First Results of Research on the Armored Bush Cricket (*Acanthopolus discoidalis*) on Pearl Millet in Namibia: Population Dynamics, Biology, and Control[1]

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Abstract

Annual attacks by the bush cricket (Acanthopolus discoidalis/. Iris 1992) cause severe losses in pearl millet production in Owamboland, Namibia, of approximately 10 000 t yr^{-1}, e.g., 30% of the total harvest in 1993. Research in this study is geared to the development of an integrated pest management (IPM) system based on the biology and ecology of the cricket relevant to the socioeconomic environment of communal farmers in Namibia. Understanding of the biology and population dynamics of the cricket should provide adequate knowledge for the development of integrated pest management components with special emphasis on (a) the development of a population forecasting method; (b) the development of yield loss evaluation methods in farmers' fields, involving the quantification of damage caused by the insect at different stages in its growth cycle; and (c) the development of cultural, biological, and chemical control methods.

The data reported comprise selected results from second-season trials and are therefore subject to later reassessment.

Introduction

Studies on the biology and control of the armored bush cricket associated with pearl millet production were started in Nov 1992. The research project was initiated by K Leuschner (SADC/ICRISAT) and the Department of Research in the Ministry of

1. This paper presents preliminary data, subject to further PhD studies, in a cooperative research project organized by the Department of Research, Ministry of Agriculture, Water and Rural Development, Namibia, the Institute of Applied Zoology, Justus-Liebig University, Giessen, Germany, and SADC/ICRISAT, Bulawayo, Zimbabwe. The data are not for citation and all rights are reserved by the author.

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Agriculture, Water, and Rural Development. The project was located at the Omahenene Research Station in northern Owamboland. The station is in the center of a large area infested by the pest.

An objective of the project is to determine the most important factors influencing the population dynamics of the cricket. Studies on the reproductive cycle, as well as an analysis of interactions between the plant, the pest, and their environment will therefore be necessary, after which it is intended to develop an appropriate control strategy. In order to ensure that research findings are relevant to specific situations within the production system in communal areas of Owamboland, field trials are carried out on-farm in close interaction with the farmers. An IPM approach to pest control measures is favored over those based on the sole use of chemicals.

Methods

The life cycle of the cricket was studied with singly-caged nymphal stages in a screenhouse and in pearl millet head cages in farmers' fields. Feeding and food preference studies were carried out in screenhouse cages.

Yield loss analysis in the field

To determine yield losses a modification of the loss-assessment method proposed by Pantenius and Krall (1993) was chosen as relevant to the problems and agricultural conditions of the area.

The modifications were the following:

a) Measurements were carried out on marked plants in the trial plots (16 plants $plot^{-1}$).
b) Panicles were classified according to their degree of compactness into three classes: (1) compact; (2) less compact; (3) loose. For every class a multiplication factor ($g\ cm^{-2}$) was determined by means of a linear regression model:
   Class 1: 0.15 $g\ cm^{-2}$ (r^2=0.76**;n=276)
   Class 2: 0.10 $g\ cm^{-2}$ (r^2=0.81*;n=130)
   Class 3: 0.07 $g\ cm^{-2}$ (r^2=0.68*;n=130)

Subsequently the weight of each panicle was calculated by measuring the surface of the head and by multiplying it with the respective class factor. Damage suffered by the plant at different stages was estimated following Pantenius and Krall's (1993) loss assessment method.

In order to ensure precision in the calculation of severe degrees of damage, the damage level was determined by estimating feeding damage on both sides of the panicle. The average damage was then multiplied by the number of damaged plants in the plot or field. The combination of these methods thus provided an accurate assessment of yield and loss for pearl millet expressed in kg ha^{-1}.

Loss evaluation of different cricket stages

Crickets of different stages (4-7) were weighed and put into panicle cages (35 x 15 cm: one cage-^{1}) placed on pearl millet heads at the plant's development stages 5-9 in a farmer's field, based on development stages proposed by Mati and Bidinger (1981). These range from 0 to 9: 5 = boot stage, 6 = 50% flowering, and 7-9 = cover grain development.

After 10 days the content of the cages, including the pearl millet head, was measured and weighed in the laboratory. The feeding damage was estimated and the weight of the crickets and the faeces was determined.

For each cricket and pearl millet development stage three replicates were carried out. The trial was repeated three times. A total of 60 cages were used for every trial.

For each cricket development stage the amount of grain consumed at different grain development stages was calculated in g day^{-1} $plant^{-1}$ (Pantenius and Krall 1993). For total yield loss per hectare, data from 10 000 planting hills were recorded, because 10 000 plants ha^{-1} represents an average pearl millet plant density on farmers' fields in Owamboland.

Integrated pest management

Choice of sowing date and millet variety. To establish the effect of sowing date and varieties' time (days) to maturity on cricket damage, the following varieties and sowing dates were tested in farmers' fields (LLV = local landrace variety):

1: LLV: 120 days	sowing date 20 Nov 1993
2: LLV: 120 days	sowing date 31 Jan 1994
3: Okashana 90 days	sowing date 31 Jan 1994.

Each plot (20 x 20 m) was hand-sown by the farmer.

The randomized block layout consisted of three replicates for each treatment. LLVs consist of a genetic mix of awned and nonawned plants, and it is claimed that awned plants are less frequently attacked by the cricket. To verify this, therefore, at the dough stage 48 awned plants were selected out of varieties 1 and 2 and were assigned to three groups (three replicates).

During the growing period farmers were asked to fill in forms at 3-day intervals concerning: plant stage, cricket stage, number of crickets, and 20% damage per plant (Jago 1993). Observations by farmers were controlled and verified at 7-day intervals.

The date of harvest was determined by the farmers (19 May 1994). Yields were estimated and damage was calculated. Collection of crickets within the trial plots was avoided.

Change of harvesting procedure. Crickets, especially during migration and aggregation, are attracted to field edges of taller crops and landmarks within a harvested field. This behavior is especially expressed during mating and oviposition. It was assumed that cricket adults would aggregate at specifically created landmarks (stooks of harvested plants) and could be controlled either by hand collection or chemicals. Any egg pods laid at this spot could be easily destroyed by digging them up, thus enabling the farmer to reduce the next year's population.

To exploit this method of cricket control, before oviposition 18 plots, each covering an area of 400 m^2, were harvested early (shortly after physiological maturity) by removing the whole plants which were then stacked to lean against both sides of trestles. These consist of a wooden beam supported on two poles. In this way tent-like landmarks were created in the bare field. These triangular stooks also provided the shade underneath required for egg-laying. The number of crickets concentrated on a single stook could be recorded weekly. Three similar-sized plots, which were not harvested, served as controls.

After the natural decline of the population at the beginning of May, the density of egg pods was determined under each stook (15 m^2) and in the remaining area (385 m^2), and compared with the egg pod density in the unharvested plots (number of egg pods m^{-2}). In this area, also, a plot of 15 m^2 was selected to simulate the area under a stook.

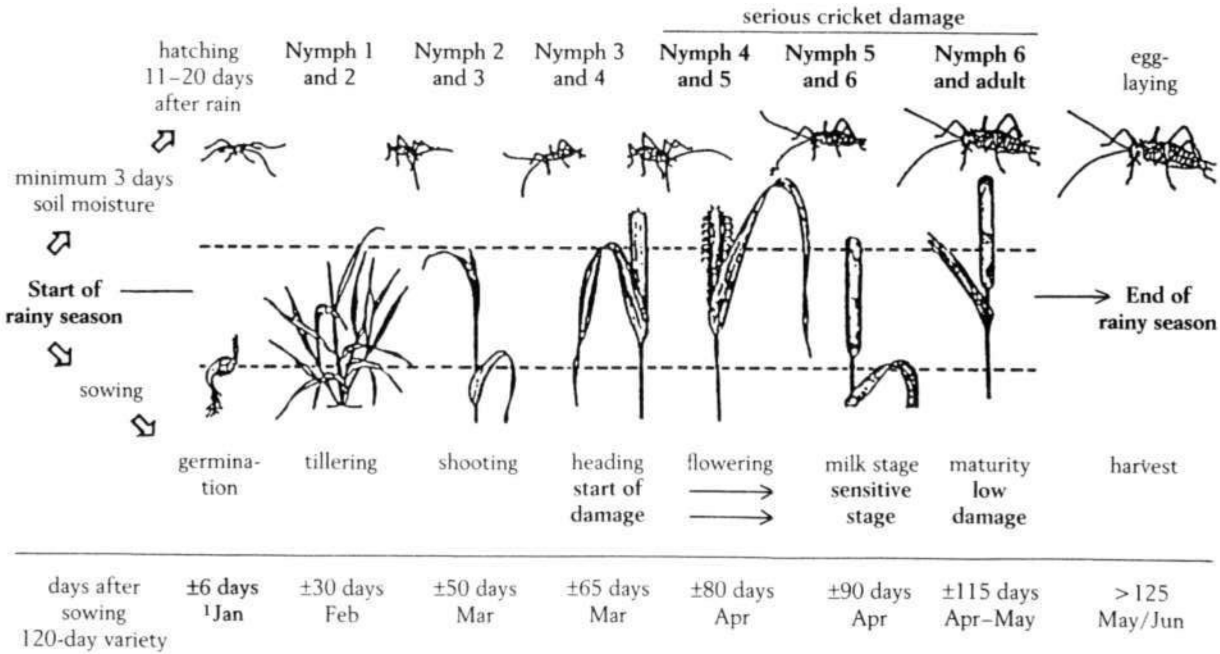
Results and Discussion

Cricket life cycle and pearl millet development

At the beginning of the rainy season in January, first-instar nymphs start to hatch from the egg pods. The rate of hatching is dependent on soil moisture. The topsoil layer (15 cm deep) has to be moist for at least 3 days before hatching starts at 11-20 days afterwards. This finding has to be verified, and could be used as an indicator for forecasting the hatching of cricket nymphs.

Hatching coincides with the germination of pearl millet. After hatching the cricket develops over six nymphal stages before the adult stage after about 70 days. Crickets can develop only on generative plant parts (flowers and grain), although they are able to maintain themselves for some time on leaves without further development. As long as pearl millet is in the vegetative growth stage cricket nymphs depend for food on the generative plant parts of grasses and broadleafed weeds.

The first damage on pearl millet appears only at flowering (Fig. 1). The most serious damage will be caused by the nymph stages 4-6 and by adult crickets. During the milk stage pearl millet is most sensitive to cricket damage. Most serious damage can be expected when the milk stage coincides with the cricket stages 5-7. Later, at grain maturity, pearl millet grain will be too hard for the mouth-parts of the cricket and therefore less attractive during all cricket stages. At the end of the season the cricket lays its egg pods in the shaded soil of perennial trees and shrubs that do not shed leaves and at the base of pearl millet plants in the field. The eggs remain in diapause in the soil until embryonic development starts in October. Fully developed embryos remain in eggs until moisture conditions are right for hatching, as mentioned above.



1 = initial date depends on first intensive rainfalls

Figure 1. Cricket life cycle and development of pearl millet from January to May. The different cricket (1–7) and pearl millet stages (0–9) are listed according to the time of occurrence. Cricket stages that cause the most damage, and plant stages in which most of the damage occurs, are shown in bold.

Yield loss caused by different cricket development stages

Figure 2 shows that, with increasing pearl millet development (grain maturity), feeding with all tested cricket development stages approaches 0. This relation between damage and grain maturity can be seen clearly by comparing the bars of pearl millet and cricket stages. All cricket stages cause most severe loss at the milk stage of the plant. However, the adult stages cause the highest yield loss.

Daily losses of 5 kg potential harvest can be expected if an arbitrary population of 10 000 crickets ha^{-1} is taken into consideration. Comparatively, cricket stage 4 does not contribute much to the yield loss except at the milk stage. Modest yield losses from physiological maturity onwards could be explained by difficulties experienced by crickets in cracking the grain.

The results indicate that major grain damage could be avoided if the milk and soft dough grain development stages of pearl millet do not coincide with the most voracious feeding stages of the cricket.

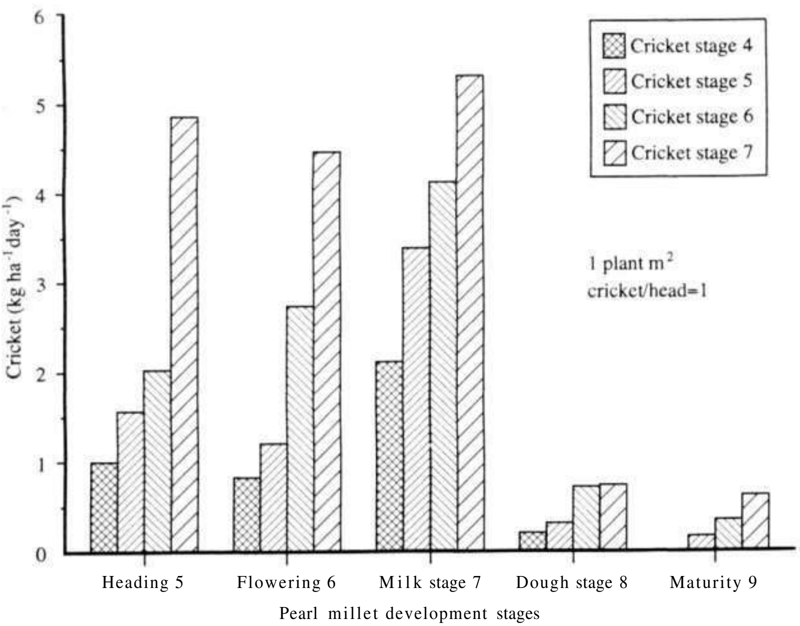


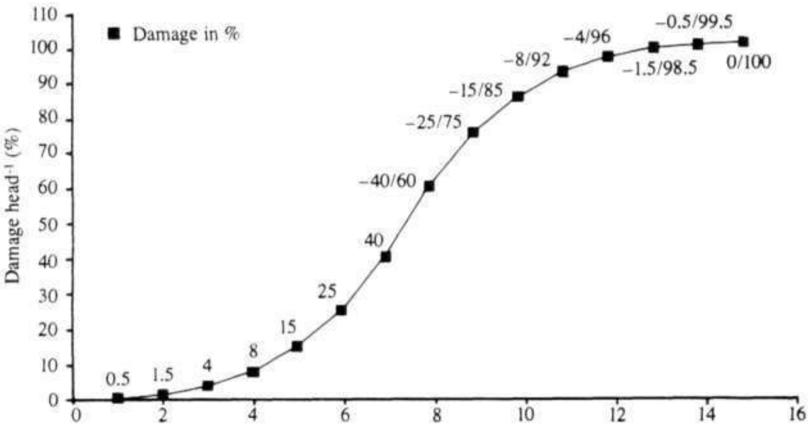
Figure 2. Cricket damage, i.e., food intake by stages 4-7 (kg ha^{1}) day^{1} at pearl millet development stages 5-9 (Mati and Bidinger 1981).

Integrated pest management

Choice of sowing date and millet variety. Yield and damage was estimated and respectively calculated according to the sigmoid curve for quantification of grain loss (Fig. 2). In Figure 3 the damage ratings (classes) can be converted into % yield loss.

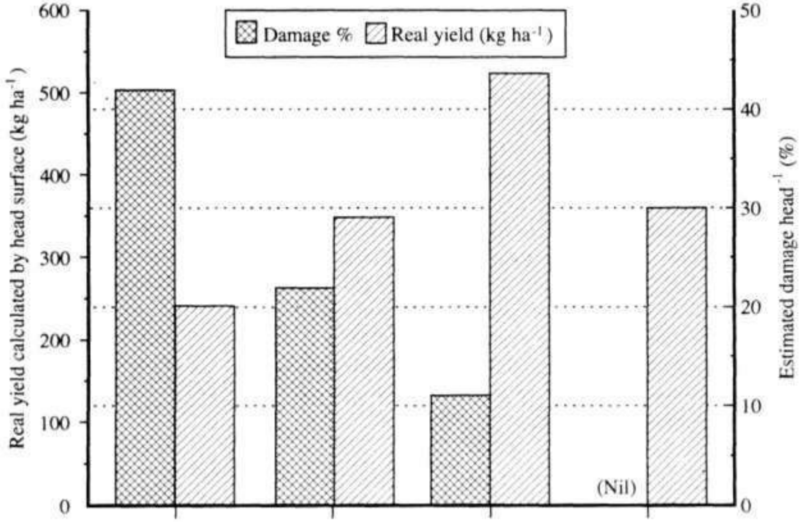
Severe grain damage caused by crickets is highly correlated with late sowing date (LLV: 42%) (Fig. 4), while a low level of damage on the same variety is associated with early sowing date (11%). Late-sown Okashana suffered 22% damage, but it partially escaped severe cricket feeding because of its early maturity (90 days).

To understand how yield losses are caused by crickets, the pest's life cycle and the damage potential of its different stages must be considered. If a 120-day variety is sown late, the sensitive pearl millet stages 5, 6, and 7 will coincide with the older cricket stages that cause the most damage. If the same variety is sown at an earlier date, severe damage can be prevented through earlier maturing of the grain. The Okashana 90-day variety takes an intermediate position, because the time required for grain development to maturity is shorter.



Damage classes (1-15)

Figure 3. Sigmoid curve for quantification of grain losses caused by crickets. Different damage ratings are shown for each loss quantity as classes from 1 to 15 (x axis). The damage level in % is shown by the y axis. From class 1 to 7 the damaged part of the panicle surface is estimated. From class 8 to 15 the non-damaged part of the panicle surface is estimated (negative damage estimation method).



Late - sown LLV | Late - sown Okashana | Early - sown LLV | Ran. select. awned variety

Late - and early - sown varieties

Figure 4. Yield loss caused by crickets for different sowing dates and varieties expressed in % and kg ha^{1}.

The results indicate that, if sowing dates are well managed and varieties are selected for their time to maturity, cricket damage can be avoided or reduced. And initial data suggest there is some effect by awns, in the awned variety, which reduces cricket damage. This needs to be further investigated.

Change in harvest procedure

By harvesting early (Fig. 5) and by erecting stooks before egg-laying starts, the concentration of egg pods under the stooks can be observed. Under stooks (15 m^2) an average of 71 egg pods were found in comparison to 21 egg pods found in the remaining harvested area (385 m^2) surrounding the stooks. On average 0.23 egg pods m^{-2} were recovered within the harvested and stooked areas (400 m^2). In the traditionally late-harvested area (400 m^2: panicles only) an average of 5 egg pods were found in randomly selected 15-m^2 plots (simulating the area under stooks). In the remaining area of 385 m^2 an average of 101 egg pods were found. In the randomly selected area egg pod density was 0.33 nv^2, compared with 0.26 egg pods nr^2 in the remaining area, which shows that egg pods are randomly laid when pearl millet plants

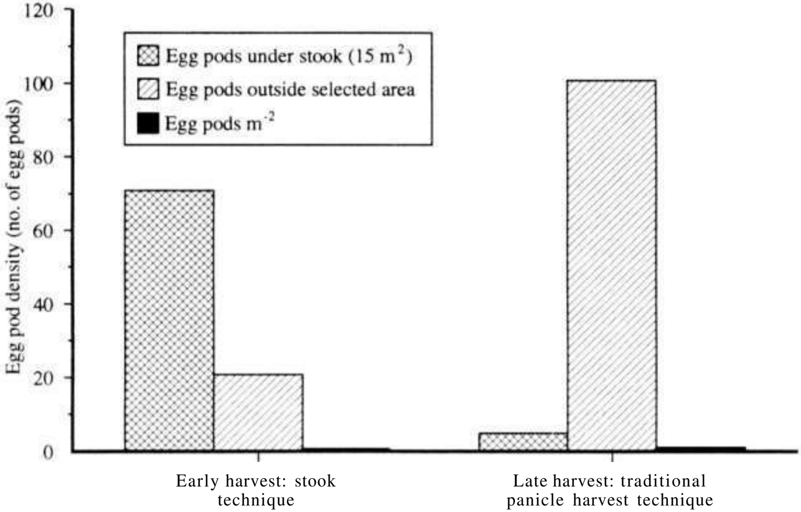


Figure 5. Number of egg pods found under stooks (15 m^2) and the surrounding area (385 m^2) compared with egg pods found in a traditionally harvested area (15 m^2, selected) and the surrounding area (385 m^2).

are in the field. The results show clearly that stooking concentrates egg-laying in the stooked areas in the field.

The reason why farmers leave their pearl millet crop in the field after grain maturity is to let the grain dry to a low moisture content suitable for storage. Such drying is also possible with early harvesting and the stooking of whole plants. So, as the stooks attract adult crickets for mating and oviposition, aggregated adults could be hand-collected from the stooks, and egg pods could be destroyed later in the season by digging them up.

Conclusion

The two methods of control described—early planting in combination with early maturity, and stooking after harvesting—are promising components of a possible integrated pest management system. Other components, such as clean-weeding and control with bait, are under investigation and, after careful testing in farmers' fields, are additional candidates for inclusion in an integrated pest management system for the sustainable control of armored cricket in Namibia.

References

Irish, J. 1992. The Hetrodineae (Orthoptera: Ensifera: Bradyporidae) of southern Africa: systematics and phyogeny. Navorsinge van die Nasionale Museum Bloemfontein, Natural Science 8(8):394-433.

Jago, N.D. 1993. Millet pests of the Sahel: biology, monitoring and control. Chatham, Kent, UK: Natural Resources Institute. 66 pp.

Mati, R.K., and Bidinger, F.R. 1981. Growth and development of the pearl millet plant. Research Bulletin no.6. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 18 pp.

Pantenius, U., and Krall, S. 1993. A new method for determining yield losses caused by damage to heads of pearl millet (*Pennisetum glaucum* (L.) R.Br.) caused by diseases and pests. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz 100(5):522-529.