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RESEARCH PAPER

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Resistance to the larger grain borer (*Prostephanus truncatus*) and yield performance in selected local maize landraces in Kenya

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Abstract

The larger grain borer (LGB) has continued to devastate maize grains especially in the dry and hot ecologies of Kenya. Resistance is a low cost environmentally sound avenue of pest management. Most of the improved cultivars are susceptible to the pest, and succumb to drought much faster. Local maize landraces are an important livelihood resource and form an alternative source of potential resistance for the LGB in these areas. The objective of this study was to evaluate selected local maize landraces for LGB resistance and yield performance. Laboratory screening was carried out for 25 germplasm at KARI-Kiboko field laboratory where the insects were also sourced. One hundred (100) grams of maize grains were infested with 50 unsexed LGB adults. Resistance was evaluated 90 days after infestation. Field data were recorded on grain yield, 100seed weight, shelling percentage, plant height and number of ears per plant. Percentage loss in grain weight and dust weight collected after three months of storage were used as measures of LGB resistance. Data were analyzed using SAS package and means separated by Fisher's protected LSD. CML492 was the most resistant followed by GBK-044593, GBK-032419, GBK-032423, GBK-044611, GBK-34659 and GBK-032357. Over half the landraces gave higher yields than the local check. GBK-043731 was the highest yielding (6 t/ha). Appreciable levels of resistance against LGB were identified in the local landraces. These landraces are recommended for both production, and use in the development of LGB resistant maize in Kenya.

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Introduction

Maize (*Zea mays* L.) is an important staple food for more than 50% of the population in sub-Saharan Africa (M'mboyi *et al*., 2010). The larger grain borer (LGB) (*Prostephanus truncatus* Horn) Coleoptera: Bostrichidae is one of the major storage pests in the region. The pest causes damage directly by feeding on stored grain and indirectly by reducing grain quality (Gethi, 2002). In Kenya the pest causes between 9 to 45% loss of stored grain (Kumar, 2002). The loss is higher when the pest attacks maize on cobs before and after harvest (Tefera *et al*., 2010). The pest is prevalent in the dry and hot ecologies where crop failure from drought is also common. During the rare occasions when there is a bumper grain harvest, the pest devastates the stored grain rendering the communities vulnerable to famine. Insecticides such as Pirimiphos methyl 1.6% + Permethrin 0.3% (Actellic Super®) have been recommended for LGB control, but the measures have not checked the losses or the spread of the pest. Besides being uneconomical, pesticides can be environmentally unsafe, and overuse can lead to development of resistance by the pest. Many farmers in sub-Saharan Africa are also resource-poor and cannot afford the recommended pesticides. An integrated pest management (IPM) that includes host plant resistance to insects is environmentally safe, economically feasible and socially acceptable (Mugo *et al*., 2002). The possible incorporation of LGB resistant genes into susceptible maize germplasm has been reported to reduce losses to less than 5% (Gethi, 2002). In the search for resistance, LGB poses a challenge for breeders since it is an exotic pest.

Generally, many improved high yielding cultivars of maize have been released in Kenya. Adoption of these cultivars is, however, low partly because of the susceptibility to both field and storage pests such as the larger grain borer. In much of the dry sub-Saharan ecologies, local maize landraces are popular to resource-poor small scale farmers as they apparently produce better under low input usage, high saline soils. low rainfall, and are generally perceived to be more resistant to both abiotic and biotic stresses than commercial cultivars (Kapindu *et al.,* 1999). Most small scale farmers in the semi-arid ecologies of Kenya, therefore, still produce local maize landraces for various reasons. In a recent study, landraces from different regions in Kenya were found to exhibit higher resistant levels to LGB damage than the commercial hybrid cultivars (Ndiso *et al.,* 2007). The local maize landraces were also found to be more tolerant to drought stress in these regions. These qualities could explain why some farmers still plant maize local landraces in spite of the newer and more yielding hybrids in the market. This implies that local landrace materials could be a repository for resistance genes to the LGB pest and other abiotic stresses. In the search for pest resistance, it is important for breeders to consider what farmers have preferred and grown over the years. While existence and production of these local maize landraces by farmers is recognized, their traits have not been fully exploited or documented (Chapman *et al*., 2003). For instance, local maize landraces in Kenya have neither been exhaustively evaluated for yield performances, nor fully exploited for resistance against LGB damage. The existence of highly valuable local maize landraces represents a potential wealth of genetic material adapted to the varying environments and can be an important source of resistance to LGB in maize improvement. Maize germplasm with improved resistance to storage pests is clearly in high demand among small-scale farmers in the tropical countries (Bergvinson, 2000). The objective of this study was to determine resistance to larger grain borer and the yield potential of selected local maize landraces grown in Kenya.

Materials and methods

Site description

The field trials were carried out at Kenya Agricultural Research Institute (KARI) Masongaleni sub-station farm, located at latitude 2° 21.6' South and longitude 38° 7.3' East, and an elevation of about 650 meters above sea level. The area falls under the dry lowland zones of Kenya.

The soils are *rhodic* and *orthic Ferrasols* (Jaetzold *et al.,* 2006). The laboratory experiment was carried out at KARI-Kiboko field laboratory located at 37.75˚ east and 2.15˚ south at an elevation of 975 m above sea level with minimum daily temperatures of 14.3˚C and maximum of 35.1˚C.

Maize Germplasm

The experiment consisted of the 25 germplasm. Fifteen were selected landraces sourced from the gene bank of Kenya; the rest included inbred lines from CIMMYT and KARI for comparison purposes, and commercial hybrid H614 was used as a check. Katumani Composite B, recommended for the dry and hot lowland ecologies where LGB is a threat was also included.

Field experiment

The experimental germplasm were established in a 5x5 lattice design replicated three times. The treatments were randomly allocated to the lattices and each of the five blocks carried five treatments. Each experimental plot consisted of ten plants in a row spaced 30 cm apart with a row spacing of 75cm. The crop was grown under normal rainfall supplemented with irrigation when necessary. All agronomic practices including weeding, field insect control, fertilizer application were carried out as recommended to ensure a healthy maize crop (Ackland, 1975). All activities including harvesting and shelling were done by hand. Data was recorded on tassel size, number of years per plant, plant height in meters (measured from the soil level to the flag leaf), 100 seed grain weight, shelling % and grain yield in t/ha. At harvest, the eight middle plants were harvested, hand-shelled and sun-dried to 13% moisture content (moisture content was determined using Dickey John® moisture tester).

Evaluation for LGB resistance

The insects used for the evaluation were sourced from CIMMYT/KARI-Kiboko post-harvest testing laboratory. The insects had been reared on commercial hybrid maize H614 under controlled conditions of 28°C and 70% relative humidity.

The grains were sterilized in tightly closed glass jars using an oven for 2 hours at 60˚C to get rid of any field infestation threat or risk. The grains were left to cool overnight and reabsorb any moisture that could have escaped into the airspace in the glass jar. One hundred grams of each grain genotype at 13% moisture content was introduced into sterilized glass jars and infested with 50 adult unsexed larger grain borers. Improvised stone weights (100g) were placed on top of the grains in the jar to enable LGB feeding as in natural conditions in a column of sack. The jars of infested maize were then placed on wooden shelves at room temperature for 90 days. The experiment was set up in a complete randomized design (CRD) replicated three times. After 90 days, the jars were opened and the contents sieved with mesh sieves of different hole sizes (Endecotts Ltd., UK) to separate the grains, insects and flour. The weights of the flour and the grains were taken using an electronic balance. Damage was calculated on weight loss in the grains and the weight of powder produced after 90 days of LGB feeding. Germplasm recording less grain weight loss and powder weight than the susceptible control H614 were considered to be moderately resistant to resistant. The grain weight loss was computed by subtracting the final weight from the initial weight of the grain sample and expressing it as a percentage.

Data analysis

Data in percent were transformed using angular transformation before statistical analysis to normalize the distribution. Analysis of variance was carried out using SAS version 7 and means separated by Fisher's protected least significant difference test (LSD) at 5% level.

Results

Grain yield and correlations

There were significant differences in grain yield for the landraces. The mean grain yield was 3.6t/ha. Grain yield ranged from 1.8 t/ha in KTL N 70188-2 to 6 t/ha in GBK-043731. The local commercial cultivar Katumani Composite B check gave 3.7 t/ha. High correlations were revealed between the two resistance parameters, grain weight loss and dust weight (r = 0.99) (Table 3). Correlation between both LGB damage parameters and 100 seed weight was positive and highly significant (r = 0.4). Correlation between number of ears per plant, plant height and grain yield was, however, unexpectedly low and insignificant. The shelling % was highly and positively correlated to grain yield (r = 0.52), but not to any other grain yield component.

Table 1. Effects of LGB damage on stored local maize germplasm.

Variable	Mean	Range	CV	Pr>F
Dust weight %	26.19	14.43-33.75	19.58	0.0002
Grain weight loss %	40.69	22.78-55.38	19.58	0.0004

CV; coefficient of variation, Pr= Probability

Table 2. Germplasm grain yield and resistance against LGB.

Germplasm code	Dust weight (%)	Grain weight loss (%)	Yield (t/ha)
GBK-043731	33.75[a]	51.0[ab]	5.9a
KTL N 70140-4	33.45[ab]	55.38[a]	2.2gh
GBK-027054	33.32[ab]	50.19[abc]	2.1h
GBK-043227	32.92[abc]	49.9[abc]	4.3bcde
GBK-045385	31.69[abcd]	49.72[abc]	4bcdef
KTL N10150-1	30.31[abcde]	48.79abcd	4.2bcde
KTL N70188-2	29.60[abcdef]	45.64[abcde]	1.8gh
GBK-027017	29.0[abcdef]	46.29[abcde]	3.7bcdef
GBK-034711	28.45[abcdef]	42.93[abcde]	3.3cdefgh
HYBRID 614-check	28.42[abcdef]	43.88[abcdef]	Not ranked
GBK-032357	27.82[abcdefg]	43.4[abcdefg]	4.7abc
GBK-034659	27.83[abcdefg]	41.9[abcdef]	2.9efgh
KTL N 10168-2	27.19[abcdefg]	42.27[abcdefg]	3.1cdefgh
KTL N 701104	26.1[abcdefg]	41.55[abcdef]	4.1bcde
DG/DT/2443.DT	23.26[bcdefgh]	36.99[bcdefg]	4.6abcd
GBK-044611	22.62[cdefgh]	35.29[cdefg]	4.55abcd
GBK-032423	22.62[defgh]	34.78[cdefg]	2.9efgh
GBK-032419	21.25[efgh]	33.14d[efg]	5.1ab
Katumani Comp B	21.03[efgh]	31.88[efg]	3.7bcdefg
GBK-044593	20.2[efgh]	31.90[efg]	3defgh
DT/BT/1470.DT	19.53[fgh]	32.22[efg]	3.9bcdef
DT/BT/1971.DT	17.61[gh]	26.85[fg]	3.7bcdefg
CML-492	14.43[h]	22.78[g]	2.5fgh

Germplasm followed by same letter were not significantly different at P<0.05

Resistance to LGB

Germplasm varied significantly in the grain weight loss and dust weight percentages (P<0.05). Dust weight ranged from 14.4% in CML-492 to 33.8% in local landrace GBK-043731. The mean dust weight was 26.1%. Grain weight loss ranged from 22.8% in

CML-492 to 55.4% in KTL N 70140-4 with a mean grain weight loss of 40.6% (Table 1). The lowest level of LGB damage was recorded in CML-492 which had the least grain weight loss and the least dust weight produced after three months storage. It recorded grain weight loss of 23% and dust weight of 14% against the trial means of 41% and 26% loss in grain weight and dust weight, respectively,. The local landrace with highest resistance to LGB was GBK-044593 with grain weight loss of 20.2% and dust weight of 31.9%. Landrace GBK-043731 was the most highly susceptible landrace at 33.75% and 51% dust and grain weight loss, respectively.

Table 3. Pearson's correlation coefficients (r) for yield and resistance variables.

	Grain yield (t/ha)	Shelling %	100Grain Seed weight (g)	Plant height (m)	Ears/ plant	Dust weight	Grain weight Loss
Grain yield (t/ha)	1						
Shelling%	0.524***	1					
100Grain Seed weight t (g)	0.304*	0.001ns	1				
Plant height (m	0.2ns	-0.152ns	0.511***	1			
Ears/plant	0.186ns	0.174ns	-0.34**	-0.126ns	1		
Dust weight%	-0.05ns	-0.106ns	0.398***	0.314*	-0.306*	1	
Grain weight Loss%	-0.032ns	-0.062ns	0.375***	0.282*	-0.295*	0.985***	1

*significant at 10%, ** significant at 5%, *** significant at 1%, ns, not significant

Discussion

Yield

The grain yield performance of any maize variety is important to a cereal grain farmer as it is the ultimate goal of production. Even though the landraces grain yield performance was relatively below that for improved hybrids, ten (10) of the landraces gave better yields than the recommended commercial composite check for the area, indicating their superiority in yield performance. Landrace GBK-043731 which gave the highest yield (6 t/ha), was however, among the most susceptible local landrace to LGB in storage. Landraces GBK-032419, GBK-044611 and GBK-032357 were, however, both high yielding and resistant to LGB damage in storage. This finding underscores the fact that some local maize landraces may be superior in boss yield and resistance to LGB than the local commercialized cultivars (Table 2). The extremely high correlation (r = 0.99) between the two damage parameters, grain weight loss and dust weight was an indication that either of these two parameters could be successfully used for evaluating resistance. This agrees with previous findings that resistance in maize against LGB could be expressed in terms of either grain damage, powder production, or the number of LGB recovered, because the parameters were highly correlated with one another (Kumar, 2002; Mwololo *et al,* 2012).

The positive and high correlation between the 100 seeds weight and both dust weight and grain weight loss in storage, may suggest that heavier and probably more compact grains were more susceptible to LGB damage in storage. These findings agrees with the report of Meikle *et al* (1998) and Tefera *et al* (2010) who noted that the adult LGB pest had remarkable ability to tunnel through even very hard compact grains. Their findings further emphasized that elite varieties with hard flinty kernels, tended to suffer high LGB damage in storage. It could be argued that heavier grains were stable and allowed easier burrowing by the pest which destroys grains by forming characteristic tunnels (Tefera *et al.,* 2011). Grain movement during feeding may limit tunneling by the pest which maybe a resistance factor in lighter grains. The weight of an individual grain, therefore, may play a key role by determining the feeding effectiveness of the LGB in storage. Ears per plant and plant height were not insignificantly correlated to grain yield, a suggestion that these parameters did not necessarily influence grain yield in the landraces. This was a deviation from other previous reports in most improved maize cultivars. For instance, in a review by Zsubori *et al.,* (2002), plant height was identified as the most important trait in influencing maize grain yield. Environmental variations, however, were also pointed as possible factors that could affect plant height and alter the expected positive correlation to grain yield. Other plant physiological factors may also not be ruled out in this deviation. In this study plant height was, however, highly correlated to 100seed weight (r = 0.51), a suggestion that plant height may have indirectly had some influence on the grain yield.

Resistance

The low (%) grain weight loss and dust weight recorded in CML492 was an indication of higher levels of resistance in the germplasm than other trial materials evaluated. It was followed by landraces GBK-032419, GBK-032423, GBK-044611, GBK-034659 and GBK-032357. These landraces registered lower grain weight losses, and dust weight produced than the hybrid check H614. Kumar (2002) and Tefera *et al* (2010) reported that grains that showed a high level of resistance had a low powder production and less grain weight loss relative to a susceptible host. Germplasm with higher levels of resistance suffered less damage from LGB and, therefore, had less grain weight losses and less dust weight at the end of the storage period. Highest damage levels were recorded in germplasm GBK-043731 and KTL N 70140-4. Both had equal dust weights of 33.5% but differed in grain weight losses which were 51% in GBK-043731 and 55% in KTL N 70140-4. This was an indication of the extensive feeding by LGB relative to the susceptible control hybrid H614 which had a 44% grain weight loss and 28% dust weight (Table 2). Bergvinson (2000) reported that in susceptible hosts, LGB could reduce the whole maize grain into powder in about five months. None of the tested genotypes experienced total grain destruction during the three months period of storage. indicating that each germplasm had a certain level of resistance.

Katumani Composite B was the fifth best in resistance level, performing better than most landraces with a weight loss of 31.9% and dust weight of 21.03%. The notably good performance confirmed that Katumani Compsite B was a suitable genotype for production in LGB prone areas. Varying degrees of resistance to LGB in landraces were similarly reported by Kumar (2002), with susceptible germplasm demonstrating extensive grain feeding and reproduction, unlike the resistant germplasm. Bergvinson (2000) noted good correlations between insect resistance and kernel hardness as a resistance mechanism. In a CIMMYT (1998) maize storage report, phenolic acids in maize toughen the outer layers of the kernel, making it less palatable for stored grain pests like LGB. These substances were found to bind to cell wall carbohydrates and then to each other, strengthening the tissue and providing a first layer of defense to storage pests. In a more recent report, Mwololo *et al* (2012) reported that the protein content in maize grain was an important biochemical mechanism of resistance against LGB in maize.

Conclusion

The grain weight loss and dust weight revealed the most resistant landraces to LGB were GBK-044593, GBK-032419, GBK-032423, GBK-044611, GBK-34659 and GBK-032357. All exhibited higher levels of resistance than the control H614, but were below CML492. The most susceptible landraces were GBK-043731, GBK-027054, GBK-043227, GBK-045385, GBK-027017 and GBK-034711. Katumani Composite B, a commercial composite recommended for low rainfall areas had a high level of resistance to LGB than most local landraces and the control H614. CIMMYT inbred line CML492 was the overall best and is recommended for use in breeding for resistance against LGB resistance. Several landrace's yield performance was superior to the local check. GBK-043731 though susceptible, was the highest yielding and maybe used in improving the current composites for yield.

Landraces identified as resistance and high yielding are recommended for use in maize improvement, as well as for farmer production in LGB prevalent ecologies as a host plant resistance strategy against LGB damage. Future research should focus on identifying the mechanisms of resistance involved in the resistant germplasm.

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