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Expected responses to selection for resistance to the pink stem borer (*Sesamia calamistis* Hampson) and the sugarcane borer (*Eldana saccharina* Walker) in two maize populations

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Abstract

Progenies from two maize populations, one white-grained (DMR ESR-W) and the other yellow (DMR ESR-Y) were evaluated under artificial infestation with two borer species (*Sesamia calamistis* and *Eldana saccharina*) in two seasons to predict responses and correlated responses to selection for resistance to stem borers. Correlations between grain yield and most agronomic parameters were significant. There were negative correlations between grain yield and damage parameters in both maize populations. The highest genotypic correlation coefficient was observed between grain yield and stem tunneling (rg = -0.52) in DMR ESR-Y, and with stalk breakage (rg = -0.67) in DMR ESR-W. A Rank Summation Index (RSI) generated using plant aspect, grain yield, stem tunneling, leaf feeding and tolerance had positive phenotypic correlations with damage parameters, but negative relationship with agronomic traits. All agronomic parameters including grain yield will increase with selection. Grain yield increase of about 210 kg/ha will be obtained per generation in DMR ESR-W using two seasons to complete a cycle, but a relatively low increase (73 kg ha^{-1}) is expected in DMR ESR-Y. Response from single trait selection was better than from RSI in DMR ESR-Y, but reverse was the case in DMR ESR-W. Correlated responses to selection showed that direct selection for most of the traits would be better than indirect selection through any other trait. Appreciable progress is expected from selection for improvement of the maize populations for resistance to the two borer species, although progress from selection may be slow.

Keywords: maize grain yield, stem borers, plant resistance, expected response, correlated response

Introduction

Breeding for host plant resistance is the most promising approach for the control of stem borers in maize. Information on the magnitude of various components of genetic variation is important in determining the best selection procedure to adopt for the improvement of maize populations for stem borer resistance. The relative efficiency of any selection procedure depends on the rate of improvement, time and cost of the procedure (Ajala et al, 2009). Therefore, predicting responses help in estimating the level of improvement attainable in a crop population within a specific time.

Predicted response differs with different selection methods, number of generations taken to complete a cycle and parental control. Comstock (1964), observed that in the absence of overdominance, inbred progeny selection was expected to be superior to other recurrent selection methods for improvement of a population *per se*. Ajala et al (2009) working on FARZ23 maize population observed that S_1 selection with parental control of two using three generations to complete a cycle gave largest predicted response for grain yield and ear number when compared with half- and full-sib selection methods with two or three generations per cycle. However, considering operational efficiency and gains from selection, full-sib selection method that utilizes two generations per cycle was reported to offer the best method for improving the population. Falconer (1989) suggested that the method that is expected to give the most rapid improvement of economic value is to apply selection simultaneously to all the component characters together, giving appropriate weight to each character. Weyhrich et al (1998) compared response to selection in BS11 maize population for seven different selection methods and observed that a selection program in which index selection was practiced was successful in improving the population. Ajala (2010) however observed that responses to single trait selection were much higher than using an index.

Rapid progress could be made through indirect selection of a trait using another trait. Rogers et al (1977) observed that selection based on percentage root lodging, size of root system or degree of secondary root development would result in population that root-lodge less readily under corn rootworm infestation. Rehn and Russell (1986) noted that selection for corn borer resistance caused reduction in total yield, stover weight and grain yield with no change in harvest index. Odiyi (2007) reported that selection for earliness would result in reduction in stem tun-

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neling by 14 % of the gain attainable from selecting stem tunneling itself. Ajala et al (2009) noted that selection for higher emergence percentage increased number of ears harvested in FARZ23. Sandoya et al (2008) reported that selection for stem resistance in maize synthetic population EPS12 significantly modified other agronomic traits. This study was therefore conducted to determine expected and correlated responses to selection for resistance to both the pink stem borer (*Sesamia calamistis*) and the sugarcane borer (*Eldana saccharina*) for rapid improvement of maize populations in West and Central Africa.

Materials and Methods

Development and evaluation of progenies

Two adapted early-maturing maize populations, one yellow-grained (DMR ESR-Y) and the other white-grained (DMR ESR-W), both resistant to downy mildew and the maize streak virus disease, were used in this study. Both populations were developed by intermating downy mildew resistant (DMR) sources from the Philippines with TZSR (Tropical Zea Streak Resistance) from IITA (Fajemisin, 1985). About 300 S_1 progenies were generated from each of the populations. 100 S_1 with well filled cobs that were representative of the population by being predominantly flint dent, were then selected from each population and used to generate 250 full-sib progenies using the North Carolina Design II (NCD II) mating scheme of Comstock and Robinson (1952). However, only 225 progenies were obtained from the white population due to problem of flowering date synchrony between males and females in one set.

The 225 progenies of the white with three checks and 250 progenies of the yellow population with six checks were subsequently evaluated in the cropping seasons of 2008 and 2009 at Ibadan (Lat 7°22N, Long 03°58E) and Ikenne (Lat 6°4N, Long 03°42E), both in southwest Nigeria. A randomized incomplete block design with two replications was used for evaluation in each location. A half-plot technique was used for evaluations in Ibadan by splitting a single row of 7 m length into two half-row plots of 3 m each with 1 m in the middle. The first 3 m was artificially infested with egg masses of the stem borers, while the other half was left as control. Plant spacing of 0.75 m x 0.25 m was used. Two seeds were planted per hole but thinned to one plant per hill at three weeks after planting (WAP) just before infestation to get a maximum of 13 plants per plot and a plant density of 53,333 plants ha^{-1}. An egg mass of *S. calamistis* containing 30-40 eggs at black head stage was inserted in-between the stem and leaf sheath of each plant at 3 WAP and egg mass of *E. saccharina* was inserted in-between the forming cob and the stem at silking. All evaluations in Ikenne were under non-infested condition using a single row plot of 5 m length. Two seeds were also planted per row using the same spacing as in Ibadan and later thinned to one plant per hill to get maximum of 21 plants per plot. Other cultural practices carried out at both locations included weed control and fertilizer application.

Data collected from both Ibadan and Ikenne trials included days to silking estimated as days from planting to the day when half of the plants in a plot have silk extrusion, plant height measured from five competitive plants per plot as distance from base of the plant to base of the tassel, plant aspect rated per plot after anthesis on a scale 1-9 with 1 representing vigorous and appealing plants without leaf defoliation, disease symptoms, or lodging, and carrying their first ear at the middle of the plant, while 9 represents lodged, diseased and defoliated plants with their first ear closer to the soil surface or to the tassel. Ears per plant were calculated as number of ears at harvest divided by number of plants at harvest per plot. Damage parameters namely leaf feeding, dead heart, stalk breakage, cob damage and stem tunneling were measured per plot only on the infested plots in Ibadan. Leaf feeding was scored at 3 weeks after infestation (WAI) based on a visual rating on a scale of 1-9 with 1 = clean un-defoliated leaves and 9 = 80-100 % defoliation of the entire leaf area. Dead heart was counted at 4 WAI as number of plants with their growing points destroyed, and expressed as the percentage of plant stand. Stalk breakage was taken as number of broken plants and expressed as percentage of plant stand. Number of damaged cobs was also expressed as percentage of ears at harvest, while stem tunneling was taken after harvesting by splitting five stalks longitudinally and measuring the length tunneled by stem borer larvae then expressed as percentage of the plant height. Grain yield (t/ha) was obtained as ear weight adjusted to 14 % moisture content.

Data analyses

Data on dead heart, stalk breakage and cob damage were normalized using arcsine transformation before analyses. Data were analyzed using PROC GLM of SAS (Version 9.2). Phenotypic and genotypic correlation coefficients were computed using variance-covariance matrix and estimates of genotypic 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 genetic 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.

Predicted response to selection was determined using the formula:

$\Delta G = i . c. \sigma_{ph}.h^2$ (Hallauer and Miranda, 1988)

where i = standardized selection differential often referred to as K, c = parental control, σ_{ph} = phenotypic standard deviation (square root of phenotypic variance), h^2 = narrow-sense heritability for the trait under

Table 1 - Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients for 10 traits of progenies of DMR ESR-W and DMR ESR-Y evaluated under stem borer infested condition at Ibadan during 2008 and 2009 seasons.

Traits	1	2	3	4	5	6	7	8	9	10
				DMR ESR-W						
1 Days to 50% silking		-0.05	0.00	0.11*	-0.15**	-0.08*	-0.08*	-0.02	-0.21**	-0.10*
2 Plant height (cm)	0.23		-0.24**	-0.22**	0.30**	-0.12*	0.02	-0.11*	-0.04	-0.11*
3 Plant aspect	-0.52	-0.68		0.30**	-0.38**	0.01	0.08*	0.03	0.18**	0.29**
4 Ears per plant	-0.24	-0.35	1.00		0.41**	0.06**	0.14**	0.02	-0.02	-0.13*
5 Grain Yield (t/ha)	0.44	0.36	-1.00	0.12		-0.01	-0.06	-0.05	0.04	-0.28**
6 Stem tunneling (%)	-0.04	-0.75	0.82	-0.75	-0.29		0.09*	0.12*	0.09*	0.10 **
7 Stalk breakage (%)	-0.50	0.49	1.00	-0.84	-0.67	0.27		0.08*	0.09*	0.07**
8 Cob damage (%)	-0.59	0.03	-0.09	0.15	-0.11	0.26	0.68		0.09	0.01
9 Leaf feeding	-0.51	0.20	-0.75	0.01	0.38	0.62	0.23	0.31		0.12*
10 RSI	-0.46	-0.35	0.71	-0.28	-0.85	0.88	-0.13	-0.11	0.24	
				DMR ESR-Y						
1 Days to 50% silking		0.20**	0.01	-0.14**	-0.08*	-0.11*	-0.10*	-0.04	-0.09	-0.06
2 Plant height (cm)	0.01		-0.21**	0.04	0.22**	0.01	0.09*	-0.06*	-0.09	-0.02
3 Plant aspect	-0.09	-0.54		-0.24**	-0.37**	0.13**	0.00	-0.36	0.26	-0.02
4 Ears per plant	0.74	-0.37	-0.81		0.48**	-0.07	0.05	-0.11**	-0.09*	0.01
5 Grain Yield (t/ha)	0.42	0.10	-0.89	0.95		-0.15**	-0.04	-0.18**	-0.18**	0.03
6 Stem tunneling (%)	-0.07	-0.03	0.51	-0.34	-0.52		0.05	0.06*	0.12*	0.00
7 Stalk breakage (%)	-0.18	0.36	-0.36	-0.01	0.15	-0.20		0.08*	0.07	-0.01
8 Cob damage (%)	0.07	0.30	-0.36	-0.40	-0.03	-0.10	0.35		0.09	0.03
9 Leaf feeding	†	†	†	†	†	†	†	†		†
10 RSI	-0.23	-0.05	-0.62	-0.66	-0.10	0.01	-0.41	0.15	†	

*, ** Significantly different from zero at 0.05 and 0.01 levels of probability, † not estimated, RSI – Rank Summation Index

consideration.

A parental control value of one was used. Gains/season or generation was obtained by dividing gain/cycle by number of years. Predicted responses were expressed as a percentage of mean of each trait for ease of comparison.

For the purpose of selection, an index, Rank Summation Index (RSI) was generated from five traits namely plant aspect, leaf feeding, grain yield, stem tunneling and tolerance. The index was formed by ranking each trait according to the order of desire. The ranks were then summed up for each entry to obtain an index. Entry with good plant appeal and tolerance, high grain yield and low leaf feeding and tunneling ranked first, while the reverse ranked the last. RSI values were then normalized using log transformation and subjected to analysis of variance. Thereafter, predicted response was also calculated for RSI using the formula above.

Correlated responses to selection were calculated as described by Falconer (1989) as:

$$CR_{y(x)} = i_x.h_x.h_y.r_{gx,y}.\ \sigma_{py}$$

where i_x = selection intensity (standardized selection differential) of trait x; h_x and h_y = square root of heritability estimates of trait x and y respectively; $r_{gx,y}$ = genetic correlation between trait x and y; σ_{py} = Phenotypic standard deviation of trait y.

Correlated response to selection was expressed as a percentage of genetic gains for each of the traits measured.

Results

Correlation of traits in DMR ESR-W and DMR ESR-Y maize populations

Correlation of traits under stem borer infested condition is shown in Table 1. In DMR ESR-W, phenotypic correlations were negative and significant for plant height and plant aspect, plant height and ears per plant, and plant aspect and grain yield, but positive for plant height and grain yield, plant aspect and ears per plant, and ears per plant and grain yield. DMR ESR-Y followed the same trend except that phenotypic correlation between ears per plant and plant height was positive and not significant. There was a negative and significant phenotypic correlation between ears per plant and plant aspect (-0.24**) in this maize population. There was a moderate genotypic correlation between days to silking and grain yield in DMR ESR-W (rg = 0.44) and DMR ESR-Y (rg = 0.42). In DMR ESR-Y, the phenotypic correlation between days to silking and plant height was positive and significant (0.20**) but negative between days to silking and grain yield (-0.08*).

Genotypic correlations between agronomic traits and damage parameters were high and negative for days to silking with cob damage (-0.59), days to silking and leaf feeding (-0.51), plant height and stem tunneling (-0.75), and for stem tunneling and ears per plant (-0.75) in DMR ESR-W. In DMR ESR-Y, genotypic correlations were high between stem tunneling and grain yield (-0.52), and stalk breakage and plant height (0.36), but low for stalk breakage with grain yield (-0.18). However, phenotypic correlations

Table 2 - Predicted responses to selection for DMR ESR-W at 10% selection intensity under stem borer infested condition at Ibadan during 2008 and 2009 seasons.

Traits	Years/ Cycle	Gains/ Cycle	Gains/ Generation	Gains/ Generation (%)
Days to 50% silking	3	1.69	0.56	1.13
	2	1.69	0.85	1.69
Plant height (cm)	3	7.70	2.57	1.78
	2	7.70	3.85	2.66
Plant aspect (1-9)	3	0.22	0.07	1.41
	2	0.22	0.11	2.11
Ears per plant (no.)	3	0.03	0.01	1.34
	2	0.03	0.02	2.01
Grain Yield (t/ha)	3	0.42	0.14	4.03
	2	0.42	0.21	6.05
Dead heart (%)	3	-0.02	-0.01	-0.37
	2	-0.02	-0.01	-0.56
Leaf feeding (1-9)	3	0.02	0.01	0.10
	2	0.02	0.01	0.15
Stalk breakage (%)	3	0.10	0.04	0.16
	2	0.10	0.06	0.25
Cob damage (%)	3	0.04	0.01	0.05
	2	0.04	0.02	0.07
Stem tunneling (%)	3	-0.01	0.00	-0.01
	2	-0.01	0.00	-0.02
RSI	3	0.04	0.01	0.18
	2	0.04	0.02	0.26

RSI: Rank Summation Index, (1-9) 1: Excellent, 9: poor

were significant but low for days to silking and stem tunneling (-0.11**), stem tunneling and plant aspect (0.13**), stalk breakage and plant height (0.09*), and leaf feeding and grain yield (-0.18**). Furthermore, phenotypic correlations were low although significant among damage parameters. For instance, values obtained for DMR ESR-W were 0.09* for stem tunneling with stalk breakage, 0.12* for stem tunneling with cob damage, 0.08* for stalk breakage with cob damage and 0.09* for leaf feeding with stem tunneling. Similarly, low but significant phenotypic correlations were obtained for DMR ESR-Y, ranging from 0.06* between cob damage and stem tunneling to 0.15* for cob damage and leaf feeding. Generally, phenotypic correlations were lower than their corresponding genotypic correlations for almost all the traits studied in both maize populations.

RSI had positive phenotypic correlations with damage parameters, but negative correlations with agronomic traits in both maize populations. The correlations were significant in DMR ESR-W except between RSI and cob damage, however, they were much lower and not significant in DMR ESR-Y maize population (Table 1). Genotypic correlation on the other hand was positive between RSI and leaf feeding, and between RSI and stem tunneling, but negative for other damage parameters in DMR ESR-W. Genotypic correlation coefficient was high between RSI and days to 50% silking (-0.46), plant aspect (0.71), grain yield (-0.85), stem tunneling (0.88) in DMR ESR-W and plant aspect (-0.62), ears per plant (-0.66) and stalk breakage (-0.41) in DMRESR-Y.

Genetic gains and correlated responses to selection for DMR ESR-W and DMR ESR-Y maize populations

Predicted responses to selection using three seasons and a modification involving two seasons per cycle, with a parental control of one for DMR ESR-W and DMR ESR-Y maize populations, are shown in Table 2 and 3, respectively. Expected gains from selection for the traits measured ranged from -0.02 for stem tunneling to 6.05 for grain yield using two seasons per cycle in DMR ESR-W (Table 2), and 0.05 for RSI to 3.36 for plant height in DMR ESR-Y (Table 3). For both populations, selection will lead to an increase in grain yield and plant height. A reduction of 0.56% and 0.02% is expected in dead heart and stem tunneling respectively in DMR ESR-W when two seasons are used to complete a cycle. RSI is expected to give better gains than single trait selection in DMR ESR-W. For instance, overall gain of 0.26% is expected from RSI using two seasons per cycle, while only a reduction of 0.02% is expected using stem tunneling alone. However, reverse was the case in DMR ESR-Y where gains from single trait selection were much higher than from RSI (Table 3). Genetic gains from DMR ESR-Y were lower compared to gains in DMR ESR-W. In both maize populations, the modification of two seasons per cycle gave better gains per generation.

Correlated responses to selection expressed as percentage of expected gain for the traits measured

Table 3 - Predicted responses to selection for DMR ESR-Y at 10% selection intensity under stem borer infested condition at Ibadan during 2008 and 2009 seasons.

Traits	Years/ Cycle	Gains/ Cycle	Gains/ Generation	Gains/ Generation (%)
Days to 50% silking	3	1.28	0.43	0.86
	2	1.28	0.64	1.29
Plant height (cm)	3	11.78	3.92	2.24
	2	11.78	5.89	3.36
Plant aspect (1-9)	3	0.09	0.03	0.70
	2	0.09	0.05	1.05
Ears per plant (no.)	3	0.01	0.00	0.21
	2	0.01	0.00	0.32
Grain Yield (t/ha)	3	0.15	0.05	1.51
	2	0.15	0.07	2.27
Dead heart (%)	3	0.00	0.00	0.24
	2	0.00	0.00	0.35
Leaf feeding (1-9)	3	0.04	0.01	0.28
	2	0.04	0.02	0.42
Stalk breakage (%)	3	0.10	0.03	0.17
	2	0.10	0.05	0.26
Cob damage (%)	3	0.10	0.04	0.08
	2	0.10	0.05	0.12
Stem tunneling (%)	3	0.01	0.00	0.06
	2	0.01	0.00	0.10
RSI	3	0.01	0.00	0.03
	2	0.01	0.00	0.05

RSI: Rank Summation Index, (1-9) 1: Excellent, 9: poor

(Table 4) showed that direct selection for most of the traits would be better than indirect selection through any other trait. Instances where indirect selection may be effective in DMR ESR-W are in selecting for grain yield through plant aspect which will results in -158.18% gain and also grain yield through RSI which will give gains of -134.04%. Indirect selection of grain yield, days to 50% silking and plant aspect will also be effective through leaf feeding. In DMR ESR-Y, selection for grain yield through plant aspect will only result in a gain of -109.56% of the gain attainable through direct selection for grain yield itself, but indirect selection for days to silking through ears per plant will be effective in this population (159.73%).

Discussion

Knowledge of magnitude of association between characters is useful in making simultaneous selection for more than one character. Some traits of economic importance such as yield are complex in inheritance and so may involve several related characters (Stuber and Moll, 1969). For improvement of pest resistance and grain yield, it is necessary to know the magnitude and direction of relationships among resistance parameters, grain yield and some other important traits as this aids selection. The degree of correlation expresses the extent to which two characters are influenced by the same gene. The positive and significant genotypic correlation between grain yield and plant height as well as days to flowering under infested condition implies that genes that cause delay in flowering also increase plant height as well as grain yield. It also indicates that taller and late maturing plants have better grain yield. This was also observed by some earlier workers (Holthaus and Lamkey, 1995; Betran and Hallauer, 1996; Odiyi, 2007). However, tall plants are not desirable because they are liable to lodging under tropical rain-storm conditions. This perhaps explains the negative and significant correlation observed between plant height and plant aspect, and the positive relationship between plant height and stalk breakage in this study since tall progenies will likely attract undesirable plant aspect rating levels and they can easily break. The positive correlation between ears per plant and grain yield indicates that the higher the number of cobs, the higher the yield, a known phenomenon since yield is a function of cob number and weight. The positive correlation between plant and ear height suggests that either of the two can be used to measure height.

Generally, negative correlations were obtained between grain yield and the damage parameters in both maize populations suggesting that selecting for reduced levels of damage will improve grain yield in these populations. Similar result was reported by Ajala (1994) and Ajala and Saxena (1994) for the spotted stem borer and by Gounou et al (1994) for stem and ear borers. Except for cob damage in DMR ESR-Y, other damage parameters had negative correlation with flowering indicating that later maturing genotypes tend to be more resistant than earlier ones as was also observed by Hudon and Chiang (1991), and

Table 4 - Correlated responses (expressed as percentage of expected gain) to selection for 10 traits of DMR ESR-W and DMR ESR-Y evaluated under stem borer infested condition at Ibadan during 2008 and 2009 seasons.

Traits	1	2	3	4	5	6	7	8	9	10
				DMR ESR-W						
1 Grain Yield (t ha^{-1})	100.00	41.48	39.01	-158.15	18.46	152.13	†	-79.75	-29.92	-134.04
2 Days to 50% silking	47.05	100.00	26.44	-87.26	-39.17	-216.64	†	-63.15	-170.30	-76.97
3 Plant height (cm)	33.49	20.02	100.00	-99.28	-49.70	73.55	†	53.84	7.53	-50.95
4 Plant aspect	-64.80	-31.53	-47.38	100.00	98.90	-193.07	†	76.54	-15.74	72.00
5 Ears per plant	-64.72	-15.79	-26.47	110.39	100.00	2.79	†	-69.79	28.48	-30.82
6 Leaf feeding	7.52	-9.45	4.24	-23.31	0.30	100.00	†	5.38	16.73	7.44
7 Stem tunneling	†	†	†	†	†	†	†	†	†	†
8 Stalk breakage (%)	-70.19	-49.01	55.19	164.41	-134.31	95.72	†	100.00	282.78	-21.31
9 Cob damage count (%)	4.98	-22.89	1.34	-5.86	9.49	51.56	†	33.31	100.00	-7.14
10 RSI	-53.48	-27.08	-23.68	70.10	-26.89	59.98	†	-9.66	-18.68	100.00
				DMR ESR-Y						
1 Grain Yield (t ha^{-1})	100.00	20.93	4.81	-109.56	101.94	†	-53.37	9.77	-1.53	-13.89
2 Days to 50% silking	81.73	100.00	0.97	-22.29	159.73	†	-14.45	-23.59	7.18	-64.28
3 Plant height (cm)	20.12	1.04	100.00	-138.25	-82.56	†	-6.40	48.78	31.82	-14.45
4 Plant aspect	-73.20	3.81	-22.08	100.00	-73.90	†	44.51	-19.94	-15.61	-73.25
5 Ears per plant	53.51	21.47	-10.36	-58.06	100.00	†	-20.32	-0.38	-11.88	-53.40
6 Leaf feeding	†	†	†	†	†	†	†	†	†	†
7 Stem tunneling (%)	-44.30	-1.32	-5.08	56.37	-32.13	†	100.00	-12.05	-4.49	1.22
8 Stalk breakage (%)	22.94	-14.18	27.37	-70.08	-1.70	†	-34.08	100.00	28.23	-90.08
9 Cob damage count (%)	-5.68	6.83	28.23	-86.73	-84.00	†	-20.09	44.63	100.00	40.79
10 RSI	-5.26	-6.24	-1.31	-41.53	-38.53	†	0.56	-14.54	4.16	100.00

† not estimated, RSI: Rank Summation Index, Negative signs indicate direction of relationship

Schulz et al (1997) for the first generation of European corn borer and by Odiyi (2007) for *S. calamistis* and *E. saccharina*. The negative relationship between plant height and stem tunneling tend to suggest that tall plants are more resistance to stem tunneling. This thus explains why DMR ESR-Y which is taller than DMR ESR-W had lesser tunneling level. However, this may be misleading because stem tunneling was estimated in this study as a proportion of plant height itself and not as absolute values. Therefore, the taller the genotype, the lesser the percentage value to be obtained even for the same extent of tunneling when compared with a shorter genotype. The significant negative correlation obtained between leaf feeding and days to 50% silking is not clearly understood as it suggest that excessive leaf feeding could reduce days to flowering, an uncommon phenomenon. Generally, clipping and cutting of leaves as usually obtained in leaf feeding delay flowering in maize. The negative correlation between stem tunneling and ears per plant is as expected. This is because when vascular bundles are destroyed, the flow of nutrient from the source to the sink which is the ear shoot in this case is disrupted, and this consequently affects cob formation as well as grain yield.

The positive and significant correlations among most damage parameters although with low coefficients indicate that there is a strong relationship among them, and that one damage can easily lead to the other. The positive correlation between stem tunneling and stalk breakage in the maize populations was expected because tunneling reduces the ability of the plant to stay erect. Positive phenotypic correlation between stem tunneling and cob damage in DMR ESR-Y though significant was rather too low for any practical consideration. The positive relationship of RSI with stem tunneling and leaf feeding, and its negative correlation with grain yield, was as a result of its construction from these traits. It therefore implies that progenies with low tunneling level, low leaf feeding rating and high grain yield will have low ranking value which is desirable because progenies with high ranking values will be dropped in the cause of selection. In general, genotypic correlations were higher than their corresponding phenotypic counterparts for the traits measured showing that relationship among the traits is under genetic effect. This confirms some earlier reports (Ajala and Saxena, 1994; Ajala et al, 2009; Odiyi, 2007). However, estimates of genetic correlation are usually subject to large sampling error and are therefore seldom very precise. Genetic correlation is strongly influenced by gene frequency and so may differ markedly in different populations (Falconer, 1989).

Reasonable gains are expected in the two maize populations if two seasons are used to complete a cycle of selection. However, these gains will be relatively low for the resistance traits. Nonetheless, selection for resistance positively influence grain yield in this study. Similar results were reported by Sandoya et al (2008), but this is contrary to the report by Sheri et al (2004) and Novoa and Russell (1988) who reported that selection for stem borer resistance reduced grain yield in their studies. Grain yield increase of about 210 kg ha^{-1} will be obtained per generation in DMR ESR-W using two seasons/cycle which is similar to the gain obtained by Ajala et al (2009). The usefulness of two seasons per cycle depends on the time and resources saved (Ajala et al, 2009), and most importantly how much gain is expected. If gain is very low, the modification is not worthwhile owing to the extra workload involved.

Improvement of resistance traits along with grain yield may be possible using an index selection. Index selection has been reported to improve a crop population *per se* (Weyhrich et al, 1998; Ajala, 2010). Use of RSI gave an appreciable response in the white population with two seasons/cycle. A similar result was observed by Ajala (2010) who reported that response from RSI constructed from emergence index, days to 50% silking and plant stand at harvest was much higher than when each of the three traits was selected singly in the improvement of three maize populations. However, in DMR ESR-Y, response from RSI was much lower than when any of the traits was selected singly. Nonetheless, Ajala et al (2010) stated that predicted gains for single or multiple trait selection will only at best, be theoretical while the actual comparison of the initial and final cycles of selection will aid the determination of actual selection differentials for traits of interest. Oft-times, data generated through ranking may not always be normally distributed but the use of appropriate transformation will correct this (Ajala, 2010). The RSI values used in this study were therefore normalized using log transformation before analysis. RSI has been reported to be a useful index due to its simplicity of use and for being weight-free (Ajala et al, 1995; Ajala, 2010).

Indirect selection for increase in grain yield through any of the damage parameters would be successful if there is substantial negative genetic correlation between grain yield and the damage parameter. Direct selection for grain yield would give better result than indirect selection through any other trait in the two maize populations. Since yield is a complex character influenced by environment, related characters with high heritability, may as well serve as better indicators of the grain yield potential of a progeny (Robinson et al, 1951). Indirect selection of grain yield through RSI resulting in better gains in DMR ESR-W further shows the effectiveness of RSI for improvement of the population for resistance to the two borer species. Selection for resistance would however increase the overall appeal of the plants, referred to as plant aspect in DMR ESR-W. This is in agreement with the observation of Sandoya et al (2010) that selection for resistance to MCB significantly reduced cob damage, days to silking, plant and ear height, and 100-kernel weight, but early vigor was increased.

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