

# Screening Kenya Local Coastal Maize Landraces for Resistance to Maize Weevil (*Sitophilus Zeamais* Motschulsky) and Larger Grain Borer (*Prostephanus Truncates*)

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**Abstract** Maize (*Zea Mays* L.) is the most important food crop in Kenya including coastal region. Kilifi and Kwale Counties account half of all the maize production in the region. The coastal region has food deficit because it produces 50,000 tonnes of maize per year, while the demand is 22 m tonnes. High poverty levels in the region are mostly due to low average maize yield as a result of low soil moisture availability due to low and erratic rainfall, and losses due to storage pests. Losses in maize grain yield which are caused by the maize weevil (*Sitophilus zeamais* M.) and the larger grain borer (LGB) (*Prostephanus truncates* H.) among post harvest pests ranges between 15 to 60%. Despite the availability of improved maize varieties in the coastal region, farmers still grow the local coastal maize landraces (LCML). The research was to study LCML in an effort to understand why farmers prefer to grow them in spite of released improved maize open pollinated varieties (OPVs) and hybrids. The objective was to screen for resistance to maize weevil and larger grain borer in 25 LCML and 5 improved checks. The screening was done in a laboratory at Kenya Agricultural Research Institute (KARI) Kiboko using complete blocks design (CBD). Data collected was on weight of ruminant grain (g), weight of flour (g) and per cent weight loss (%). From the comparisons of weight losses caused by both pests, it appears that weevils cause more damage than LGB. Maize weevil caused 12.2% (Kanjerenjere) - 32.4% (KDV-3) weight losses compared to only 5.0% (Chitweka) - 8.7% (Matsere) caused by the LGB. This implies that, given the same conditions, weevils are more disastrous and priority should be given to controlling them. There was variability for resistance to maize weevil and LGB in storage among Kenyan local coastal maize landraces. A pattern was identified whereby, landraces from Kwale, Kilifi and Lamu showed resistance to LGB. No such pattern was observed for the maize weevil where resistance was wide spread in the region. The length of exposure to maize weevil has been considerably longer than LGB, which was observed only in the early 1990s. The susceptibility of some improved varieties to storage pests may partly explain why farmers grow local cultivars since PH 4 is the most readily available commercial cultivar. Landraces with superior responses to storage pests were identified, and these may be used directly or as sources of resistance in various insect resistance breeding program objectives in coastal Kenya.

**Keywords** Maize, Landraces, Storage pests, Weevils and large grain borer

## 1. Introduction

Maize can store well when harvested at the right time and stored at the right moisture content less than 15% grain moisture content. Because most farmers store their maize while still in the cobs it is hard to bring the moisture content to less than 15%. Stored maize is normally kept above the

cooking place to dry and prevent pest from attacking it. While the abiotic factors like drought stress cause loss in grain yield in the region, the biotic factors like storage pests cause heavy losses. Most farmers (70%) grow local coastal maize landraces (LCML) despite the improved varieties which have been released for growing in the region. There was need to screen the LCML for resistance to storage pests for conservation and breeding purposes. According to Gethi (2002) maize grain is subjected to infestation of a complex of pests consisting primarily of insects, mites and fungi, which contribute to post harvest losses. Post harvest insect pests are known to jeopardize food security throughout the developing

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world. Among the insects that destroy maize, the weevil (*Sitophilus* spp) and the LGB are most important in Kenya. They cause direct damage by feeding on stored grain and damage grain through physical deterioration by encouraging fungi development, thus reducing grain quality. Unfortunately traits that contribute to improved grain storage have been largely ignored (Bergvinson, 2000). Grain is most susceptible to maize weevil (*Sitophilus zeamais* Motschulsky) damage if it is stored at moisture content higher than 15% (CIMMYT, 2001).

A consequence of the above facts is that maize weevil is a greater problem in developing than in developed countries. Maize weevil (*Sitophilus zeamais* Motschulsky) (Figure 1) is an important pest of stored maize in the tropics, particularly in the lowland and mid-altitude, hot, and humid environments (Longstaff, 1981; DeVries and Toenniessen, 2001; Pingali and Pandey, 2001). Studies in Malawi (Golob, 1984) and Zimbabwe (Giga *et al.*, 1991) have reported >20% weight loss caused by weevils for untreated grain of maize hybrids stored in traditional structures, whereas up to an 80% loss may occur in on-farm stores in tropical countries (Mutiro, *et al.*, 1992; Pingali and Pandey, 2001). Maize weevil damage maize kernels after dough stage. The maize weevil larvae feed on the kernel internally in the field and in storage (McMillian, *et al.* 1968). Weevil damage results directly in lost food and may also reduce future maize production for farmers who save grain as seed (a practice that accounts for 70% of all maize) planted in Eastern and Southern Africa (Pingali and Pandey, 2001). The use of pesticides for control of weevil is broadly recommended, but resource poor farmers of the developing world often cannot afford or obtain them. Also the increasing occurrence of insecticide resistance (Perez-Mendoze, 1999) and environmental concerns about use of chemical insecticides mean alternative control methods are required (Dhliwayo and Pixley, 2003). Use of resistant cultivars is the most promising method of minimizing damage due to *S. zeamais* where high input control measures such as pesticides and other integrated pest management (IPM) systems are difficult or unwise (Tiger, *et al.*, 1994). Significant genetic variation for resistance to weevil has been found in several studies (Kim, *et al.*, 2003).

Numerous sources of resistance to weevils have been identified (Widstrom, *et al.* 1983), and inheritance of resistance has been investigated (Widstrom, *et al.* 1975). Resistance to maize weevil was reported for Mexican landraces, notably Sinaloa 35 and Yucatan-7 (Arnason, *et al.*, 1994), for the Tanzanian open-pollinated variety 'Kilima' (Derera, *et al.*, 1999), for tropical inbred lines Hi41, Hi34, ICA L29, KU1409, Hi39, and ICA L221 (Kim, *et al.*, 1988). Grain factors reported to contribute to resistance include increased grain hardness and sugar content (Singh and McCain, 1963; Dobie, 1977), and increased phenolic acid content, especially E- Ferulic acid content (Classen, *et al.*, 1990; Arnason *et al.*, 1994, Arnason, *et al.* 1997). Genetic information on weevil resistance among African maize landraces is scarce (Kim, *et al.*, 2003).

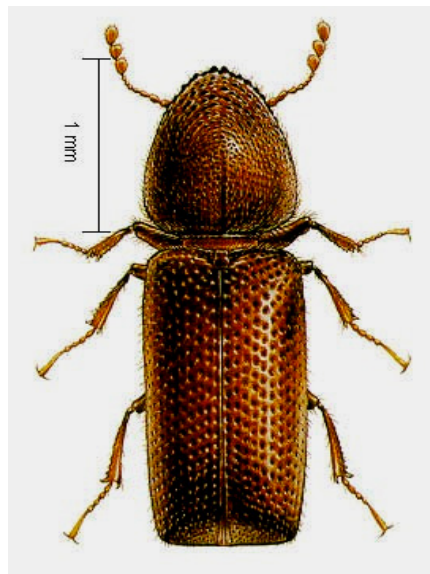


Figure 1. Maize weevil



Figure 2. Larger grain borer (LGB)

The larger grain borer (Figure 2) is one of the most destructive maize pests known in Africa nicknamed "Osama" because of its sheer devastation to stored maize grain (Mungai, 2005). Well documented records in Africa and Latin America show that losses in maize caused LGB attack varied from 9 to 45% depending upon the period of storage (Markham *et al.*, 1991). It is said to cause losses totalling to Ksh. 7 billion in Kenya annually (Mungai, 2005). A large number of insecticides have been tested and subsequently used to control LGB (Giga and Canhao, 1991). These measures have failed to check maize losses and spread of this destructive pest. The extensive use of pesticides by farmers in these regions is neither practicable nor desirable because of the close relationship between maize living organisms. An integrated approach to control LGB had been proposed to reduce the use of pesticides (Hodges, 1994). Host plant resistance (HPR) is practically missing in this integrated approach because the traditional landraces and modern maize varieties / hybrids have not been evaluated systematically for resistance to LGB although biochemical studies have indicated phenolics in the grains to be correlated with the resistance against LGB (Arnason, *et al.*, 1992).

Resistance to storage pests is polygenically controlled and has a strong maternal effect (Serratos, et al. 1997). The mechanism of resistance is thought to involve phenolic compounds located within the aleurone layer or pericarp of the kernel (Serreti, et al., 1997). Most landraces that have been grown by communities in weevil infested areas are likely to possess resistance to weevil (Gethi and Likhayo, 2004). Maize germplasm with improved resistance against storage pests is clearly in high demand among small scale farmers in tropical countries (Bergvinson, 2001). In Malawi, improved maize varieties showed increased susceptibility to pests under traditional storage practices than local landrace (Kapindu, et al., 1999). It is for this reason that the 30 local maize landraces were evaluated for resistance to the maize weevils and to LGB.

## 2. Materials and Method

### *Experimental site*

The screening was carried out at Kenya Agricultural Research Institute (KARI) Kiboko, Kenya. This is located at longitude 37.75°E and latitude 2.15°S, at an elevation of 975 meters above the sea level (ASL), receives 530 mm annual rainfall, maximum temperature were 35.1°C while minimum temperatures were 14.3°C and has predominantly sandy clay soils (Jaetzold et al., 2012).

### *Experimental design*

#### *Maize weevil*

Complete block design (CBD) was used. Maize kernels (from Morphological characterization trial at KARI Mtwapa) was disinfected of any field infestation of the maize weevil by heating in ventilated electrical oven a 60-70°C for 2 hours and the grain was left to cool in the oven overnight (used kilner jars with glass lids). Sterilized the jars in an electric oven set at 100°C for 15 minutes, together with their lids and wire gauze. This was aimed at controlling mites and other pathogens. Weighed 50g of each sample into the jars, replicated 3 times. Count 50 active adult insects and introduce into each jar. As a guide, use one insect per gram of host. Close the lids, arrange the jars in a complete randomized design, with the checks placed in such a way to take care of microclimate changes. Incubate (keep on the shelves) in the culture room where the relative humidity was 70% ±5% and temperature of 27°C ±2° for 10 days to allow oviposition. At the end of 10 days, remove the parents and take record of dead ones. Return the grains to respective jars. The jars are left in the incubation room for 90 days, while being rotated occasionally to minimize positional effects in the growth chamber. After 90 days, sieve the contents of each jar across a set of sieves (4.75 mm and 1 mm aperture) to separate grains from insects and flour from insects. Take record of weight of grain, flour (dust) and insect counts. Note. % dust produced = ((wt dust)/50g) x 100. Grain weight loss (%) = ((50 - wt of grain at 90 days)/ 50g) x 100 (CIMMYT, 1989).

#### *Lager grain borer*

Complete block design (CBD) was used. Maize grains was disinfected of any field infestation of the LGB pest by heating in ventilated electrical oven a 60-70°C for 2 hours and let the grain cool in the oven overnight (use kilner jars with glass lids). The jars were sterilized in an electric oven set at 100°C for 15 minutes, together with their lids and wire gauze. This is aimed at controlling mites and other pathogens. Weighed 50g each sample into the jars, replicated 3 times. Count 50 active insects and introduce into each jar. As a guide, use one insect per gram of host. Close the lids and incubate (keep on the shelves) in the culture room where the relative humidity was 70% ±5% and temperature of 27°C ±2° for 90 days. Arrange the jars in a complete randomized design, with the checks placed in such a way to take care of microclimate changes. After 90 days, sieve the contents of each jar across a set of sieves (4.75 mm and 1 mm aperture) to separate grains from insects and flour from insects. Take record of weight of grain, flour (dust) and insect counts. Note. % dust produced = ((wt dust)/50g) x 100. Grain weight loss (%) = ((50 - wt of grain at 90 days)/ 50g) x 100 (CIMMYT, 1989).

#### *Data collection*

Data collected was flour weight and grain weight loss (%) calculated from the difference of the weight before and after maize weevil/LGB infestation.

#### *Statistical analysis*

Analysis of variance of resistance to storage pests (traits) was performed using general linear model (GLM) SAS computer package (Appendix 6). The means were separated using Duncan's multiple range tests at 5% level of significance according to Steel and Torrie (1980).

## 3. Results

### *Results of maize weevil screening*

There was a significant flour weight and weight loss caused by storage pests (Table 1). The mean flour weight of Kenyan coastal maize landraces after damage by *Sitophilus zeamais*, indicate that entry 9 (accession 044454) from Lamu had the lowest mean flour weight (1.4 g). Lower flour weight indicated less damage by maize weevil. Entries 2 (032372) - Matsere, 5 (0.32423) - Tela, 11 (046360) - Kanjerenjere and 12 (047624) - Mengawa, from Kilifi, 6 (034619) from Taita Taveta, 18 (047635) - Kienyeji, 24 (047643), and 25 (047644), all from Kwale were as good as the better checks, which had a mean of 3.0 g and excluded PH4 and KDV-3. Pwani Hybrid 4 (PH 4) and Katumani drought variety 3 (KDV-3) checks performed poorly with flour weights 5.0 g and 6.6 g, respectively. Entry 11 (046360) - Kanjerenjere had the lowest weight loss 12.2 %. Lower weight loss indicated less damage by weevils. Entries 4, 5, 6, 8, 9, 12, 14, 17, 18, 19, 20, 22, 23, and 25 with weight losses of 16.4 - 27.5% were as good as Coast Composite, which was the best amongst the

checks with 19.2% weight loss.

### Discussion on maize weevil screening

It is worth noting that thirteen germplasms performed better than entry 27 (PH4) and entry 30 (KDV 3), which were checks. This was in agreement with Girma *et al.*, (2008) who reported that hybrid varieties were highly susceptible to

insect pest attack in the field and storage. The fact that some germplasm were as good as the better checks, Coast Composite may partially explain why the farmers in the region have stuck to the local coastal maize landraces despite the improved varieties which have been released for growing in the region.

**Table 1.** Flour weight and weight loss of Kenyan coastal maize landraces after damage by *Sitophilus zeamais* and by *Prostephanus truncatus*

Entry	Accession	District	Local variety name	Maize weevil		Larger grain borer	
				Flour Weight (g)	Weight loss (%)	Flour Weight (g)	Weight loss (%)
1	32329	Kwale	Matsere	5.2efgd	27.9ebdac	6.6bdac	8.0bdac
2	32372	Kilifi	Matsere	3.7kljgh	28.2ebdac	6.9ba	8.7ba
3	32379	Kilifi	Mdzihana	4.3efgh	30.1bdac	6.7bac	8.6ba
4	32404	Kilifi	Mingawa	4.5efgd	23.5egdacf	6.7ba	8.6ba
5	32423	Kilifi	Tela	2.3nlm	20.1edhgf	6.5ebdac	8.2bdac
6	34619	T/Taveta	-	2.3nlm	16.4hg	7.2b	9.1a
7	34660	T/Taveta	-	4.7efgd	28.1ebdac	6.9ba	8.7ba
8	34661	T/Taveta	-	3.3kljlh	24.5ebdagcf	6.9ba	8.6ba
9	44454	Lamu	-	1.4n	17.2hgf	6.7ba	8.3bac
10	44458	Lamu	-	5.1efcd	29.9bdac	5.8ebdfc	7.3fbdec
11	46360	Kilifi	Kanjerenjere	2.1nm	12.2h	5.7ebdfcg	6.8fgdeh
12	47624	Kilifi	Mengawa	2.9kljlm	20.2edhgcf	3.9ji	5.2gjhi
13	47625	Kilifi	Mdzihana	7.1a	33.4a	5.7ebdfcg	7.5fbdec
14	47628	Kilifi	Chinga cha mosi	5.5bcd	24.5ebdagcf	4.9hjflg	6.3fgejhi
15	47629	Kilifi	Mwangongo	4.7efgd	29.1ebdac	4.5hjflg	6.1fgejhi
16	47631	Kilifi	Mungindo	4.0lfggh	28.4ebdac	5.3ehdfg	6.8fgdec
17	47632	Lamu	Gonjora	6.4ba	22.4egdgcf	5.0hflg	6.7fgdeh
18	47635	Kwale	Kienyeji	2.8kljm	25.2ebdagcf	4.6hjflg	6.1fgejhi
19	47636	Kwale	Chitweka	3.9ljgh	22.8ebdagcf	3.9ji	5.0ji
20	47638	Kwale	-	4.3efgh	25.7ebdagcf	3.7j	5.0ji
21	47639	Kwale	-	6.0bc	30.8bac	5.4ehdfg	6.6fgdeh
22	47641	Kwale	Kanjerenjere	4.0lfggh	26.7ebdagcf	4.8hjflg	6.1fgejhi
23	47642	Kwale	-	5.9bc	27.5ebdacf	5.0hflg	6.6fgdehi
24	47643	Kwale	-	3.8ljgh	29.3ebdac	5.2ehflg	6.2fgejhi
25	47644	Kwale	-	2.6klm	19.2ehgf	4.5hji	5.2jhi
26	CCM	Check	Coast composite	2.9kljlm	19.2ehgf	4.6hjflg	5.7fgjhi
27	PH 4	Check	Pwani hybrid 4	5.0efcd	30.6bdac	5.4ehdfcg	6.6fgdehi
28	CLC-1	Check	CLC-1	3.0kljlm	24.8ebdagcf	4.5hjlg	5.6gjhi
29	CLS-3	Check	CLS-3	3.2kljlhm	24.8ebdagcf	4.8hjflg	5.8fgjhi
30	KDV-3	Check	-	6.6ba	32.4 b a	5.3ehdfg	6.5fgdejhi
			<b>Mean</b>	<b>4.09</b>	<b>25.19</b>	<b>5.43</b>	<b>6.885</b>
			<b>CV</b>	<b>20</b>	<b>29</b>	<b>17</b>	<b>16</b>
			<b>LSD</b>	<b>0.96</b>	<b>8.49</b>	<b>1.09</b>	<b>1.31</b>
			<b>Year</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>
			<b>Rep (Year)</b>	<b>ns</b>	<b>ns</b>	<b>**</b>	<b>**</b>
			<b>Entry</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>
			<b>Year*Entry</b>	<b>**</b>	<b>**</b>	<b>**</b>	<b>**</b>

Means followed by the same letter are not significantly different ( $p=0.05$ )

### Results on LGB screening

Mean flour weight of Kenyan coastal maize landraces after damage by *Prostephanus truncatus* (Table 1), indicate that entries 12, 19 and 20 had the lowest flour weight (3.9, 3.9, and 3.7g, respectively), which was significantly lower than flour weight for PH 4, the best hybrid check with 5.4g. Entries 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24, and 25 all with flour weight less than 6.0 g were as good as all checks (mean 4.9 g). Entries 19 and 20 each with 5.0% weight loss also showed significantly less weight loss due to LGB than PH 4 and KDV -3 checks, which had 6.6% and 6.5%, respectively. Entries 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24, and 25 all with weight loss <7.3% were as good as all checks that had a mean grain weight loss of 6.0%. Entries 19 (047636) and 20 (047638) all from Kwale County had lower flour weight and weight loss.

### Discussion on LGB screening

Considering flour weight and weight loss due to damage by LGB, most genotypes collected from Kwale, Kilifi and Lamu showed resistance, while those from Taita Taveta tended to be susceptible. These landraces may be used as sources of resistance in breeding programs for storage pests. Apart from PH4, all other checks (CCM, CLC- 1, CLS- 3 and KDV- 3) had low flour weight and weight loss, indicating that LGB resistance was either improved or maintained during the improvement process. The resistance may be from a correlated response from breeding process used in their development.

Pwani Hybrid 4 (PH 4) and KDV-3 were susceptible to both weevil and LGB with 5.0g and 6.6g respectively for weevil flour weight and 5.4g and 5.3g respectively for LGB flour weight. For the weight loss assessment PH 4 and KDV 3 weevil weight loss was 30.6 % and 32.4% respectively and 6.6% and 6.5% respectively for LGB. There were resistant landraces from all county to maize weevil. This observation is probably expected as all collections have had exposure to maize weevil for a long time as opposed to the LGB that appeared only recently. The susceptibility may partly explain why farmers grow local cultivars since PH 4 is the most readily available commercial cultivar. It appears that weevils cause more damage than LGB. From the comparisons for weight losses caused by both pests, maize weevil caused 12.2% (Kanjerenjere) - 32.4% (KDV-3) weight losses compared to only 5.0% (Chitweka) - 8.7% (Matsere) caused by the LGB. Kerstin *et al.*, (2010) reported 10 to 12% loss of maize stored in traditional storage containers due to insect pests. Loss of about 18% was also reported in other African countries (Waktole and Amsalu, 2012). This implies that, given the same conditions, weevils are more disastrous and priority should be given to controlling them.

### Results of correlation coefficient relationships for resistance to storage pest traits

Correlation Coefficient (r) for resistance to storage pest traits (Table 2). The correlation coefficient (r) for weight loss (%) and flour weight (g) of weevil is highly significant and

positive 0.71 while the same for LGB is also significant and positive 0.98. This implies that increase in flour weight will result in increase in weight loss in weevil infestation and increase in flour weight will result in weight loss in large grain borer infestations. Therefore, the reliability of determining weight loss (%) from flour weight (g) is 71% for weevil and 98% for LGB.

**Table 2.** Correlation Coefficient relationship of Resistance to storage pest traits

Trait	Flwww	Wtwv	Flwlgb	Wtlgb
Flour weight weevil (Flwv)				
Grain weight loss weevil (Wtwv)	0.71**			
Flour weight LGB (Flwlgb)	-0.09	-0.02		
Grain weight loss (Wtlgb)	-0.02	0.03	0.98**	

\* Significant (P < 0.05) and \*\* highly significant (P < 0.01)

### Discussion of correlation coefficient relationships for resistance to storage pest traits

The fact that flour weight is positively correlated to weight loss implies that increase in flour weight will result in increase in weight loss in weevil infestation and increase in flour weight will result in weight loss in large grain borer infestations. Therefore, the reliability of determining weight loss (%) from flour weight (g) is 71% for weevil and 98% for LGB. This also indicates that one can select for reduced flour weight using reduced weight loss.

### Results of principal component analysis (PCA)

Principal Component Analysis (PCA) for Storage Pest Traits is given in Table 3. The first two principal components with an eigenvalue of more than 1.0 contributed to 92.4% of the variations, with the first PC contributing 49.9% of the variations. It is worth noting that flour weight (g) and weight loss (%) of weevil correlated positively while flour weight (g) and weight loss (%) of LGB contributed negatively to the first PC1. The second PC accounting for 42.5% of the variations flour weight (g) and weight loss (%) of LGB; flour weight (g) and weight loss (%) of weevil correlated negatively associated with PC 2.

**Table 3.** Principal Component Analysis (PCA) for Storage Pest Traits

VARIABLE	PC 1	PC 2
Flour weight (g) weevil (Flwww)	0.159	-0.688
Weight loss (%) weevil (Wtwv)	0.112	-0.699
Flour weight (g) LGB (Flwlgb)	-0.698	-0.111
Weight loss (%) LGB (Wtlgb)	-0.689	-0.161
Eigenvalue	1.9949	1.6993
Individual (%)	0.499	0.425
Cumulative (%)	0.499	0.924

### Discussion of principal component analysis (PCA)

The significance indicates the importance of these traits in measuring resistance to storage pests. That why in the first PC flour weight weevil and weight loss weevil contributed correlated positively while the flour weight and weight loss LGB correlated negatively in the second principal component (PC 2).

## 4. Conclusions

There were resistant landraces from all districts to maize weevil. This observation is probably expected as all collections have had exposure to maize weevil for a long time as opposed to the LGB that appeared only recently. The susceptibility may partly explain why farmers grow local cultivars since PH 4 is the most readily available commercial cultivar. It appears that weevils cause more damage than LGB. From the comparisons for weight losses caused by both pests, maize weevil caused 12.2% (Kanjerenjere) - 32.4% (KDV-3) weight losses compared to only 5.0% (Chitweka) - 8.7% (Matsere) caused by the LGB. This implies that, given the same conditions, weevils are more disastrous and priority should be given to controlling them. There was variability for resistance to maize weevil and LGB in storage among Kenyan coastal maize landraces. A pattern was identified whereby, landraces from Kwale, Kilifi and Lamu showed resistance to LGB. No such pattern was observed for the maize weevil where resistance was wide spread in the region. The length of exposure to maize weevil has been considerably longer than LGB, which was observed only in the early 1990s. Landraces with superior responses to storage pests were identified, and these may be used directly or as sources of resistance in various insect resistance breeding program objectives in coastal Kenya.

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