

CHAPTER SIX

Assessment of damage to sorghum by armoured bush cricket, *Acanthopplus discoidalis* (Orthoptera: Hetrodinae).

ABSTRACT

A technique to assess armoured bush cricket (ABC) damage to sorghum was developed and evaluated. The study quantified a relationship between panicle structure and exposure period to ABC and yield loss. Yield losses of 22 %, 37 %, and 45 % were observed for 15, 30 and 45 days of feeding duration respectively. It was also demonstrated that growth stage of sorghum at the time of attack is critical in determining the level of damage. More damage and yield loss occurred in sorghum that was attacked at an early growth stage compared to a late growth stage. This implies that to minimize yield loss, farmers should intensify their control efforts at the early stages of sorghum grain development. Observations of feeding behaviour indicated that the most frequently fed on the top one-third section of sorghum panicles compared to the middle and bottom sections. Comparing Segalane and Zakazaka, two local sorghum varieties, it was shown that yield from control plots was higher for Segalane (0.8 t ha^{-1}) than that of Zakazaka (0.58 t ha^{-1}). The yield loss at a moderate infestation level was also significantly higher in Segalane at 81 % compared to 42 % in Zakazaka. As a result, significantly more grain was available for harvest in Zakazaka than Segalane cultivars. This was attributed to the panicle architecture of Zakazaka which has drooping primary branches which do not provide adequate perching sites to feed effectively on the grain. Such resistant varieties may have a role in pest management in areas subject to frequent outbreaks.

Key words: *Acanthopplus discoidalis*, Botswana, estimated damage, feeding duration, yield loss, resistant cultivars.

INTRODUCTION

Grain sorghum is the staple food crop in semi-arid Botswana. Rainfall occurs mostly in the summer months of November to January and varies between 350 mm – 500 mm per annum in the main arable eastern areas (Sims 1981). Insect pests are a chronic problem in subsistence sorghum production in Botswana and have been reported to reduce yields by 30 % (Ingram *et al.* 1973; Manthe 2000). One of the most important sorghum pests is the armoured bush cricket (ABC), principally *Acanthopplus discoidalis* (Walker) (Orthoptera: Heterodinae). This species is widespread in Botswana, Namibia and parts of South Africa, whilst a related species, *A. speiseri* Brancsik, is a serious pest in Zambia, Zimbabwe and Malawi. Both species can inflict severe losses on the cereal harvest (Leuschner & Manthe 1989; Bashir *et al.* 1991; Mbata 1992; Van den Berg & Drinkwater 1998; Wohlleber 2000). In a survey conducted in Central District, Botswana, farmers ranked ABC as the second most damaging pest, just after quelea birds but far ahead of all other crop pests (Matsaert *et al.* 2000). ABC are omnivorous, and occasionally even cannibalistic, but they feed selectively with a preference for the panicles of certain grasses (Mbata 1992). In cultivated areas they attack cereal panicles, whose emergence typically coincides with a decline in availability of wild grasses (Wohlleber 1996).

A method of accurate assessment of the extent of crop losses due to identified pests is important for effective pest management. Yield loss estimation can guide decisions relating to short-term action plans, e.g. whether pest intervention is necessary to avoid economic damage, as well as guiding long-term decisions relating to relative pest status and allocation of resources. Relatively little progress has been previously made on loss assessment in cereals (Flattery 1982; Nwanze 1988; Pantenus & Krall 1993; Jago 1995). Legg & Togola (1993) estimated damage to pearl millet by the grasshopper *Diabolocatanops axillaris* (Thunberg) (Orthoptera: Acrididae) and found that it reduced yield by up to 25.7 %. The accuracy of such estimates varies however because, for practical reasons, Subjective decisions are used. Several authors have reported crop damage levels for ABC. Damage levels of 10 - 30 % were observed by Wohlleber (1996) using Pantenius and Krall's (1993) yield assessment method on pearl millet in northern Namibia. Minja (2000) subsequently reported yield losses in sorghum and millet in Namibia to range between 10 - 80 %, depending on cricket density. Bashir *et al.* (1991) estimated visually, a loss of 40 % in sorghum

yield during a serious ABC outbreak in Botswana. These estimates suggest a wide range in yield losses to ABC, but due to the lack of a standardized technique to estimate yield losses it is questionable just how comparable these figures really are. There is a clear need for simple but accurate methods for estimating yield loss that can be adopted over the entire region.

The main purpose of this study was therefore to develop and evaluate a technique for determining yield loss assessment and to quantify the impact of ABC attack on sorghum.

MATERIALS AND METHODS

Study site

Studies were carried out at the Agricultural Research Station at Sebele (24° 34 S, 25° 57 E) during the 2000/2001 and 2001/2002 cropping seasons. Sorghum was planted in mid-December in each season. The inter-row spacing was 0.75 m and within row spacing was 0.30 m. Weeding was carried out by hand. No fertilizer was applied because the fields were rotated to leguminous crops. Meteorological conditions consisted of clear summer skies with diurnal temperatures ranging between 15 °C and 32 °C.

Description of methods used in the study

Wire mesh cages with a base area of 1.0 m² and a height of 2.0 m were used to enclose 0, 3, 6, or 9 adult crickets on 10 sorghum plants growing in a field. Crickets were checked daily and only dead ones were removed and replaced with live ones. Tillers that formed on plants were removed to avoid providing any additional food source other than the ten panicles. Besides containing the ABC on the test panicles, the cages also prevented damage from other pests such as birds. Percentage surface area damage to each panicle was estimated directly after each feeding period was completed.

To estimate damage levels in the field, each panicle was visually assessed for damage by dividing each panicle into three equal sections labelled as top, middle and bottom (Fig. 6.2). Damage on each section was scored as a percentage of the whole one-third portion being examined. The damage estimates for these sections were combined to give a damage estimate for the whole panicle. It took about one minute

to estimate each panicle for surface damage in the field. After each damage estimate, the crickets were removed and the sorghum was left in the field until physiological maturity. The panicles were harvested 125 days after crop emergence, when all grain had matured. Physiological maturity was defined as the appearance of a dark spot on the opposite side of the kernel from the embryo as described by Vanderlip and Reeves (1972). Grain mass (yield) was then recorded for each panicle in the laboratory.

Effect of ABC feeding duration on surface damage and yield

To determine the effect of ABC feeding duration on estimated surface damage and yield, a field trial was conducted using the well-known sorghum variety, Segaoane. Similar wire mesh cages were used to enclose 10 sorghum plants growing in the field. The experiment consisted of four treatments (different exposure periods) replicated three times. The four exposure periods of 0, 15, 30 and 45 days were used to assess damage inflicted during these feeding periods before cricket removal. Six crickets were introduced into each cage at 65 days after crop emergence (soft dough stage) and allowed to feed for the above designated feeding periods. No crickets were placed in control cages. The number of damaged sites was recorded separately for the upper, middle and lower sections on the panicle to determine whether ABC preferred certain sections.

Effect of sorghum development stage on surface damage and yield

A field experiment was conducted by infesting sorghum at two crop growth stages with three different cricket numbers, plus a control treatment. The different cricket numbers were used to simulate different levels of ABC field infestations. The infestation levels were three, six and nine ABC per cage and inoculation was done either at the soft dough or hard dough stage of panicle development. Four cages with the above dimensions were allocated to each sorghum growth stage and replicated three times. Each replicate included ten sorghum plants. Crickets were allowed to feed continuously for 15 days and then removed from the cages. The feeding duration of 15 days was determined from the previous study conducted above. Surface damage of panicles and grain mass for each panicle were then determined, as described earlier.

Effect of panicle type on surface damage and yield loss

To assess surface damage on different panicle types, a field experiment was conducted using two sorghum varieties with diverse panicle structures. Two sorghum varieties, Segaolane and Zakazaka, were planted in mid-December 2001. These particular varieties were also selected because of their popularity amongst farmers. Segaolane has a compact elliptic panicle whilst Zakazaka has a very loose panicle with drooping primary branches. A completely randomised block design was used to allocate six plots (5 m x 5 m) to each variety.

Three pairs of male/female adult crickets were introduced in each of three cages per plot, each containing 10 sorghum plants, when the sorghum was at the 50 % flowering stage.

The technique for damage assessment was similar to that described above except that ABC were left to feed for 15 days at the soft dough stage only and then removed from the cages. The cages were also removed to allow for ease of daily observation of the plants. Bird scarers were employed throughout the grain development period to ensure that there was no additional damage from birds. Plots were inspected daily for any insect or disease infestation. The crops were left in the field until physiological maturity when they were harvested and their yield determined. A total of 120 sorghum panicles of each variety were used to estimate percent damaged surface area on panicles and yield loss. The yield potential of each variety was determined using panicles harvested from control plots.

Statistical analysis

Regression analyses were used to describe the relationship between the numbers of crickets at different growth stages and damage estimates. ANOVAs were used to determine if there were significant differences between damage estimates at the different growth stages. Non-linear regression analyses were used to describe the relationship between estimated and actual yield loss. ANOVA was used to determine if differences between yield potential and yield loss of different varieties were different.

RESULTS

Effect of ABC feeding duration on surface damage and yield

Typical damage symptoms to sorghum are shown in Fig. 6.1. Meteorological conditions during period of study consisted of open skies with temperatures ranging from 22 – 32 °C and night temperatures ranging between 15 – 25 °C. A quadratic relationship was demonstrated between feeding duration and yields loss (Fig 6.4: $r^2 = 0.98$). After feeding periods of 15, 30, and 45 days on Segaolane, yield losses were 22 %, 36 % and 45 % respectively. Hence, the yield losses inflicted by each successive 15-day feeding periods was 22 %, 14 %, and 9 %, respectively, indicating diminishing increments in yield loss. Under field conditions, crickets were observed to feed on developing grain for an estimated period of 30 days.

Fig. 6.2 shows a typical sorghum panicle and the division of the head for assessing damage while Fig. 6.3 & Table 6.1 illustrates the various panicle shapes. Estimated damage was significantly higher in the top section than either the middle or bottom sections (Top versus bottom Fig 6.5: $t = 7.8$, $df = 13$, $p < 0.001$; Top versus middle Fig 6.5: $t = 2.7$, $df = 13$, $p < 0.009$). Estimated damage from the middle and the bottom sections were not significantly different from each other (see Fig. 6.5: $t = 1.44$, $df = 13$, $p < 0.09$). This is consistent with observations during field visits, when crickets were usually observed perching on the top section of sorghum heads. They would subsequently climb down to lower parts of the panicles or fall to the ground when approached. Results from this study therefore suggest that ABC infestations during outbreak seasons could result in yield losses ranging between 15 and 25 %.

Effect of sorghum development stage on surface damage and yield

The growth stage of sorghum at the time of ABC attack was found to have a significant effect on surface damage and yield loss (Table 6.2). More surface damage was inflicted at the soft dough stage than hard dough stage at each infestation level tested (Fig 6.6). Feeding for 15 days, three crickets resulted in 19 % yield loss at soft dough and 15 % yield loss at hard dough stage; six crickets resulted in 38 % yield loss at soft dough stage and 21 % yield loss at hard dough stage; nine crickets resulted in 58 % yield loss at the soft dough stages while a similar number, feeding on panicles at hard dough stage resulted in 29 % yield loss (Fig 6.7). The statistical summary of this

experiment is shown in Table 6.2. To sum up, more damage occurred at the soft dough stage.

Effect of panicle type on surface damage and yield loss

Fig. 6.3 illustrates the different panicle structure found in grain sorghum. Quadratic relationships were observed between surface damage and yield loss in both varieties (Segaolane $r^2 = 0.88$; Zakazaka $r^2 = 0.92$) (Figs. 6.8 and 6.9). A phenomenon of diminishing increments is shown by yield loss levelling off at 95 % and 80 % for Segaolane and Zakazaka varieties respectively. Yield and yield loss data are provided in Table 6.3. The Segaolane and Zakazaka cultivars suffered average yield losses of 81 % and 42 % respectively (Table 6.3). Very few crickets were observed perching on Zakazaka as compared to Segaolane. A summary of the yield losses observed in this study is provided in Table 6.4.

DISCUSSION

This study indicated that yield loss caused by ABC on sorghum varied with plant growth stage and infestation level. A summary of the yield losses observed in this study is provided in Table 6.4.

Overall, the yield losses recorded in this study ranged between 19 and 58 %. This latter figure could be considered abnormally high since the infestation level at one ABC per panicle was higher. Under field conditions infestation levels of 3.3 ABC per m^2 have been observed in an isolated sorghum field (P. Mosupi and J. van den Berg, pers. observation). This number translates to approximately 0.3 ABC per sorghum panicle which is one of the infestation levels used in this study (Table 6.4). The percentage yield loss at an infestation level of 0.3 ABC per panicle, feeding on sorghum for a 15-day period, was 19 % and 15 % at the soft and hard dough stages respectively. This figure is similar to the 10 – 30 % observed for ABC on pearl millet (Wohlleber 1996). It is however much lower than the 10 – 80 % yield losses indicated by Minja (2000) and the 41 % estimated by Bashir *et al.* (1991). Results from this study therefore suggest that ABC infestations during outbreak seasons could result in yield losses ranging between 15 and 25 %.

Dividing the panicle into three equal portions during damage assessment allowed an accurate estimation of yield loss. Assessing entire panicles directly would probably have been faster, but would have presented difficulties when it came to scoring isolated patches of damage on the panicle. These results have shown that the levels of yield loss to ABC are dependent on duration of the feeding period. The increase in damage and yield loss caused by longer feeding durations calls for early control of the ABC by farmers to prevent serious crop damage being inflicted.

A practical problem which should be recognised for sorghum panicle damage evaluation, however, is that of the pest causing the damage cannot always be identified with certainty. In particular, quelea and bollworm damage resembles ABC damage and the two can easily be confused. Quelea are more wasteful feeders than ABC, and the presence of grain fragments that have fallen onto the ground below is a good indicator that birds have recently attacked the seed head. However, these fragments tend to be removed by ground foraging invertebrates, leaving only the evidence of the panicle damage itself, and so if both pests are active in the area then confusion can result. The feeding habits of ABC have been shown here to result in particularly high grain loss on the top section of the sorghum panicle. This could relate to the observation that ABC tend to bask perched on the top part of sorghum panicles and hence may feed more on the immediately available top grain than on the middle and bottom sections below.

ABC caused more damage by feeding on panicles during the soft dough stage of sorghum development. Once the grain matures it becomes hard and less palatable to ABC. Therefore farmers would benefit by intensifying control efforts during the early stages of sorghum grain development.

The relationship observed between surface damage and yield indicates that there is a diminishing increment in yield loss for both sorghum varieties that were studied. Damage was more pronounced in Zakazaka than in the compact headed Segalane variety. The open headed cultivar Zakazaka has a significantly lower yield potential than the compact headed Segalane under normal conditions. However, at similar ABC infestation levels, Zakazaka suffered much less damage and produced a significantly higher yield than Segalane. This appears to be due to the panicle architecture of the two varieties. Zakazaka panicles are loose with drooping primary branches that make perching and feeding by ABC more difficult. Interestingly, another instance of panicle structural protection was recently reported (Ekandjo, pers.

comm.) from an awned local variety of pearl millet in northern Namibia. The spiny panicles impede feeding by ABC and this variety consistently experiences very low damage levels during ABC attacks. The use of ABC-resistant varieties offer potential in areas where ABC infestation is frequent. However, this would be at the cost of reduced yield in low frequency cricket areas. New varieties need to be bred to reduce ABC loss.

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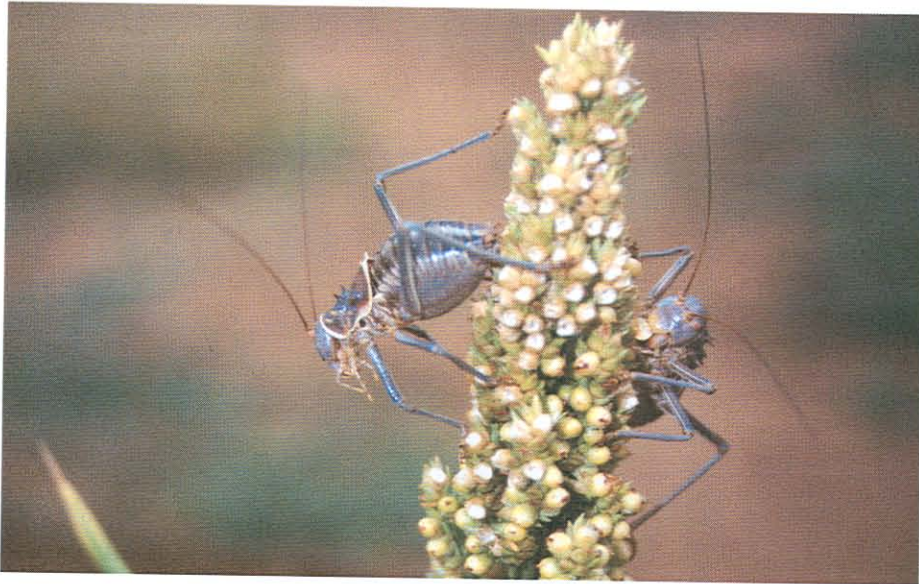
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Fig. 5.1 1-4. 20 symptoms caused by the armoured bush cricket on sorghum.

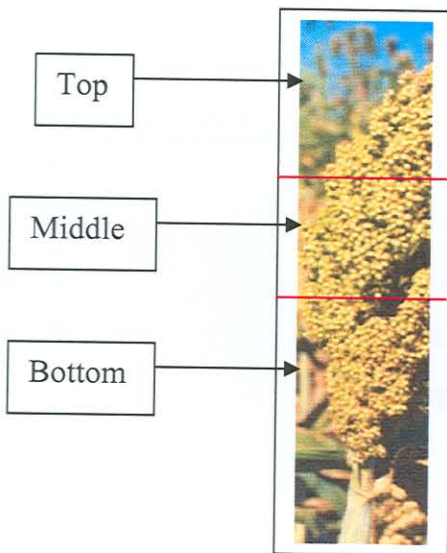


Fig 5.2. Division of panicle into three sections for damage assessment in the field



1:0.9

Fig. 6.1 Damage symptoms caused by the armoured bush cricket on sorghum.



1:0.75

Fig 6.2. Division of panicle into three sections for damage assessment in the field.

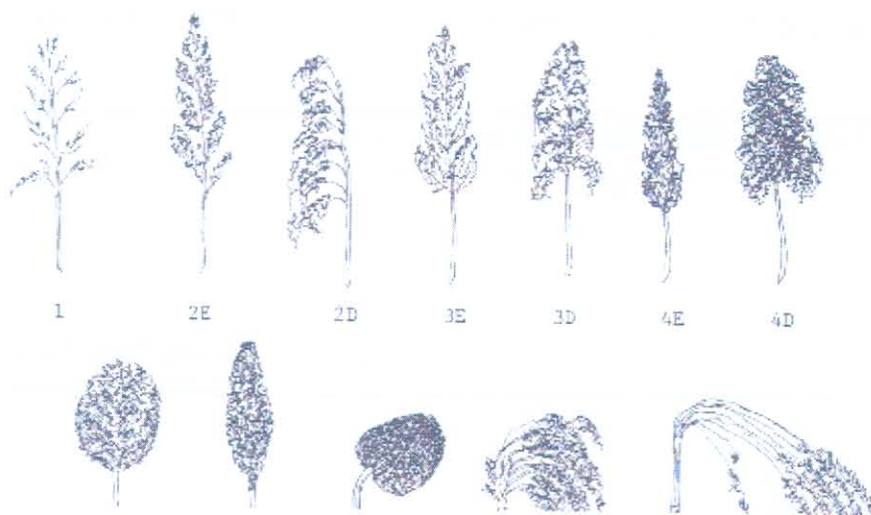


Fig. 6.3. Panicles of sorghum with different levels of compactness and shapes (House 1982).

Table 6.1. Description of different ear compactness and shapes of sorghum (House 1982).

Ear compaction and shape index	Description
1	Very lax panicle
2E	Very loose erect primary branches
2D	Very loose drooping primary branches
3E	Loose erect primary branches
3D	Loose drooping primary branches
4E	Semi-loose erect primary branches
4D	Semi-loose drooping primary branches
5	Semi-compact anglicize
6	Compact anglicize
7	Compact oval
8	Half broom corn
9	Broomcorn

Table 6.2. ANOVA for effect of sorghum development stage on surface damage and yield

Source	df	Sum of squares	Mean square	F Value	Pr > F
Crop stage	1	1308	1308	32.58	0.0001
ABC density	3	5122	1707	42.52	0.0001
Interaction					
Crop stage * ABC density	3	1275	425	10.59	0.0004

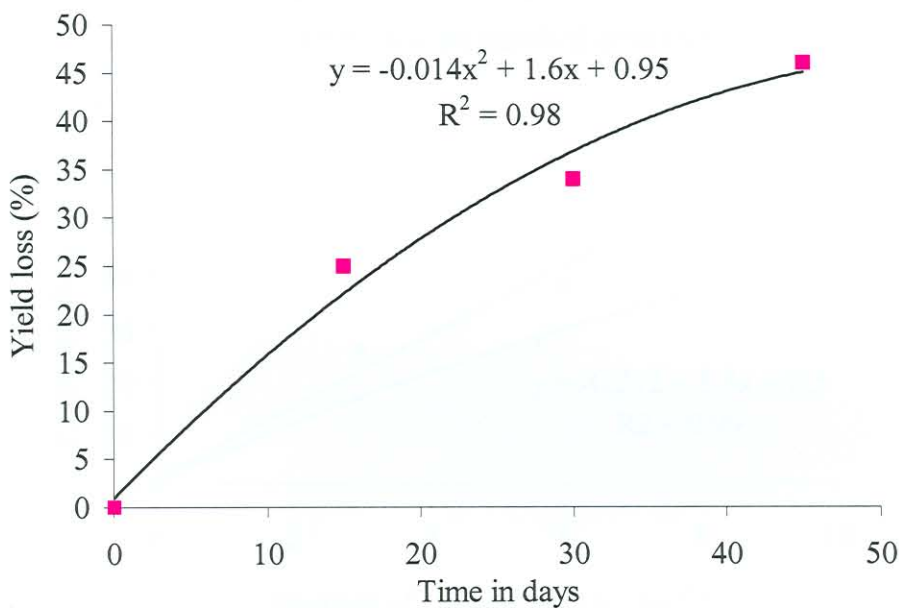


Fig. 6.4. Relationship between feeding duration and percent yield loss caused by crickets in Segaolane sorghum.

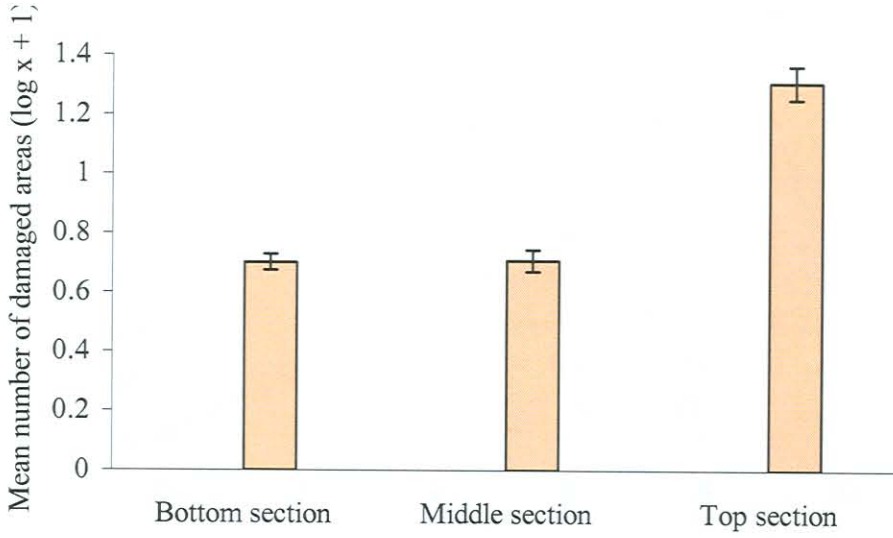


Fig. 6.5. The number of feeding sites of armoured bush crickets on different sections of sorghum panicles. Bars indicate standard error (S.E.).

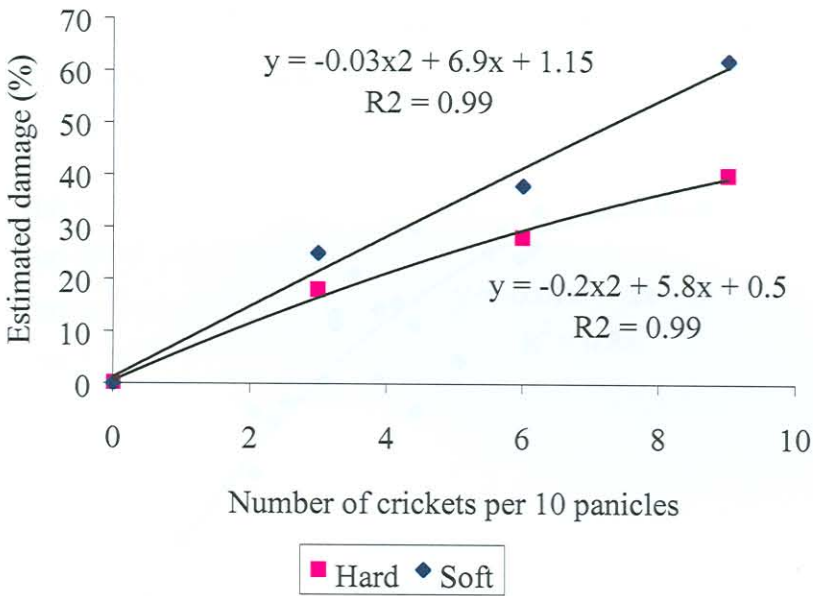


Fig. 6.6. Effects of sorghum growth stage on estimated damage levels for different cricket densities. Bars indicate standard error (S.E.).

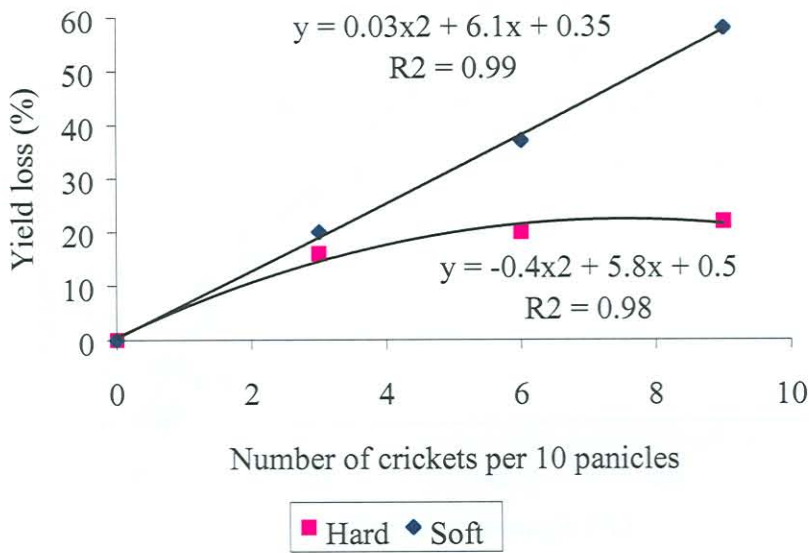


Fig. 6.7. Effects of sorghum development stage on observed yield loss percent caused by different cricket densities.

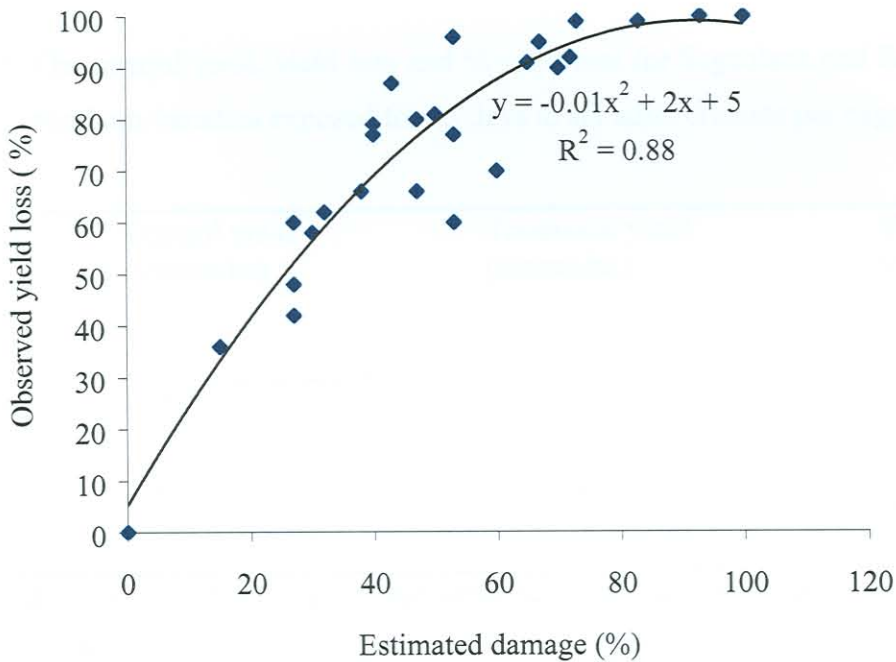


Fig. 6.8. The relationship between estimated damage and observed yield loss caused by armoured bush crickets in the Segalane variety.

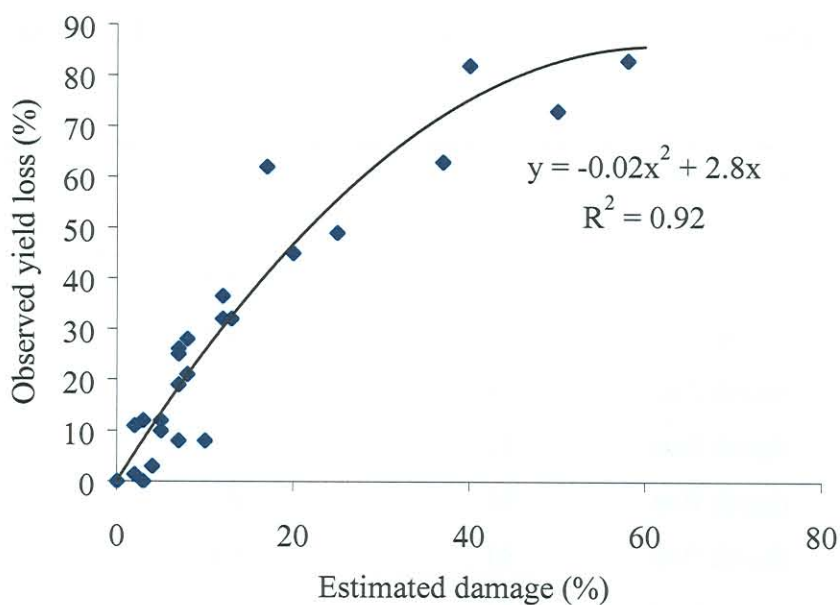


Fig. 6.9. Relationship between estimated damage and observed yield loss caused by armoured bush crickets in the Zakazaka sorghum landrace.

Table 6.3. The control yield, yield loss and % yield loss for Segaolane and Zakazaka sorghum varieties exposed for 15 days to six adult crickets per cage.

Sorghum variety	Control yield (tonnes/ha)	Treatment yield (tonnes/ha)	Yield loss (%)
Segaolane	0.800 a	0.152 a	81.0 a
Zakazaka	0.575 b	0.333 b	42.0 b

Means within columns followed by the same letter do not differ significantly ($p < 0.05$).

CHAPTER SEVEN

Table 6.4. Summary of yield losses observed in experiments conducted in this study.

Number of crickets per cage	Mean number of crickets per panicle	Feeding period (days)	Plant growth stage	Yield loss (%)
6	0.6	15	soft dough	22
6	0.6	30	soft dough	36
6	0.6	45	soft dough	45
3	0.3	15	soft dough	19
6	0.6	15	soft dough	38
9	0.9	15	soft dough	58
3	0.3	15	hard dough	15
6	0.6	15	hard dough	21
9	0.9	15	hard dough	29