Relationship of Rice Crop Depredation to Rodent Density Estimates in Eastern Kano, Nigeria

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Abstract

In many parts of Africa rodent depredation on growing rice has been the cause of distressing losses. In rain-fed fields near Tarauni, northeast of Kano, Nigeria, the Nile rat, Arvicanthis niloticus and the Multimammate rat, Mastomys natalensis, are major rodent pests involved in upland rice damages. The objectives of this work were to determine the proportion of rice damaged at selected growth phases and maturation (=yield loss); differences in amount of damage between rice varieties; and relationship between abundance of rodents to scale of damage. Methods involved random selection of four replicates of ha-1 plots each of two varieties, namely, FARO-54 and FARO-58. In each plot were at least 676, 2m X 2.5m or larger planting beds (Clusters) from which 246 were randomly selected, meeting 95% confidence value for sample size estimates. From each cluster 25 hills were randomly selected for damage counts using Cut-Tiller-Count method. A mix of Burrow-Count and other rodent abundance indices along five replicates of 300m x 2m transects were selected to estimate rodent densities after calibrating the values of the indices to known population sizes drawn from capture-removal and regression analysis. Mean yield loss was up to 13%, with significant differences at P<0.05 in damage between rice varieties, rice growth phases and population densities. Rodent density estimates were 48-108 animals per ha-1, with statistically significant relationship to magnitude of damage. Investigations such as this were thought to offer vital data for crop insurance and other agro-financial decisions.

Keywords: Arvicanthis niloticus, rice depredation, Mastomys natalensis, Nigeria, rodent population
Introduction

African rodents are amongst the most serious pests in both farms and storage. Rice is especially prone to damage because of the plant cover that it offers to scurrying rodents. In several studies of African small mammals, the Nile Grass rat, *Arvicanthis niloticus* (Desmarest, 1822) and the Multimammate mouse, *Mastomys natalensis* (Smith 1834), the two murid rodent species concerned in the present study, are fairly common and dominant across tropical Africa (Caro, 2001; Dobigny et al, 2013; Duplantier, 2013; Goyens et al, 2013; Kingdon, et al, 2013; Leirs, et al. 1989, 1994; Nicolas, et al, 2010; Rabiu and Rose, 1997, 2004), and have been indicted as pests of cereal crops (Stenseth et al, 2001; Sluydts, 2009; Massawe, et al., 2007; Stenseth, 2006). In northern Nigeria, Rabiu and Rose (2004) attribute field rice and wheat yield losses of over 13% and 30%, respectively, to depredation caused by the two species in irrigated fields. Records going back to the 1960s (Taylor, 1968) report 34-100% loss of wheat and barley during the 1951 and 1962 rodent outbreaks in western Kenya. Both species, *M. natalensis* especially, are also infamous as agents of several zoonotic diseases, including Lassa fever, leptospirosis and plague (Gratz, 1997; Meerburg et al, 2009).

Both *A. niloticus* and *M. natalensis* are semi-commensals with human, inhabiting natural and cultivated fields near villages and other settlements (Granjon and Duplantier, 2011; Kingdon, et al., 2013; Rabiu and Fisher, 1989). They are very prolific, breeding mainly during the rains when foods are abundant or, shortly before or after (Chekol, et al., 2012; Fisher, 1991; Makundi, et al, 2009; Neal, 1991; Rabiu and Rose, 1997), and show tendencies for population explosion, especially following periods of draught followed by heavy rains or extended supply of moisture through irrigation (Delany, and Monro, 1986; Mwanjabe et al., 2002; Poulet, 1978; Rabiu and Rose, 1997; Taylor and Green 1976). Several species complexes exist for both *A. niloticus* and *M. natalensis* in east, west and southern Africa (Kingdon, et al., 2013; Sicard, et al., 2004).

The objectives of this work were to determine extent of depredation; proportion of rice crop damaged during growth phases and maturation (=yield loss); differences in amount of damage between rice varieties; and the relationship between abundance of rodents to the scale of rice damage during the July-October, 2016 growing season.

Materials and Methods

Study area

This is about three kilometers east of Tarauni village, 12° 07’ 26.56’’ N; 8° 54’ 51.59’’ E; and 405.38m ASL, near the town of Zakirai, Kano, Nigeria. General landscape represents a degraded Sudan Savannah similar in plant cover and other features to the fields described in Rabiu and Rose (1997; 2004). Although not a natural flood plain, heavy monsoon rains would saturate the depressions, providing abundant water, thereby encouraging the cultivation of rice, sugar cane and other hydrophytic crops. Rodents would also easily establish refuge populations in nearby fallow fields and inside crop farms, as well as, inside uncultivated marginal lands that separate farm holdings. Annual precipitation during May-June to early October varies from year to year but, averages about 950mm.
Much of the area is simply r exhausted arable land with scattered trees that included Parkia biglobosa (Jacq.) Benth. Sclerokaya birrea (A. Rich) Hochst, Acacia albida Del, and Tamarindus indica L. Shrub vegetation was dominated by Acacia ataxacantha DC., Acacia Senegal L. Willd., and Dichrostachys glomerata (L.) Chiov. Amongst the herbs, Indigofera hirsuta L., Teprosia purpurea (L.) Pers., Waltheria indica L., were dominant, especially during the rains. The grass and sedge were predominantly Andropogon gayanus Kunth, Hynpharrenia and Schizachyrium spp., Pennisetum pedicelatum Trin., and Cynodon dactylon (L.).

**Sampling plots**

In mid June 2016, about three weeks into the rain-fed rice growing season, four ha⁻¹ random primary sampling plots each for two varieties of high-yield, early-maturation, upland rice, namely, FARO-54 and FARO-58, were selected for sampling, totaling eight ha⁻¹ plots in all. We found that the rice farms had already been subdivided by the farmers into planting beds, henceforth here referred to as clusters. These were clearly marked and demarcated by mounds of dirt and channels for supplying or shunting water; were shaped square or rectangular; sized 2m X 2.5m or larger. This planting configuration made random selection and numbering of sampling clusters fairly easy. Then, pegging the Confidence level at 95% for sample size, I made a random selection of 246 clusters per ha⁻¹ (a ha⁻¹ has approximately 676 clusters). Each contained roughly 80 rice hills each.

**Damaged tiller counts**

The hills represent the basic sampling units for damaged tiller counts (Rabiu and Rose, 2004; Rennison and Buckle 1988). We (present author and his field assistants) examined 25 hills from each cluster, about the number commonly suggested in this kind of study (Benigno,1979; Rabiu and Rose, 2004). Individual hills had varying number of tillers, but with a rough average of 10. It was also assumed that the rodents select tillers to eat in a random manner. Damage was assessed by the Cut Tiller Count Technique (Aplin, et al., 2003; Benigno,1979; Rabiu and Rose, 2004).

Assessment for damage was done every fortnight, the first count beginning at six Weeks After Sowing (WAS) and continuing until the crop reached the phase of maturation/pre-harvest, 14 WAS. Mean percent depredation was determined at the end of each sampling period. Percent loss of tillers in the period less than two weeks prior to harvest approximates the percent crop yield loss because of the absence of compensation after crop maturation (Aplin, et al., 2003; Lavoie et al., 1970). Percent yield loss in a mature crop was estimated using the Remnison and Buckle (1988) formula: PL = 100 (A-B)/A. Where PL = percentage tiller loss, A= number of tillers per hill in undamaged hills, and B = tillers per hill in damaged and undamaged hills. Percent values were transformed by arcsine square root prior to statistical analysis, using the General Linear Model ANOVA to evaluate the effects of rice variety, growth phase, rodent population size and their interaction on tiller damage.

**Rodent population estimates**

In light of recent Lassa fever incidences in many parts of Nigeria and lack of readiness to handle potentially infectious rodent specimens, hence concerns for safety, direct contact with animals was avoided, and no live trapping was conducted. Instead, a mix of indices of animal abundance were
counted and compared to regression data that calibrated the same indices to animal numbers. The regression data was from a previous, separate, capture-removal study in the same general area, a generous data from rodent gatherers who would work with my plans, and mass capture vast fields over five to ten days. The indices of abundance included Active Burrow, Spotlightening (visual sightings), Fresh Fecal Pellet and Cut Plant/Crop Stem for both *A. niloticus* and *M. natalensis*, counted every two weeks along five randomly selected 300m x 2m transects that traversed my selected farms that had both rice crop varieties. The earlier, separate capture-removal study had mean densities estimated from five-day capture and removal effort in nearby fields, using traps made of snares from nylon thread strapped to sticks or twigs, and wedged into the ground about the intersections of lines and rows of 10m x 10m configuration, and especially across runways. The traps blended well in the ground, were unnoticeable by the animals, and proved very effective. The snare trap made it possible to capture, remove and process or dispose of rats with limited risk of contamination. There were hardly any ethical concerns in the removal effort, as the animals were pest species, destructive to the farmer, and until the recent Lassa fever scare, food to hunters that snare them. In fact, their removal is recommended in several rice-farming manuals.

**Results**

**Analysis of tiller damage and crop yield losses**

Rodent damage to rice tillers and yield loss assessed in a bi-weekly sampling and population estimates from similar fields are shown in Table I. Damage appeared to increase from the booting to the maturation phases of the crop at 14 WAS. The earlier weeks of the crop, at pre-tillering and tillering had lower percent damage for both varieties. Although the highest mean damage was 13.7 percent, the highest damage value was 17 percent. The animal population density actually doubled from the eighth week, and remained nearly unchanged till the week of harvest (Table I).

The interactions for mean percent crop damage with rice crop variety and phase of growth are shown in Figure 1. The trends are the similar to those in Table I, i.e., increasing damage as rice crop matures and rodent pest populations increased. The damage to FARO-58 was higher than to FARO-54 throughout the study, and had therefore little to do with slightly earlier time of maturation for the former. For both rice varieties there were clearly the presence of more rodent pests and greater depredation during the last four weeks of the growing season than in the earlier weeks.

**Indices of rodent abundance versus population density estimates**

The indices of rodent population abundance and known population sizes during each of five sampling periods are given in Table II. Except for active burrow counts (*T* = 2.08; *P*<0.05), most of the indices did not appear to help predict population size in the field during the sampling periods. It should be noted that, except for two house mice, no other species besides *A. niloticus* and *M. natalensis* were noted. This is probably on account of trap bias that was specifically designed to target rodents in the weight range of 45g - 200g.

**Statistical Analysis**

Tests for the effects of rice variables - variety, growth phase, and interactions of variety and growth phase on magnitudes of rodent depredation
were made using the general linear model, GLM of Analysis of Variance, ANOVA and basic statistics. That rodents ate more of FARO-58 than FARO-54 was not accidental (DF=1; F=7.07; P<0.05). The growth phase of the crop did influence levels of depredation as more of the maturing crops were preferred to the earlier growth phases (DF=4; F=31.55; P<0.05). Similarly, population size had significant effect on degree of depredation (F=24.79; P<0.05).

There were no significant interactive effects amongst any two or all three of the factors - crop variety, growth phase and rodent population size. Pearson correlation for rodent densities to level of rice crop damage was significant (=0.70; p< 0.05).

**Discussions**

**Rice yield losses**

Differences in the rates of depredation amongst phases of rice growth and development ranged from low to high and was similar to observations elsewhere in the region (Rabiu and Rose, 2004). A nearly 14 percent yield loss as in the case of FARO-58 is rather substantial, especially in the case of small farm holders. During the early growth and tillering, the crops did not offer much cover to shelter the rodents from predators, and probably did not present superior nutritional value over natural grass and herbs which were common at the time. However, as the rice crop matures, its value in seed supply and plant cover increased leading to higher magnitude of damage. These observations were consistent with results in Rabiu and Rose (2004) and others. In parts of Asia rodent damage to rice crop can be enormous (Aplin et al., 2003), perhaps even more so than in Africa. The pinnacles of FARO-58 appeared to be heavier and more voluminous than those of FARO-54, thus bending the stem, and perhaps making it easier for the rodents to cut it, consequently higher levels of damage in FARO-58. This might explain some of the difference in damage between the two varieties.

I rarely encountered damage to panicles on an upright, standing tiller. When that happened, it was because of the weight of the panicle bending down the stem or, or perhaps caused by the force of wind, and not because the rodents mounted up the stem. I had no evidence of active mammals that would characteristically scale up the stem in order to damage the pinnacles, as suggested by some members of the farming communities. Nevertheless, the house mouse has shown some tendency of vertical movements on trees and tall grasses. This species is entirely fully commensal, and only two were capture during the study. Nearly all the damage was the characteristic angular tiller cut towards the base of the tillers. Generally, damage was readily noticeable from heaps of cut tillers, pinnacles or seeds present on the ground.

Rice would show various responses to damage depending on the variety or when the damage was done (Sanchez, 1974). There is usually good compensatory response to low and moderate depredation of ≤ 30% at earlier, pre-dough phases (Aplin, et al., 2003; Benigno,1979; Haque and Fiedler, 1985). In rice depredation experiments, Mulungu, et al, (2014) notes only damage at the maturation phase, some 110 Days After Sowing (DAS) resulted in significant reductions in rice crop yield. The highest crop yield loss seen in the present work, approximately 14%, was lower than values from previous studies in the same region (Rabiu and Rose, 2004). This was probably due to more extensive, irrigation-aided, hectarage that expanded the habitat and refugia of the rodents.
leading to greater crop damage seen in the Rabiu and Rose (2004) report.

**Rodent population estimates**

Although the size of population in the field has shown clear connection between animal numbers and level of damage (Pearson correlation =0.70; p<0.05), level of damage in itself was not a reliable index of population size as shown by coefficients of regression (Table II). Other indices of abundance, including spotlightening, cut grass stems/crop tillers, fresh fecal pellet count and others did not appear helpful in accounting for population size. The only index that was useful for providing clue to population size was the number of active burrows in the field. I would caution against hasty adoption of indices of abundance where strongly reliable estimates of population size are required. A rapid estimation of rodent population size over a short period of time using such indices, as against full scale population study would be useful, but may not have universal application for all species or, even for the same species in different localities and times. Many workers have alluded to this caution, e.g., Aplin, et al., (2003). The breeding season of both *A. niloticus* and *M. natalensis* in the study area and the rest of the region is during the rains and reaches peak when rice and other crops are maturing (Rabiu and Fisher, 1989; Rabiu and Rose, 1997, 2004), and as monoculture practices become more intense, rodent crop depredation will probably be on the increase. An integrated approach that combines minimizing rodent refuge habitat and intensive removal will help but only when populations are low. Rodent eruption might require the careful application of rodenticides in critical situations. Intensive studies and analysis of rodent depredation of crops, as well as reliable data on the populations sizes during various phases of crop development are critical for important agribusiness decisions.

**Acknowledgments**

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**References**


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Figure 1. Interaction of Crop Damage (Mean Percent) With Crop Growth Phase (Weeks After Sowing, WAS) and Rodent Pest Population (Density/ha) during the July-October, 2016 growing season.
Table I. Mean percent rice FARO-54 and FARO-58 tillers damaged by rodents, and rodent population estimates (SE) in fields near Tarauni Village, Kano, Nigeria, during July-October, 2016.

<table>
<thead>
<tr>
<th>Growth Phase (Weeks After Sowing)</th>
<th>Rice Crop Varieties showing mean percent damage (SE)</th>
<th>Combined A. niloticus and M. natalensis density estimates/ha(^1) (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FARO-54</td>
<td>FARO-58</td>
</tr>
<tr>
<td>6</td>
<td>*2.01 (0.45)</td>
<td>*1.88 (0.51)</td>
</tr>
<tr>
<td>8</td>
<td>*3.80 (0.6)</td>
<td>*5.55 (0.42)</td>
</tr>
<tr>
<td>10</td>
<td>**9.38 (1.16)</td>
<td>**9.47 (1.35)</td>
</tr>
<tr>
<td>12</td>
<td>***10.98 (2.29)</td>
<td>***13.49 (1.12)</td>
</tr>
<tr>
<td>14</td>
<td>*8.60 (0.91)</td>
<td>***13.70 (0.88)</td>
</tr>
</tbody>
</table>

Sampling for indices of population abundance traversed fields planted with the two rice varieties. *Percent damage at maturity phase of growth (14 Weeks After Sowing, WAS) represents yield loss. *Low damage; **Moderately high damage; ***High damage (Damage Assessment Scale, after Benigno, 1979). Pearson correlation for animal numbers against level of damage (=0.70; p< 0.05).
Table II. Performance of selected indices of population size and (standard error) linked to known population estimates from regression analysis during July-October, 2016.

<table>
<thead>
<tr>
<th>Predictors (Indices of Population abundance)</th>
<th>Mean transect values of indices of population. Weeks after rice crop sowing (WAS). Estimated densities are in last row.</th>
<th>SE of Coeff.</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>42.15</td>
<td>8.69</td>
<td>4.84</td>
<td>0.00</td>
</tr>
<tr>
<td>Active warrens count</td>
<td>6.80 (0.86)</td>
<td>8.80 (2.42)</td>
<td>19.20 (4.74)</td>
<td>25.60 (4.91)</td>
</tr>
<tr>
<td>Spot lightening</td>
<td>1.60 (0.51)</td>
<td>5.00 (1.38)</td>
<td>3.400 (0.92)</td>
<td>9.40 (1.50)</td>
</tr>
<tr>
<td>Cut grass stems/crop tillers</td>
<td>613 (104)</td>
<td>2617 (375)</td>
<td>3444 (391)</td>
<td>4112 (558)</td>
</tr>
<tr>
<td>Fresh fecal pellets</td>
<td>13.80 (1.20)</td>
<td>14.00 (1.82)</td>
<td>27.00 (4.30)</td>
<td>25.00 (4.09)</td>
</tr>
<tr>
<td>Combined rodent species density estimates per ha²(SE)</td>
<td>44.20 (3.40)</td>
<td>59.00 (4.46)</td>
<td>100.20 (4.76)</td>
<td>108.20 (7.55)</td>
</tr>
</tbody>
</table>

Only *active warren count (P<0.05) could serve as predictor for population size. Regression $R^2 = 51.2\%$. Sampling for indices of population abundance traversed fields of the two rice crop varieties, FARO-54 and FARO-58. Estimates for combined populations of *Arvicanthis niloticus* and *Mastomys natalensis* are given in the last row.