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Potential in a collection of adapted and exotic tropical maize inbred lines as resistance source for stem borers

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Lepidopteran borers are the most devastating field pests of maize in West and Central Africa. In view of the rapidly changing climate which favours an upsurge of more destructive biotypes of insect pests, diverse sources of resistance from different genetic backgrounds need to be harnessed for crop improvement purposes. Forty tropical maize inbreds comprising adapted and exotic lines from International Institute of Tropical Agriculture (IITA) and International Maize and Wheat Improvement Centre (CIMMYT) maize breeding programs were evaluated for resistance to two species of stem borers- *Sesamia calamistis* and *Eldana saccharina* at Ibadan and Ikenne, Nigeria, under artificial infested and non-infested conditions in 2015 and 2016 cropping seasons. The experiment was laid out in a randomized complete block design in three replicates. Data were collected on agronomic traits and stem borer damage parameters. On average, the CML lines had relatively higher grain yield despite the high level of stem tunneling, stalk breakage and cob damage, with the exception of CML 67 (0.19 ton/ha) and CML 71 (0.06 tons/ha). BD 74-395 had the highest yield (1.45 t/ha) among the BDs, despite its high stalk breakage and cob damage. Among IITA lines, KU1414SR/SR, 1368 and 9030STR were the highest yielding with grain yields of 1.71, 1.39 and 1.19 t/ha, respectively. Moderate to high heritability was observed among the stem borer damage parameters. Negative genetic gain was observed in stem tunneling. Mean square of lines was significant for all the traits studied. The top-performing inbreds were similarly grouped using the rank summation index and principal component analysis. The exotic lines had good adaptability and showed potential as sources of stem borer resistance, and could therefore be explored in breeding programs for resistance to Eldana and Sesamia.

Key words: *Eldana saccharina*, maize inbreds, resistance, *Sesamia calamistis*, tropics.

INTRODUCTION

Maize is the most widely cultivated staple food crop in sub-Saharan Africa (SSA), providing up to 70% of the daily calorie intake for over 300 million people (FAO, 2007). In West and Central Africa (WCA), maize has evolved from subsistence to a cash crop (Fajemisin, 2014). Nigeria is the largest producer of maize in SSA with current estimates for green and grain maize production at 0.74 and 10.8 million tonnes respectively

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(FAO, 2017). Numerous biotic and abiotic stresses limit maize yields in SSA (Semagn et al., 2015) depriving resource poor farmers of 10-100% of potential yield.

Stem borers are among the most damaging insect pests of maize causing yield losses of 20-100% in susceptible germplasms (Bosque-Perez and Mareck, 1990; Schulthess and Ajala, 1999; Oloyede-Kamiyo, 2013). In Africa, the four most destructive species are the African stalk borer (*Busseola fusca,)* the pink stem borer (*Sesamia calamistis),* the sugar cane borer (*Eldana saccharina),* and the spotted stem borer *(Chilo partellus)*. The first three are African, and are present in most countries of SSA (Bosque Perez and Marek, 1991), while *C. partellus* originated in Asia and was accidentally introduced to East Africa (Tams, 1932). Stem borer resistant genotypes showing specific and cross resistances to the prevalent borer species have been developed for WCA, and East and Southern Africa (ESA) (Ajala et al., 2008; Murenga et al., 2015).

Sourcing of novel alleles in introduced or exotic germplasm has been identified as an effective breeding strategy for diversifying the genetic base of adapted materials and for raising the odds of developing superior hybrids (Dhliwayo et al., 2009; White et al., 2011; Adebayo et al., 2013). Recurrent selection procedure has been used extensively in concentrating genes of resistance into the maize genepool. Exchange of tropical maize germplasm in collaborative research efforts in Africa with International Institute of Tropical Agriculture (IITA) and International Maize and Wheat Improvement Centre (CIMMYT), and partners has fast-tracked varietal development and release in recipient countries through partial and total inclusion of introduced germplasms. Many newer tropical hybrids contain at least some exotic germplasm, often as a part of a hybrid pedigree (Goodman, 1999). Tropical maize has been reported to combine wide geographic range, opportunities for genetic germplasm improvements, and higher potential biomass yields attributed to perennial grasses (White et al., 2011).

Following combining ability studies involving inbreds from IITA and CIMMYT, some CIMMYT lines were identified to have potentials for improving IITA’s early maturing and intermediate maturing germplasms for drought and low nitrogen tolerance (Adebayo et al., 2013; Ifie et al., 2015; Badu Apraku et al., 2016). However, limited studies have been conducted to examine the potentials of adapted and exotic non-borer maize inbred lines for their direct use in hybrid combinations aimed at stem borer resistance efforts. The effects of the rapidly changing climate which favours proliferation and evolution of new strains of insect pests call for rapid development of better forming varieties with horizontal resistance to cope with changing times. This study was carried out to (i) explore potentials in a collection of IITA and CIMMYT maize inbreds for stem borer resistance, and (ii) assess the performance of the exotic inbreds in the forest ecology of WCA.

MATERIALS AND METHODS

Germplasm

Forty maize inbred lines comprising of both adapted and exotic materials were used for this study. The maize lines were of different maturity groups and possess different levels of resistance to various field stresses. Sixteen of the lines were introduced from CIMMYT Mexico and Kenya, while others are lowland adapted lines from IITA, Nigeria. The attributes and stress adaptation of the lines is shown in Table 1.

Experimental protocol

The 40 maize inbred lines were evaluated in 2015 and 2016 cropping seasons (Table 1). Evaluations were carried out under artificial stem borer infested and non-infested conditions at Ibadan (Lat.7° 22'N, Long. 03° 58'E) in the derived savanna and Ikenne (Lat. 6° 54'N, Long.03° 42'E) in the humid forest zone of Nigeria. A Randomized Complete Block Design (RCBD) with three replications was used. In Ibadan, a plot was a single row of 7 m length. Half plot technique was employed by dividing each row into two halves of 3 m each, separated by 1 m in the middle. Spacing was 0.75 m between rows and 0.25 m within row. Two seeds were planted per hole but thinned to one plant per hill at three weeks after planting (WAP) just before infestation. A maximum of 13 plants per plot was obtained resulting in a plant density of 53,333 plants/ha. Each plant in the first half was artificially infested with egg masses of *S. calamistis* and *E. saccharina,* containing 30-40 eggs at black head stage, while the other half was left uninfested (control). *Sesamia* was introduced 3WAP, while plants were infested with *Eldana* at flowering. Evaluations in Ikenne were planted in 5 m single row plots and non-infested. All agronomic practices were carried out as appropriate at both locations.

Data collection

Number of days to 50% silking was determined as the number of days from planting to the day when half of the plants in a plot produced silk. Leaf feeding damage was rated on the infested plots at 3 weeks after infestation (WAI) on a scale of 1-9 based on visual rating, with 1 representing 0-5% defoliation of the leaf area of the plants in a plot, and 9 for 80-100% defoliation of the entire leaf area. Plant aspect was rated per plot after anthesis on a scale of 1 - 9, with 1- representing vigorous and appealing plants without lodging, leaf defoliation, nor disease symptoms 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. Plant height was measured in centimeters (cm) as average of five competitive plants as distance from the ground level to the collar of the upper most leaf after flowering. Stalk breakage was counted at maturity as number of broken stalks above the first ear per plot and expressed as percentage of plant stand. Cob damage was recorded at harvest as the number of damaged cobs due to stem borer infestation and expressed as percentage of number of ears at harvest. Stem tunneling was assessed on five competitive plants per plot after harvesting by splitting each plant stalk longitudinally and measuring the length tunneled by the insect larvae. The length was then expressed as percentage of the plant height.

After taking cob weights, small quantities of shelled grains were taken per plot to determine grain moisture content using Dickey-John moisture meter, Mini GAC® 2500, United States. Grain yield (t/ha) adjusted to 15% moisture content, was calculated from ear field weight (FWT) per plot, assuming 80% shelling percentage. Percentage yield reduction was estimated from grain yield on

Table 1. Source, kernel colour and attributes of the maize inbred lines used for the evaluation.

Lines	Source	Kernel colour	Attributes
CML 67	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 70	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 139	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 334	CIMMYT Mexico	White	Resistant to SWCB/FAW
CML 331	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 345	CIMMYT Mexico	White	Resistant to SCB/FAW
CML 71	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 338	CIMMYT Mexico	Yellow	Resistant to SWCB/FAW
CML 346	CIMMYT Mexico	White	Resistant to SCB/FAW
BD74-219	CIMMYT Kenya	Yellow	Elite yellow
BD74-59	CIMMYT Kenya	White	Low nitrogen tolerant
BD74-221	CIMMYT Kenya	Yellow	Elite yellow
BD74-164	CIMMYT Kenya	Yellow	Drought tolerant
BD74-162	CIMMYT Kenya	Yellow	Drought tolerant
BD74-217	CIMMYT Kenya	Yellow	Elite yellow
BD74-161	CIMMYT Kenya	Yellow	Drought tolerant
BD74-395	CIMMYT Kenya	White	Low nitrogen tolerant
TZEI 2	IITA Nigeria	White	Early maturing
TZEI 158	IITA Nigeria	Yellow	Early maturing
TZEI 9	IITA Nigeria	White	Early maturing
TZEI 18	IITA Nigeria	White	Early maturing
TZEI 46	IITA Nigeria	White	Early maturing
TZEI 89	IITA Nigeria	White	Early maturing
TZEI 5	IITA Nigeria	White	Early maturing
TZEI 1	IITA Nigeria	White	Early maturing
TZEI 60	IITA Nigeria	White	Early maturing
TZEEI 29	IITA Nigeria	White	Extra-early maturing
TZEEI 21	IITA Nigeria	White	Extra-early maturing
TZEEI 13	IITA Nigeria	White	Extra-early maturing
TZEEI 14	IITA Nigeria	White	Extra-early maturing
TZEEI 55	IITA Nigeria	White	Extra-early maturing
TZEEI 15	IITA Nigeria	White	Extra-early maturing
5012	IITA Nigeria	White	Drought tolerant and streak resistant
4001	IITA Nigeria	Yellow	Striga resistant , low nitrogen tolerant
9071	IITA Nigeria	White	Striga resistant, drought tolerant and streak resistant
1368	IITA Nigeria	White	Streak resistant, striga resistant and drought tolerant
5057	IITA Nigeria	White	Drought tolerant and streak resistant
9450	IITA Nigeria	Yellow	Striga resistant, streak resistant, drought and low nitrogen tolerant
9030STR	IITA Nigeria	White	Striga resistant, drought tolerant and streak resistant
KU1414SR/SR	IITA Nigeria	Yellow	Drought tolerant and streak resistant

SCB- Southern corn borer; SWCB- South western corn borer; FAW- Fall armyworm; SR- Streak resistance.

infested and non-infested plots and adjusted by the extent of stem tunneling to obtain level of tolerance of the maize inbreds according to Ajala (1992).

Data analyses

Percent data were transformed using arcsine before analysis. Means and ranges were estimated. Means of the maize lines were separated using the least significant difference (LSD). Analysis of variance (ANOVA) was performed using Proc Mixed of SAS, version 9.1. Combined ANOVA was conducted separately for data collected under infested and non-infested conditions from which estimates of variance components were generated. Broad-sense heritability was estimated from the variance components on entry-mean basis. The location-year combinations were considered as environment in the ANOVA. The effects of environments, replication, and environment by lines interaction were considered random, while effect of maize lines was considered fixed.

Expected gains from selection (Gs) and standard error of heritability were computed according to Hallauer and Miranda (1988). Expected gains (Gs) was estimated as:

$Gs = k\ \sigma^2g/\ \sigma p$

Where k = standardized selection differential at 20% selection intensity (k=1.399), σ^2g = genotypic variance, and σp denotes square root of phenotypic variance. Gains were expressed as percentage of means for easier comparison.

Rank Summation Index (RSI) of Mulumba and Mock (1978) was used to rank the maize lines using plant aspect, stalk breakage, grain yield, cob damage and tolerance as selection criteria. This was used to select the top maize lines based on 20% selection intensity. Principal component analysis was also conducted to determine contribution of traits to the variation observed using data from the infested plots. The traits contributing most to the variation were used to perform cluster analysis on the inbreds. Similarity was measured based on Euclidean distance.

RESULTS

Mean performance of the maize inbreds is shown in Table 2. The CMLs had relatively good grain yield except CML 67 (0.19 tons ha^{-1}) and CML 71 (0.06 tons ha^{-1}), despite the high level of stem tunneling, stalk breakage and cob damage. CML334 had the highest yield (4.46 tons ha^{-1}) followed by CML 331 (2.42 tons ha^{-1}). Among the BDs, BD 74-395 was the highest yielding (1.45 tons ha^{-1}) despite the high stalk breakage and cob damage recorded. Among the IITA lines, KU1414SR/SR, 1368 and 9030STR had significantly high mean grain yield of 1.71, 1.39 and 1.19 tons ha^{-1} respectively. Among these lines, 1368 had the lowest stem tunneling and stalk breakage with moderate leaf feeding damage (Table 2).

Means of stalk breakage and cob damage were high among the maize lines (Table 3). Range was high for all the traits studied. Moderate to high heritability was observed for the damage parameters ranging from 30.51% for tolerance to 68.9% for cob damage except for stem tunneling (Table 3). Heritability was however low for grain yield under stem borer infestation (10%). Genetic gains were generally low for the damage parameters. Only stem tunneling had negative genetic gain. Heritability was generally low among the agronomic traits measured with increased genetic gains. Days to 50% silking (27.25%) had the highest broad-sense heritability value.

Combined analysis of variance revealed significant mean squares for the maize lines, and line × environment interaction for all the traits under infested and non-infested conditions (Table 4). Mean square of environment was significant for grain yield both under infested and non-infested conditions. Mean square for environment was significant for all the damage parameters except for stalk breakage. The top 20% maize lines selected by RSI are shown in Table 5. Line 1368 was selected as the best followed by 9450 and 4001. CML 334, a stem borer resistance source ranked fifth on the list. Out of the eight selected lines, five were selected from IITA lines, while two were selected from the BD lines. Only CML334 was selected among the CML lines.

From the result of principal component analysis, PCA 1, 2 and 3 accounted for 90% of the variation (Table 6) with days to 50% silking, plant height, yield loss, tolerance, cob damage and stalk breakage being responsible for this variation. Based on these traits, a dendrogram was developed (Figure 1). At 30% similarity distance, six distinct groups were identified. It is worth noting that the best 8 entries (on 20% selection intensity) were grouped into the best three clusters (G2, G3, G4) based on data from infested plots (Figure 1). Inbred CML 334, the only CML among the best 8 inbreds, stood alone in a group (G3) with the highest grain yield despite its high percentage cob damage and stalk breakage. Inbred 1368, 4001, BD 74-219, BD74- 395 and KU1414SR/SR also formed one of the best groups (G4) with good grain yield and tolerance level and low stalk breakage. Inbred 9450 and TZEI 2 clustered in G2 (Figure 1).

DISCUSSION

Mean performance of the lines, the wide ranges and the moderate to high heritability of most of the stem borer damage parameters showed a high level of variability among the maize lines for stem borer resistance and that the traits are under genetic control. The wide range is expected because the lines are from diverse background, maturity group as well as diverse stress adaptations. The high heritability for the damage parameters indicated that rapid progress would be achieved in selection. Ajala (1992) also reported moderate heritability for resistance to the spotted stem borer, *Chilo partellus.* The low heritability for plant aspect, plant height and grain yield under infestation indicated that expression of the traits is greatly influenced by the environment and direct selection for the characters may be ineffective. The low heritability for grain yield under infested condition was also reported by Oloyede-Kamiyo (2013) in DMR ESR-Y maize population under stem borer infestation.

The CMLs having high grain yield despite the high level of damage showed that they are tolerant to stem borer infestation. The CML lines were actually developed at CIMMYT for resistance to different species of stem borers. BD74-395 with high grain yield despite the high stalk and cob damage showed that it is a stem borer resistance source. Inbred 1368 is also a promising source of stem borer resistance. It is used as a general check at IITA for various field stresses. Hence, inbred CML 334 and BD74-395 are good exotic stem borer resistance lines which could be adopted in stem borer breeding programs in the tropics. White et al. (2011) reported that hybrids derived from local × exotic germplasm (temperate adapted × tropical parents) successfully combined the high biomass potential of

Table 2. Mean performance of the 40 maize inbreds evaluated under artificial stem borer infestation in Ibadan in 2015 and 2016.

Inbreds	Days to 50% silking	Plant height (cm)	Plant aspect (1-9)	Stem tunneling (%)	Leaf feeding damage (1-9)	Stalk breakage (%)	Cob damage (%)	Grain yield (tons/ha)	*Tolerance
1368	63.33	144.00	3.67	8.00	3.00	0.00	36.67	1.39	-1.37
4001	60.33	132.67	3.67	13.67	3.00	0.00	21.67	0.68	0.81
5012	57.67	155.00	4.33	11.00	3.33	30.00	75.40	0.65	4.18
5057	69.67	112.67	5.00	5.67	4.33	9.70	66.67	0.48	-20.00
9030STR	62.67	106.17	4.67	8.95	3.17	15.06	52.22	1.19	-5.26
9450	63.00	116.67	3.00	4.33	3.67	9.09	0.00	0.81	-13.86
BD74-161	61.00	89.33	5.33	6.00	3.00	72.22	83.33	0.27	-9.52
BD74-162	63.17	102.67	4.33	7.17	2.83	0.00	85.71	0.75	-25.31
BD74-164	58.33	144.33	4.33	11.33	2.40	15.38	54.17	0.94	-8.28
BD74-217	64.00	96.67	4.33	7.33	3.00	34.07	56.35	0.50	-8.14
BD74-219	58.00	148.00	2.67	12.67	2.00	10.26	37.50	1.30	1.51
BD74-221	66.50	94.83	4.00	8.78	3.00	9.26	64.29	0.88	-9.02
BD74-395	60.67	138.83	4.00	5.35	3.50	19.44	57.80	1.45	-12.80
BD74-59	71.33	100.67	5.33	12.00	4.67	33.33	25.00	0.41	-
CML 139	59.33	127.33	5.00	2.67	2.67	5.56	0.00	0.44	0.00
CML 331	63. 00	124.00	4.17	14.45	3.00	6.48	85.00	2.42	-1.71
CML 334	65.00	124.83	4.50	5.12	3.50	28.24	47.44	4.46	-66.65
CML 338	59.67	165.67	3.17	14.18	3.17	15.81	57.14	1.86	0.82
CML 345	60.67	107.83	4.50	16.82	3.50	7.41	83.33	0.84	-5.46
CML 346	60.67	115.00	5.00	15.00	4.67	14.69	25.00	0.45	1.33
CML 67	64.67	76.33	4.33	0.00	4.33	36.36	33.33	0.19	.-
CML 70	65.67	107.00	4.33	10.90	2.67	5.56	75.40	0.68	2.39
CML 71	71.33	76.33	5.33	5.33	3.33	6.67	155.56	0.06	10.00
KU1414SR/SR	67.33	127.17	3.83	10.35	2.50	10.37	56.67	1.71	-1.00
TZEEI 13	57.83	111.00	4.50	12.57	3.33	33.84	66.94	0.78	7.30
TZEEI 14	55.17	98.17	4.67	3.62	3.50	10.28	50.40	0.78	-0.48
TZEEI 15	60.00	90.50	5.50	5.00	2.83	0.00	40.00	0.22	6.00
TZEEI 21	55.00	121.17	5.00	8.35	2.83	21.69	86.67	0.66	5.75
TZEEI 29	56.67	117.33	6.00	11.13	3.17	43.91	80.16	0.75	-0.78
TZEEI 55	57.50	101.50	5.50	1.00	4.25	32.37	78.57	0.21	-18.75
TZEI 1	59.67	126.67	4.00	10.72	3.50	16.92	66.87	1.10	-1.76
TZEI 158	56.17	94.67	5.83	0.00	3.33	4.23	83.33	0.36	.-
TZEI 18	58.00	113.50	4.33	6.60	3.83	34.89	81.11	0.91	1.45
TZEI 2	58.17	103.50	4.00	12.10	3.50	11.03	55.56	1.18	-8.43
TZEI 46	59.00	113.33	5.17	7.07	3.83	40.28	87.96	0.69	-107.40
TZEI 5	60.33	110.17	5.00	10.88	3.00	37.15	68.52	0.73	-1.13
TZEI 60	62.17	144.00	4.83	13.75	3.17	21.17	48.33	0.46	-1.47
TZEI 89	56.33	120.33	5.17	11.48	3.83	42.58	61.67	0.71	7.21
TZEI 9	54.67	86.50	5.50	0.00	3.50	30.70	61.91	0.96	.-
Mean	60.74	115.05	4.58	8.72	3.28	19.85	63.79	1.01	-7.94
S.E	0.34	1.69	0.08	0.54	0.08	1.61	3.1	0.11	3.18
LSD (0.05)	6.25	30.61	1.41	0.23	0.97	0.45	0.49	1.52	65.13

*The lower the value, the better the tolerance. The negative values are equated to zero.

tropical maize with the genetic improvements from the past century of corn breeding for high grain yields in temperate environments.

The low genetic response for the traits studied indicates slow progress from selection. However, the estimated negative gains for stem tunneling indicated that stem tunneling will reduce with selection. The significant means squares of lines for days to flowering, plant height and

Table 3. Mean± S.E, range and estimate of genetic variability of characters of the maize inbreds under artificial stem borer infestation in Ibadan in 2015 and 2016.

Traits	Mean ± S.E	CV (%)	Range	H^2 (%) ± S.E	Expected gain	Gain as% of mean
Days to 50% silking	60.74±0.34	6.36	53.0 -75.0	27.25± 0.45	0.94	1.54
Plant height (cm)	115.05±1.69	16.29	63.0-172	3.02± 14.28	0.52	0.85
Plant aspect (1 – 9)	4.58±0.08	19.22	2.0-8.0	8.12± 0.03	0.06	0.10
Stem tunneling (%)	8.72±0.54	54.97	0- 36.3	-5.75± 0.001	-0.01	-0.01
Leaf feeding damage (1 – 9)	3.28±0.08	18.08	0-5.0	49.54± 0.01	0.29	0.48
Stalk breakage (%)	19.85±1.61	69.59	0-100.0	42.90± 0.003	0.13	0.21
Cob damage (%)	63.79±3.10	31.65	0-100.0	68.86± 0.002	0.20	0.32
Grain yield (t/ha)	1.01±0.11	25.36	0- 11.86	10.00± 0.06	0.11	0.18
Tolerance	-7.94±3.18	-326.1	-350- 24.99	30.51± 24.03	7.79	12.82

CV: Coefficient of variation; S.E: Standard error; H^2: Broad-sense heritability.

Table 4. Mean squares from combined analysis of variance of characters of the 40 maize inbreds evaluated under artificial stem borer infestation at Ibadan and under non-infested condition at Ibadan and Ikenne in 2015 and 2016.

Source	df	Days to 50% silking	Plant height (cm)	Plant aspect (1-9)	Grain yield (tons/ha)	Leaf feeding damage (1-9)	Stem tunneling (%)	Stalk breakage (%)	Cob damage (%)	Tolerance
Infested condition										
Env	1	214.65**	214.40	0.51	124.93**	61.88**	0.10*	0.17	17.52**	284.21
Rep (Env)	4	49.86	1198.11	12.10	0.27	0.75	0.07	0.10	0.03	710.92
Inbreds	39	36.23**	905.44*	1.74**	4.07**	1.06**	0.04**	0.26**	0.25**	1993.8**
Env x Entry	32	26.36*	878.26**	1.60**	3.69**	0.53**	0.04**	0.15**	0.08	1385.3**
Error	126	14.94	358.58	0.76	0.89	0.36	0.02	0.08	0.09	638.93
Non-infested condition										
Env	3	33.40	28930.02**	76.74**	25.68**	-	-	-	-	-
Rep (Env)	8	29.96	1847.40	4.79	0.77	-	-	-	-	-
Inbreds	38	36.54**	1283.69**	2.40**	0.97**	-	-	-	-	-
Env x Entry	85	30.92**	1174.53**	2.08**	1.24**	-	-	-	-	-
Error	236	14.00	410.99	0.69	0.29	-	-	-	-	-

*, **: Significant at P = 0.05 and 0.01 respectively.

Table 5. Means of the top performing inbreds (20% selection intensity) from the evaluation of the 40 maize inbreds under stem borer infested condition at Ibadan in 2015 and 2016.

Selected inbreds	Gain yield (tons/ha)	Plant aspect (1-9)	Cob damage (%)	Stalk breakage (%)	*Tolerance	RSI
1368	1.4	4	36.7	0	-1.3	36
9450	0.8	3	0.0	9.1	-13.0	48
4001	0.7	4	21.7	0.0	0.8	58
BD74-219	1.3	3	37.5	10.3	1.5	58
CML 334	4.5	4	47.4	28.2	-66.7	58
TZEI 2	1.2	4	55.6	11.0	-8.4	61
BD 74-395	1.5	4	57.8	19.4	-12.8	62
KU1414SR/SR	1.7	4	56.7	10.4	-1.0	63

*The lower the value, the better the tolerance. Negative values are equated to zero.

grain yield was also reported by Mary (2016) for tropicalized temperate maize lines under well watered and water-stress conditions. The significant mean squares of lines for all the traits studied suggested that the traits

Table 6. Percentage variation from the principal component (PC) analysis.

PC	Eigenvalue	% variance
1	5327.46	67.719
2	996.59	12.668
3	868.87	11.045
4	243.42	3.094
5	128.38	1.632
6	121.38	1.543
7	68.56	0.871
8	51.06	0.649
9	32.71	0.416
10	16.25	0.207
11	8.80	0.112
12	1.81	0.023
13	0.85	0.011
14	0.29	0.004
15	0.23	0.003
16	0.19	0.002
17	0.11	0.001

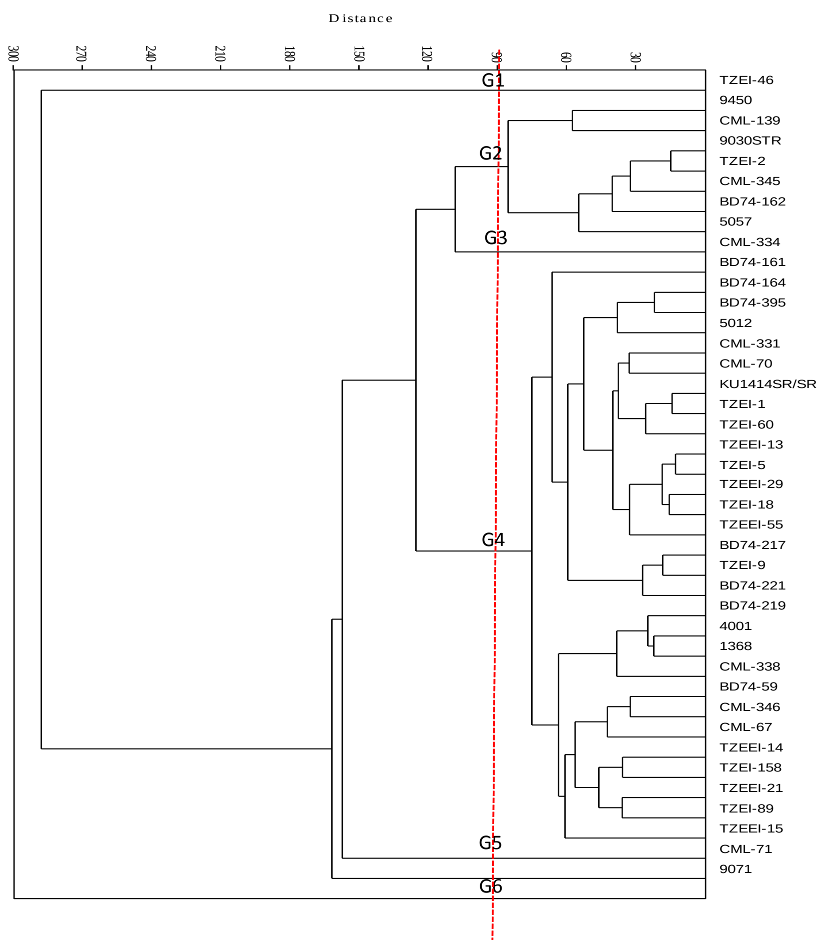

Figure 1. Dendrogram of the 40 maize inbred lines based on Euclidean similarity distance.

are under genetic control and improvement can be made. The significant line by environment interaction for the traits suggests that the lines responded differently in the test environments.

The RSI ranking selected lines with different genetic backgrounds from CIMMYT and IITA as the top 20%. BD74-395 is a low nitrogen tolerant line, while BD74-219 is an elite yellow inbred line and both are from CIMMYT, Kenya. CML 334 is a borer resistant line (resistant to southwestern corn borer and fall armyworm) from CIMMYT Mexico, while the others (1368, 9450, 4001, TZEI 2, KU1414SR/SR) are elite tropical lines tolerant to different field stresses from IITA, Nigeria currently used in hybrid production. This suggests good adaptation of the exotic lines in the low land ecology of WCA and also an indication that the lines have direct utility for breeding for resistance to *S. calamistis* and *E. saccharina.* Goodman (1999) reported that tropical germplasm has traditionally been used in the U.S. as a source of disease- and insect-resistance. Hallauer and Carena (2013), in a study involving four populations with 25% tropical germplasm and four populations with 100% exotic germplasm reported that the yield of the 25% tropical germplasm was significantly greater (average yield of 7.72 tons/ha) than that of the exotic (average yield of 6.47 tons/ha). They were therefore reported to have potential as alternative sources of germplasm for temperate environments.

The result of the cluster analysis complemented that of the RSI. Some of the lines selected as the best by RSI also cluster together in the dendogram. Ajala et al. (1995) stated that the possible limitation of RSI is its inability to indicate significant differences between ranks to enable classification of varieties into homogenous groups. Result of the present study suggested that the perceived limitation is not a hindrance to the use of RSI for selection purposes. In summary, there is existence of useful genes for adaptability and resistance to stem borers in the exotic maize inbreds which could be exploited for breeding purposes in WCA. Planned crosses involving IITA and CIMMYT inbreds could produce outstanding hybrids for commercialization in SSA.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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