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Pre-harvest Loss Assessment of Maize crop in Semi-arid Areas in Tanzania Due to Rodent pests

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Two experiments were conducted, first was to estimate maize seedling damage in farmers' fields and a simulation experiment. This study aim to investigate the impact of rodent pest species, damage to maize crop in semi-arid areas at pre-harvest, with a view to provide farmers with appropriate information on rodent pest management interventions. In farmers' fields, damage assessment was done by counting the number of damaged or removed seedlings at each planting hole while yield loss was determined from simulation experiment at five damage levels, viz; 0, 10, 25, 50, and 75% by removing seedlings per plot. Variation of damaged maize seedlings was compared between soil type and fields. The fields with black clay soils had higher damage of maize seedling (mean = 59.201±1.714) as compared to sandy loam soils (means = 49.742±1.714). The damage ranged from 30.17 to 71.91% in different fields. However, no effect was observed between interactions of maize fields and soil types. Results from simulation experiment showed no significant difference (p = 0.2357) among maize damage levels, although relatively higher yield losses were observed at 75%, while lowest yield losses in the control (0%). The increased seedling damage has an impact on final harvest; therefore, ecologically-based rodent management strategies appear to be good solution for reducing crop damage and should be encouraged to improve food security for smallholder farmers.

Key words: Damage, habitats, *M. natalensis*, rodent pest, semi-arid.

INTRODUCTION

Rodent pests are serious impediment in agriculture (Singh, 2017; Fayenuwo et al., 2007; Stenseth et al., 2003), especially because they breed quickly leading to serious economic losses (Mulungu et al., 2005). Rodents also spread diseases through biting people and they kill poultry chicks (Meerburg et al., 2009; Katakweba et al., 2012). The damage to crops by rodents can be high especially during rodent outbreaks, which occur in some years and locations (Mulungu, 2017; Mulungu et al., 2003).

The patterns and the extent of damage of maize crop by rodents depend upon the pest species, the intensity of infestation, type and the growth stage of the crop, and the nature of the surrounding habitat (Mulungu et al., 2005). It is reported that, there are about 31 rodent pest species that cause crop damage in Tanzania (Mulungu et al., 2005). However, *Mastomys natalensis* is the predominant rodent pest species in the country (Massawe et al., 2012; Mulungu et al., 2011), and is found in all maize-growing areas causing serious damage to crops before and after harvest (Mulungu, 2017). It is also the most widespread rodent pest across Sub-Saharan Africa (Mulungu et al., 2014).

In Northern Ethiopia, for example, farmers reported an estimated pre-harvest yield losses of 9-44% in annual production of cereal crops due to rodent attacks (Meheretu et al., 2010), while 26.4% loss of yield in maize was reported in Central Ethiopia (Bekele et al., 2003). In Western Kenya, rodent pests cause a considerable pre-harvest damages and losses of 20% to maize plantation (Tsegaye and Asfawosen, 2015). In Tanzania and Sub-Saharan Africa, a large proportion of crop yield is lost due to rodents (Mdangi et al*.,* 2013). During rodent outbreaks, significant impact on food security at different scales, beginning at the household through regional level has been observed (Leirs et al., 2010) and damage ranges from negligible destruction to >80% crop loss (Mulungu et al., 2003). However, maize damage by rodent pests has been reported to vary depending on crop growth stages and the infesting rodent pest species (Mulungu, 2017).

In Iringa region, farmers have reported specifically Isimani division, which has a unimodal rainfall patterns and semi-arid condition, serious rodent outbreaks and severe damage to maize crop, for the past 20 years. Little is known concerning the extent of damage by rodent pests on the maize crop. Many studies on maize losses have been reported in smallholder fields in areas with bimodal rainfall patterns (Mulungu et al., 2003; Mwanjabe et al., 2002; Mwanjabe and Leirs, 1997). It has been reported that more losses occur at pre-harvest stages of the crop than at the maturity stage (Mulungu, 2017). Understanding the cause and the extent of the damage caused by rodents in maize is important in planning management strategies (Mulungu, 2017). The aim of this study was therefore to investigate the impact of rodent pest species damage to maize crop in semi-arid areas at pre-harvest, with a view to provide farmers with appropriate information on rodent pest management interventions.

MATERIALS AND METHODS

Study area

This study was conducted in Isimani division, Iringa region, Tanzania. The area is located between 35°16'128” and 35°56'560" E and 8°8'142” and 7°13'678" S, covering an elevation of 1073 to1356 m above sea level (Figure 1).

The study area has an unimodal rainfall pattern with clear dry and wet seasons and the mean annual precipitation ranges from 200 to 750 mm/year. It is characterised by low erratic rainfall and periodic droughts giving it a semi-arid nature where precipitation is below potential evapotranspiration.

The seasons were subdivided based on rainfall and evapotranspiration into three sub seasons. The rainy season is divided into dry and wet seasons. The dry season is further divided into three sub seasons namely: start dry, mid dry and end dry sub-seasons. The start dry sub season is from May to July while, mid dry is from August to September and end dry sub-season lasts from October to November. The wet season is divided into three sub seasons namely; start wet, mid wet and end wet sub seasons. The start wet is from December to January while, mid wet is in February and end wet sub-season lasts from March to April. Land use is dominated by agriculture with the dominant maize cultivation alternating with fallow lands. Maize reaches physiological maturity between May and June and is harvested starting from July to August.

Crop damage assessment and sampling procedures

Farmer’s fields

Seven farmers’ maize fields of one acre each from four sites/villages (namely; Kising’a, Mkungugu, Nyang’oro and Ndolela) were visited for crop damage assessment at maize seedling stage. The soil types, vegetative characteristics and agricultural practices of the fields were established as shown in Table 1.

The size of the plots counted were 70 m x 70 m, each that corresponds to the field size that is one acre in smallholder farms in Tanzania. Crop damage assessment was carried out 10 to 12 days after sowing. The non-stratified systematic row-sampling technique described by Mulungu et al. (2003) and Mwanjabe and Leirs (1997) was used by sampling every individual planting hole in each field. Sampling units were maize rows, four rows apart, leaving out the two outer rows. The assessor walked across the field and recorded the number of seedlings at each sampled hole in a row. Since two seeds were planted per hole, damage was expressed as the proportion of non-emerging seedlings. It was assumed that no other pests were causing damage to the seedlings and all missing seedlings were therefore attributed to rodent damage. Germination failure due to drought or seed quality was assumed to be evenly distributed, but was also considered of low importance in the experimental fields.

Damage for each planting hole was recorded separately for each field in different sites. Data recorded for each planting hole were: planting row number, position in the row, and number of non-emerging seedlings (that is two minus the number of emerged seedlings).

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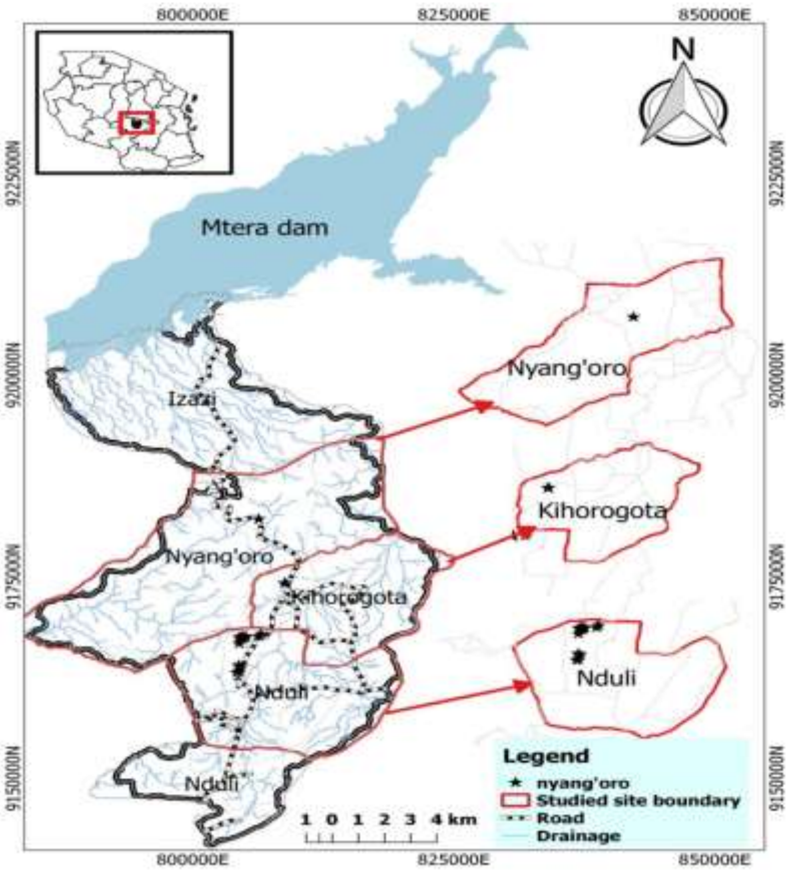

Figure 1. Location of the study sites in Isimani division, Iringa region, Tanzania.

Simulation experiment

A simulation experiment was conducted in three replications and 5 treatments. The main area was 62 m x 44 m and each treatment was 10 m x 10 m in size. The plot was located in mosaic landscape of maize fields surrounded by fallow land. Maize seeds (of the hybrid variety Pannar®) were planted in the field with a spacing of 90 cm by 30 cm. The maize damage levels of 0, 10, 25, 50 and 75% of the plant population were established and seedlings were removed to maintain these levels 14 days after sowing (DAS). All treatments received standard agronomic practices, that is early ploughing, weeding, application of Di Ammonium Phosphate (DAP) 18% nitrogen (N) and 46% phosphorus (P) as P_2O_5 was applied at rate of 20 kg/ha. Since its nitrogen content is in ammonium (NH4) form, it is particularly effective in the early developmental stages of plants.

Maize harvesting was done when the yield reached the required moisture content of 23% at 158 DAS. Each treatment was harvested and its produce put in a labeled separate sack for one week to obtain the standard moisture content. Thereafter, maize cobs were threshed separately and sieved. The weight of each separate sack with maize grains was recorded.

Data analysis

Seedling stage

Percentage damage of maize seedlings was calculated by dividing the total missing seedlings over total expected emerging seedlings, and was multiplied by 100 in each field. The data were normalized and further subjected to two-way analysis of variance (ANOVA), using XLSTAT 2018.1.49386 software where soil types and field were factors. The means separation was done using Fisher's Least Significant Difference method ($LSD_{0.05}$) in order to determine variables with effect among soil types and fields.

Simulation method

The collected yield loss was subjected to one-way analysis of variance (ANOVA) using SAS System (1997). The means separation was done using Turkey-test method to determine the effect of damage levels.

RESULTS

Seedling stage

There were variations in maize seedling damage among the seven fields (Table 2). A significant difference ($F_{6, 195}$ = 45.25, $p < 0.0001$) of maize seedling damage was observed among fields, with highest seedling damage were observed at Mkungugu field B and lowest at Nyang'oro field A (Table 2).

Table 1. Soil characteristics and agricultural practices of study villages in Isimani division for maize crop assessment at seedling stage.

SN	Name of village	Soil characteristics				Vegetative and agricultural practices
		Soil type	Colour	Drainage	Cracks	
1	Kising'a-Uyole Agric research Institution	Sandy loam	Red	Moderate	No	Surrounded by maize fields and fallow land with scattered trees, hebercious and grasses. Oxen ploughing was used.
2	Mkungugu field A	Clay	Black	Moderate	No	Maize fields, fallow land with Shrubs, herbs, trees and grasses. Tractor tilling was used.
3	Mkungugu field B	Clay	Black	Moderate	Yes	Maize fields, fallow land with Shrubs, herbs, trees and grasses. Tractor tilling was used.
4	Nyang'oro field A	Sandy loam	Grey	Well	No	Maize and sunflower fields, fallow land with trees, shrubs, bushes and grasses. Oxen ploughing was used.
5	Nyang'oro field B	Clay	Black	Poor	Yes	Maize and sunflower fields, fallow land with shrubs and grasses. Oxen ploughing was used.
6	Ndolela field A	Sandy loam	Brown	Moderate	No	Maize and sunflower fields, fallow land with shrubs, grasses. Oxen ploughing was used.
7	Ndolela field B	Clay	Black	Poor	Yes	Maize and sunflower fields, fallow land with shrubs, grasses. Oxen ploughing was used.

Source: Chidodo, 2017.

Table 2. Damage to maize crop seedlings by rodents in villages-Isimani division, Iringa region, Tanzania.

Name of village	Planting holes visited	Seedling counted per field	Expected number of seedlings per field	Number of seedlings damaged	Percentage seedling damage
Mkungugu field B	1338	756	2676	1920	71.91±2.25[a]
Ndolela field B	1557	989	3114	2125	69.17±1.98[ab]
Ndolela field A	991	735	3184	2195	64.21±2.39[b]
Mkungugu field A	1631	1624	3262	1638	50.27±1.85[c]
Nyang'oro field B	973	947	1946	999	50.18±2.49[c]
Kising'a-Uyole	1143	1377	2286	909	39.79±1.92[d]
Nyang'oro field A	655	913	1310	397	30.17±2.84[e]

[1]Means of the same column followed by the same letter are not significantly different at 5% probability level using Tukey's test method.

Similarly, there was an effect ($F_{1, 200}$ = 15.23, p = 0.000) between soil types, whereby higher seedling damaged (mean, 59.20±1.714) was observed in black clay soils than (mean, 49.74±1.714) in sandy soils. However, there was no effect (p = 0.362) of interactions between fields and soil types.

Table 3. Means of maize grain weight per treatment for the simulation experiment.

Treatment	Means (tons/ha)
Control	6.45±0.19
Ten	6.28±0.19
Twenty five	6.25±0.19
Fifty	6.28±0.19
Seventy five	6.85±0.19
$LSD_{0.05}$	0.62

Simulation experiment

No statistically significant effects ($F_{4, 8}$ = 1.73, p = 0.236) were observed among maize damage levels. However, relatively higher yield losses (means = 6.85 tons/ha) were observed at 75% compared to the relatively lower yield losses (means = 6.45 tons/ha) at control treatment (Table 3).

DISCUSSION

Farmers' maize fields in the current study area have showed variations in rodent maize damage at seedling stage ranging from 30.2 to 71.9%. The current results are within the reported range of pre-harvest maize damage by Mulungu et al. (2003) who observed maize damage from 17 to 82% in some locations and seasons. In addition, smallholder farmers in different areas and locations in Tanzania have been reported the chronic rodent damage of sometimes over 80% (Mwanjabe et al., 2002).

Results showed that maize fields with black clay soils suffered serious attacks on maize seeds/seedlings by rodent pest species than sandy loam soils. This can be attributed partly to the agricultural practices in this area, which include, among others, the use of tractor tiling during seed sowing. In the process of covering, some seeds might have been exposed to the surfaces, which were easily eaten by the rodents. According to Brown et al. (2017) rodent pests can consumed exposed seeds in the field, resulting in few plants or plant stands per field. Rodent pests are in abundance in agricultural landscapes (Heroldová et al., 2007; Fischer and Schröder, 2014) and can be important seed predators (Daedlow et al., 2014)

Another reason could be the failure of seeds to germinate due to the effect of tillage method where seeds are planted deeply in a compacted soil with low moisture content, a characteristic of semi-arid areas, although this was not studied in the current experiment. In soils with low moisture content, the germination rate is reduced and seedling emergence is delayed, which increases the chance of depredation by rodent pest species (Mulungu, 2003). Soil compaction is a big challenge for seed germination in poorly drained clay soils (Chen et al., 2005) especially in some specific ecological conditions such as semi-arid areas (Sladonja et al., 2014). It has been reported that soils and moisture levels may interact and affect seed viability hence poor seed germination in clay as compared to sandy loam soils (Valde´s-Rodrı´guez et al., 2012). Deeper planting (in the case of some seeds during tractor tilling) apart from reducing final emergence, also exposes the germinating seeds to soil pathogens and insects thus increasing the risk of seed rots (Molatudi and Mariga, 2009) this could explain the reduce number of plants recorded during this study. In additional, poor aeration, water logging and an impervious layer formed by the compact mass structure of the black clay soil could have lowered germination capacity. According to Idu et al. (2003), soil suitability and effectiveness at inducing germination in seeds and subsequent seedling emergence, depends largely on physical properties such as texture, aggregate size, water-holding capacity, consistence, and bulk density of the soil.

It is evident from the present study that maize damage levels (0 to 50%) indicated variations in yield losses when plant populations were removed at the early stage and yield losses became increased with maize damage level of 75%. Other studies indicated that yield losses of 10.9 and 26.4% were recorded when 30 and 45%, respectively of the plant population was removed at the early stage indicating that crop damage and yield loss are not the same, and maize plants could tolerate up to 15% loss of plant populations due to pest damage without significant yield reductions (Abdulahi 1994). However, according to Pommel and Bonhomme (1998) who observed that with plant populations of 130 000 per hector, the ears lost corresponding to missing plants are poorly compensated by increased yield of surrounding plants because of additional light interception: when two or three adjacent plants were missing, compensation for missing plants was only 16 and 34%, respectively.

Results from the current study indicated that the simulated yield losses from damage levels was compared to maize damage assessment during seedling stage, and it was found that both of them showed the same trends, increasing from lower to greater than 70%. This implies that seedling loss can lead to yield loss of the crops with relatively the same amount. High seedling losses have also been observed to lead to high crop yield losses for both rice (Mulungu et al., 2014) and wheat (Meheretu et al., 2014).

Conclusion

The results of this study demonstrate how maize yield losses occur in semi-arid areas because of seedlings damaged by rodent pest species under different soil types and fields.

To minimize damage, appropriate ecologically based rodent management strategies should be practiced to improve food security for smallholder farmers. It is clear that the control of rodents depends on the site, neighborhood and available food. In this research, the most important approach for preventing rodent damage on maize seedlings and yield losses is to improve cultivation practices.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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