.29 | 1.00 | 0.02 | 0.78 | 4.05** | 0.06 | 0.009 | 0.04 |
| Entry | 249 | 5.17** | 400.25** | 1.30 | 0.02 | 1.16** | 1.53 | 0.09** | 0.009** | 0.07 |
| Env*Entry | 249 | 1.74 | 142.47 | 1.15* | 0.02* | 0.78 | 1.73 | 0.06** | 0.006 | 0.07* |
| Error | 498 | 1.70 | 127.26 | 0.96 | 0.02 | 0.66 | 1.55 | 0.05 | 0.007 | 0.06 |

*, **; Significant F-Test at 0.05 and 0.01 levels of probability respectively.
+Number of broken stalk

**Table 2. Phenotypic(above diagonal) and genotypic(below diagonal) correlation coefficients of 9 traits for progenies of DMR ESR-Y evaluated under stem borer infested condition.**

| Traits | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 Days to silking | | 0.20** | 0.01 | -0.14** | -0.08* | -0.11* | -0.10* | -0.04 | -0.09* |
| 2 Plant height (cm) | 0.01 | | - 0.21** | 0.04 | 0.22** | 0.01 | 0.09* | -0.06* | -0.09* |
| 3 Plant aspect | -0.09 | -0.54* | | -0.24** | -0.37** | 0.13** | 0.00 | -0.36* | 0.26* |
| 4 Ears per plant | 0.74* | -0.37 | -0.81* | | 0.48** | -0.07 | 0.05 | - 0.11** | -0.09* |
| 5 Grain Yield (t/ha) | 0.42* | 0.10 | -0.89* | 0.95** | | -0.25* | -0.04 | -0.20* | -0.18* |
| 6 Stem tunneling (%) | -0.07 | -0.03 | 0.51* | -0.34 | -0.52* | | 0.05 | 0.06* | 0.12* |
| 7 +Stalk breakage (%) | -0.18 | 0.36* | -0.36 | -0.01 | 0.15 | 0.20 | | 0.08* | 0.07 |
| 8 Cob damage (%) | 0.07 | 0.30 | -0.36 | -0.40* | -0.03 | 0.10 | 0.35 | | 0.09 |
| 9 Leaf feeding damage | † | † | † | † | † | † | † | † | |

*,** : Significant at 0.05 and 0.01 level of probability respectively
+Number of broken stalk

**Table 3. Direct (bold on diagonal) and indirect effects (off diagonal) of agronomic and damage parameters on grain yield reduction for DMR ESR-Y maize population under stem borer infested condition in 2009 and 2010.**

| Traits | Indirect effect via: Days to 50% silking | Plant height (cm) | Plant aspect | Ears per plant | Cob damage (%) | Stem tunneling (%) | Leaf feeding damage | C | I |
|---|---|---|---|---|---|---|---|---|---|
| Days to 50% silking | **0.078** | 0.006 | 0.002 | 0.000 | 0.001 | -0.010 | 0.000 | 0.077 | -0.001 |
| Plant height (cm) | -0.007 | **-0.074** | 0.021 | -0.001 | 0.000 | 0.001 | 0.000 | -0.060 | 0.014 |
| Plant aspect | -0.002 | 0.023 | **-0.067** | 0.006 | 0.000 | 0.017 | 0.001 | -0.022 | 0.046 |
| Ears per plant | 0.000 | -0.003 | 0.021 | **-0.019** | -0.004 | -0.015 | -0.001 | -0.020 | -0.001 |
| Cob damage (%) | 0.003 | 0.000 | -0.001 | 0.003 | **0.028** | 0.009 | 0.000 | 0.041 | 0.013 |
| Stem tunneling (%) | -0.008 | -0.001 | -0.011 | 0.003 | 0.002 | **0.106** | 0.000 | 0.092 | -0.014 |
| Leaf feeding damage | 0.002 | 0.004 | -0.020 | 0.002 | 0.002 | 0.000 | **0.005** | -0.005 | -0.010 |

C- Total correlation, I- Total indirect effect

**Table 4. Direct (bold on diagonal) and indirect effects (off diagonal) of damage parameters on grain yield reduction in DMR ESR-Y under stem-borer infested condition in 2009 and 2010.**

| Traits | Indirect effect via: Cob damage (%) | Stem tunneling (%) | Leaf feeding damage | +Stalk breakage (%) | C | I |
|---|---|---|---|---|---|---|
| Cob damage (%) | 0.033 | 0.008 | 0.000 | 0.000 | 0.041 | 0.008 |
| Stem tunneling (%) | 0.003 | 0.094 | 0.000 | -0.004 | 0.092 | -0.001 |
| Leaf feeding damage | 0.002 | 0.000 | 0.005 | -0.012 | -0.005 | -0.009 |
| Stalk breakage (%) | 0.000 | 0.002 | 0.000 | -0.174 | -0.172 | 0.003 |

C- Total correlation, I- Total indirect effect

+ Number of broken stalk

vascular bundle could lead to reduction in level of stunted growth, and hence taller plants. Positive relationship was observed among damage parameters in this study. Previous studies (Bosque-Perez and Mareck, 1991; Gounou *et al*., 1994; Kling and Bosque-Perez, 1995; Odiyi, 2006; Ajala *et al.,* 2008) have also reported significant positive correlations between *Sesamia* and *Eldana* damage parameters. Hence, selecting for reduced levels of damage occasioned by one borer species would have positive impact on damage caused by another borer, resulting in greater progress in breeding for combined resistance to both borer species (Ajala *et al.,* 2008).

The high negative direct effect of plant height and ears per plant on grain yield reduction in the present study had earlier been reported by Ajala and Saxena (1994) for *Chilo partellus*. The relatively high positive direct effect of stem tunneling on grain yield revealed that stem tunneling is the most important damage parameter contributing to grain yield reduction. Similar observation wasmade by Ajala and Saxena (1994) on *Chilo partellus,* and Odiyi (2007) on *S. calamistis and E. saccharina*. However, it will be difficult to pick a single parameter as the most important damage parameter contributing to yield reduction when two different borer species are involved because each has its major damage. From the result of path analysis, apart from stem tunneling, direct effect of cob damage which is caused by *Eldana* contributed 68% of total correlation. Hence, for yield reduction due to both *Sesamia* and *Eldana*, both stem tunneling and cob damage should also be considered important. The positive and significant phenotypic correlation between stem tunneling and cob damage, and their significant negative correlations with grain yield confirms this.

Tunneling by stem larvae affects the overall growth of maize plant resulting in serious yield loss. *Eldana* larvae feed on developing cobs causing extensive damage to the young kernels. This reduces the quality and quantity of grains leading to grain yield loss. Leaf feeding damage affect maize mostly at early stage but the plants overcome it as they grow older because the leaves become too hard for the larvae to chew. Stalk breakage is only a resultant effect of stem tunneling. Consequently, stem tunneling and cob damage are the most important damage parameters causing grain yield loss by *S. calamistis and E. saccharina*. Reduced levels of stem tunneling and cob damage should therefore be used as criteria to determine the level of tolerance or susceptibility of maize populations for combined resistance to *S. calamistis* and *E. saccharina*.

**Acknowledgments**

The authors thank the International Institute of Tropical Agriculture (IITA), Ibadan and all the Technical staff of Maize Improvement Programme, IITA for their contributions to the success of this study.

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