Panicle Insect Pest Damage and Yield Loss in Pearl Millet

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Abstract

*It is often difficult to identify panicle pest damage and estimate yield losses due to the presence of multiple pests and other biotic and abiotic factors. In addition, the technology used to assess insect-related crop losses in pearl millet [*Pennisetum glaucum *(L.) R. Brown] is limited. This paper provides a description of the basic principles for identifying pest damage and covers the techniques available for evaluating losses resulting from such damage. Examples of crop loss assessment methods are given, with estimates of losses from selected pearl millet insect pests.*

Introduction

Biologically intensive integrated pest management has received wide support as being an environmentally friendly approach to crop protection. Besides an accurate identification of the causative pest, other prerequisites for integrated crop protection measures include detailed information on the extent of damage and the resulting yield losses. This information is available for a number of important crops (e.g., cotton), but is inadequate or completely lacking for many basic food crops. Pearl millet [*Pennisetum glaucum* (L.) R. Brown)] is a major food crop in Sahelian West Africa and is attacked by several insect pests. One hundred and sixty-one species were reported in Nigeria (Ajayi 1987), 84 in Niger (Guevremont 1982), and 81 in Senegal (Ndoye 1979). Knowledge of pest biology is available for only a few important species (Anonymous 1988, Gahukar 1989, Jago 1993a, Krall and Dorow 1993, Matthews and Jago 1993, Ndoye 1989, Sharma and Davies 1988). Many pearl millet insect pests, especially the panicle-feeding species, have not been studied adequately, and information on their pest status is often not available. Wewetzer et al. (1993) have reviewed the methods for the assessment of crop losses. Although advantages and drawbacks vary from one method to another, the overall merit of developing such methods remains crucial. Much work has been conducted on basic insect biology and on crop damage caused by a few insects, but relatively little on pearl millet pests. In this paper, an overview of the current state of knowledge is presented, and areas in which further research is needed are highlighted and discussed.

Damage Caused by Panicle Insect Pests

Pantenius and Krall (1993) listed 15 insect species in six genera as the major pests (in addition to other diseases and birds) of pearl millet (Table 1). The importance of these pests varies from region to region, as well as within a particular country.

Millet head miner

The millet head miner (*Heliocheilus albipunctella* de Joannis) is widely distributed and is one of the most serious pests of pearl millet (Nwanze and Sivakumar 1990, Nwanze 1991, Bal 1992). The larvae mine into the panicle in a spiral path, and depending on larval and panicle stage, they destroy either the florets or the grain. In certain cases the damage can be serious.

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Table 1. Pests and diseases of pearl millet (adapted from Pantenius and Krall 1993).

Insects

Lepidoptera

Spodoptera spp (1)[1]

Coniesta ignefusalis (Hampson) (2)

Heliocheilus albipunctella de Joannis (3)

Coleoptera

Lema planifrons Weise (1)

Pseudocalaspsis setulosa Lefèvre (3)

Rhinyptia infuscata Burmeister (3)

Pachnoda interrupta (Olivier) (3)

Mylabris (= *Decapotoma*) *affinis* (Olivier) (3)

Psalydolytta spp (3)

Cylindrothorax spp (3)

Diptera

Geromyia penniseti (Felt.) (3)

Orthoptera

Oedaleus senegalensis (Krauss) (1,3)

Heteroptera

Dysdercus völkeri Schmidt (3)

Spilostethus spp (3)

Dermaptera

Forficula senegalensis Serville (3)

Birds

Quelea quelea L. (3)

Passer luteus Lichtenstein (3)

Diseases

Tolyposporium penicillariae Bref. (3)

Sclerospora graminicola (Sacc.) (1,3)

Claviceps fusiformis Loveless (3)

1. (1) = damage to leaves, (2) = damage to stems, and (3) = damage to panicles.

Pachnoda interrupta

The life cycle of the beetle *Pachnoda interrupta* (Olivier) is well adapted to pearl millet and the appearance of adults is closely associated with the different stages of grain development. Grain damage can be severe if feeding occurs during the milky and dough stage, in which case the grain is completely destroyed and shriveled. Damage to mature grain is usually superficial. These beetles are widely distributed, but are rarely observed in large numbers. Consequently, their pest status is often not considered important. Apart from *P. interrupta*, other cetonid beetles are associated with panicle damage of pearl millet, but are not considered to be serious pests (Grunshaw 1992).

Blister beetles

The species complex of blister beetles [*Psalydolytta* spp, *Cylindrothorax* spp, *Mylabris* (= *Decapotoma*) *affinis*] that feed on pearl millet panicles as adults, is quite heterogeneous and varies with region (Doumbia 1992). For example, while *Psalydolytta fusca* (Olivier) is designated as a major pest in Mali and Gambia (Coop and Croft 1992, Zethner and Laurense 1988), and *P. vestita* (Dufour) is often reported as an important pest in Mali and Senegal (Doumbia 1992) these two species are of negligible importance in Niger (Krall and Dorow 1993). The pest status of *Cylindrothorax dussaulti* (Dufour) and *C. westermanni* Maklin, which occur locally in Niger, have been poorly investigated. Observations in field cage trials in Niger in 1992 and 1993 showed their feeding preference for stamens (S Krall, unpublished). However, since pearl millet is cross-pollinated, the consumption of all the stamens on a panicle has not been associated with yield loss and the presence of several individuals on a panicle did not affect grain formation. Serious damage, however, could arise when these insects are present during the very early stages of panicle development. This is rarely the case in farmers' fields due to the differential development of panicles and because these insects are often localized. *Mylabris* (= *Decapotoma) affinis* (Olivier) is more widely distributed, prefers to feed on stamens like *C. dussaulti* and *C. westermanni*, and is unlikely to be a serious pest.

Rhinyptia infuscata

Adult *Rhinyptia infuscata* Burmeister beetles are nocturnal, with a peak in activity between 2200 and 2400 (ICRISAT 1992). Studies at the ICRISAT Sahelian Center and at other locations in Niger, have shown that these insects feed on both florets and stamens, resulting in the formation of empty spikelets. Farmers recognize these beetles as serious pests and often set night fires to lure them to be burned. Their precise status as pests, however, remains uncertain.

The local occurrence of this species is quite variable and in some regions, epidemics may result in severe damage and crop loss.

Pseudocolaspsis setulosa

The beetle *Pseudocolaspsis setulosa* Lefèvre has not been adequately studied. Adult activity begins at dusk and continues through the night, when the insects feed on the flowers and can be found locally in large numbers on the panicles. Adults are only a few millimeters long. Their damage is assumed to be of minimal importance.

Millet grain midge

The larvae of this tiny midge [*Geromyia penniseti* (Felt)] develop inside the flowers. When the adults emerge, the white exuviae remain on the panicle and can be seen hanging on the shriveled spikelets. The extent of the damage caused by *G. penniseti* is still unknown and is also difficult to determine (Coutin and Harris 1968).

Grasshoppers and locusts

Various species of grasshoppers (both adults and nymphs) can damage millet panicles. When an attack occurs during flowering or early seed development, the panicles can be severely damaged, depending on the density of grasshoppers. With fully mature grain, only a part of the grain is eaten away. The more common species include *Oedaleus senegalensis* (Krauss) and *Oedaleus nigeriensis* (Uvarov) (Nwanze and Harris 1992). Grasshoppers are certainly more serious during early vegetative growth than at the grain development stage. Nonetheless, they are major pests, as they occur widely in most countries (Coop and Croft 1993). The desert locust, *Schistocerca gregaria* (Forskal), and the African migratory locust, *Locusta migratoria* (L.), often occur in swarms, devouring all vegetation (Nwanze and Harris 1992). Concerted international efforts are often required for their control.

Head bugs

Adult bugs and their larvae, primarily *Dysdercus völkeri* Schmidt and *Spilostethus* spp, are regarded as important pests. Field observations in Niger have shown that the most widely prevalent species, *D. völkeri*, attacks newly exserted panicles and feeds on the young, tender florets. Such florets dry out and can later be recognized as light brown patches between undamaged grains. Feeding continues into the milk and dough stages. Damage is greatest at the milk stage. Other species of head bugs occurring on pearl millet are not known to cause any significant damage to grain.

Earwigs

Earwigs (*Forficula senegalensis* Serville) sometimes appear in high densities on pearl millet panicles, but their incidence is often localized and highly aseasonal. Nymphs and adults feed on all parts of the spikelet and are primarily active in the evening and at night. The damage they cause to grain is negligible.

Crop Loss Assessment Techniques

Most of the information provided here on the assessment of panicle and crop yield losses is derived from practical field work in West Africa. There are several approaches for estimating damage and yield losses. One method involves the caging of individual panicles (Grunshaw 1992, Coop and Croft 1992), or whole plant stands (S Krall, unpublished) into which a known number of insects are introduced. Apart from providing direct quantitative information on pest damage, this method can also be used to study pest activity. However, field trials and extensive surveys are necessary to obtain data on the extent of crop damage and yield losses. Nwanze (1988) classified crop loss assessment methods as follows:

- incidence ratio
- visual score paired analysis
- damage density loss ratio
- quantitative assessment (insecticide trials).

Cage Experiments

Single panicles

Grasshoppers and blister beetles. In experiments by Coop and Croft (1992) in Mali, five grasshopper species [*Hieroglyphus daganensis* Krauss, *Kraussaria angulifera* (Krauss), *Kraussella amabile* (Krauss), *Cataloipus cymbiferus* (Krauss), and *Oedaleus* *senegalensis* (Krauss)] and two blister beetle species (*Psalydolytta pilipes* Maklin and *P. fusca*) were introduced into plastic gauze cages containing individual panicles and allowed to feed for 4 days. Each treatment included 12 individually caged panicles. For grasshopper treatments, two females of each species were used per panicle, except for *C. cymbiferus* (one female per cage due to cannibalism). Beetle treatments were based on a ratio of 1.24:1 female:male. There were 12 repetitions for each species. Dead insects were routinely replaced in each cage. After 4 days, the damaged surface area of the panicle was measured and related to the number and dry weight of the insects introduced into the cages.

Pachnoda interrupta. In Mali, *P. interrupta* was investigated by introducing different densities in cages which enclosed individual panicles. The number of insects per panicle was 0 (in the controls), 1, 2, 3, 5, and 10. The duration of the experiment was from 7 to 9 days. The number of replications was 30. The losses were calculated from the yield of the infested panicles relative to that of uninfested ones. Here the surface area of the panicles was included in the calculation of losses (Grunshaw 1992).

Dysdercus völkeri. In Burkina Faso experiments were carried out with *D. völkeri* in a project sponsored by the Canadian International Development Agency (CIDA), but no concrete data are available (Anonymous 1991).

Whole plants

Flower-feeding insects. In Niger, in the framework of a GTZ project, experiments were undertaken (S Krall, unpublished) to determine the damage potential of different insect species including *D. völkeri, Spilostethus* spp, *F. senegalensis, P. setulosa, R. infuscata, M. affinis, Cylindrothorax* spp, and *P. interrupta*. The pest species was introduced on 1–2 plant stands enclosed in cages (1.3 × 1.3 × 2 m). Observations were made primarily on the behavior of the insects, as well as on their damage potential and feeding pattern. Losses here were only estimated semi-quantitatively.

Rhinyptia infuscata. Experiments were carried out in 3 × 3 × 9 m cages to determine losses due to this insect. Six different adult populations were maintained in cages for 15 consecutive days in Aug to simulate damage under natural conditions. At harvest, plants were divided in five groups: 0, 1–25%, 25–50%, 51–75%, and 76–100% damage. This method was compared with an open field assessment of yield loss due to *Rhinyptia* beetles. In this case 400 panicles were collected from the field at harvest and classified into five groups as described above. Losses in grain yield based on level of damage were recorded. The losses from the harvested panicles were determined (ICRISAT 1990).

Paired Plant or Plot Analysis

The paired plot analysis (comparing treated plants/plots with untreated controls) is the oldest and most frequently used applied experimental method. In some cases, the extent of damage by different insects was also determined, with the control kept more or less damage-free by very frequent spraying with pesticide (more than once $week^{-1}$) or by enclosing the individual panicles before damage could occur. The pests most frequently investigated with this method were *C. ignefusalis* and *H. albipunctella* (Bal 1992).

In Senegal, Guinea Bissau, and Gambia, experiments were carried out in 1980–82 in which plots were kept pest free and compared with untreated ones (Settle 1981, 1982, 1983). In this way the total damage attributable to pests was determined.

Surveys and Field Studies

Crop loss estimation in Niger

In Niger, a method to assess crop losses using the damage pattern of different insect species has been developed. The damaged area on the panicles was estimated for each pest (insects, birds, diseases) with the help of damage rating keys. Later, on the basis of standard values in cm^2-weight per panicle surface, these were recalculated as yield loss. Since 1989, wide scale investigations have been carried out in Niger using this method; about 300 fields have been studied during the past 2 years (Pantenius and Krall 1993).

Millet head miner

Assessment of crop loss due to the millet head miner (*Heliocheilus albipunctella*) was conducted in 1987 at Sadoré (ICRISAT Sahelian Center). The method consisted of randomly sampling 1000 panicles which were stored in paper bags. The number of larvae which had completed their development were counted and recorded. Panicles were then weighed and threshed. Yield losses resulting from different levels of panicle infestation were estimated.

Crop loss assessment in Mali

In Mali, a 5-year project was carried out to establish an approach for integrated pest management for pearl millet. It began with insecticide experiments but was then expanded to include observations on individual pests as well as socioeconomic studies (Jago et al. 1993).

Adjusted length method

Based on the work of Settle and Dively in West Africa from 1981–84, the adjusted length method was developed (Dively and Coop 1993). Pearl millet panicles were evaluated with respect to various kinds of damage, and the damaged area was measured by hypothetically projecting the affected area onto an enclosing cylinder. Yield loss was also calculated on the basis of damaged area. Since this method is very similar to that of Pantenius and Krall (1993), a direct comparison of the methods was undertaken in Mali (Sidibé 1992).

Results and Discussion

Cage experiments

a) Single panicles

Grasshoppers and blister beetles. Results showed that the two species of *Psalydolytta* were potentially more damaging than the grasshopper species. They consumed 10.3 cm^2 of pearl millet panicle day^{-1} compared with 1.3–4.3 cm^2 day^{-1} by the grasshopper species (Coop and Craft 1992).

Pachnoda interrupta. For *P. interrupta* investigated by Grunshaw (1992) in Mali, losses ranged from 9.7% for an infestation level of one insect $panicle^{-1}$ to 48.7% (10 individuals $panicle^{-1}$). A regression curve for the damage threshold at various millet prices based on known levels of beetle densities was presented.

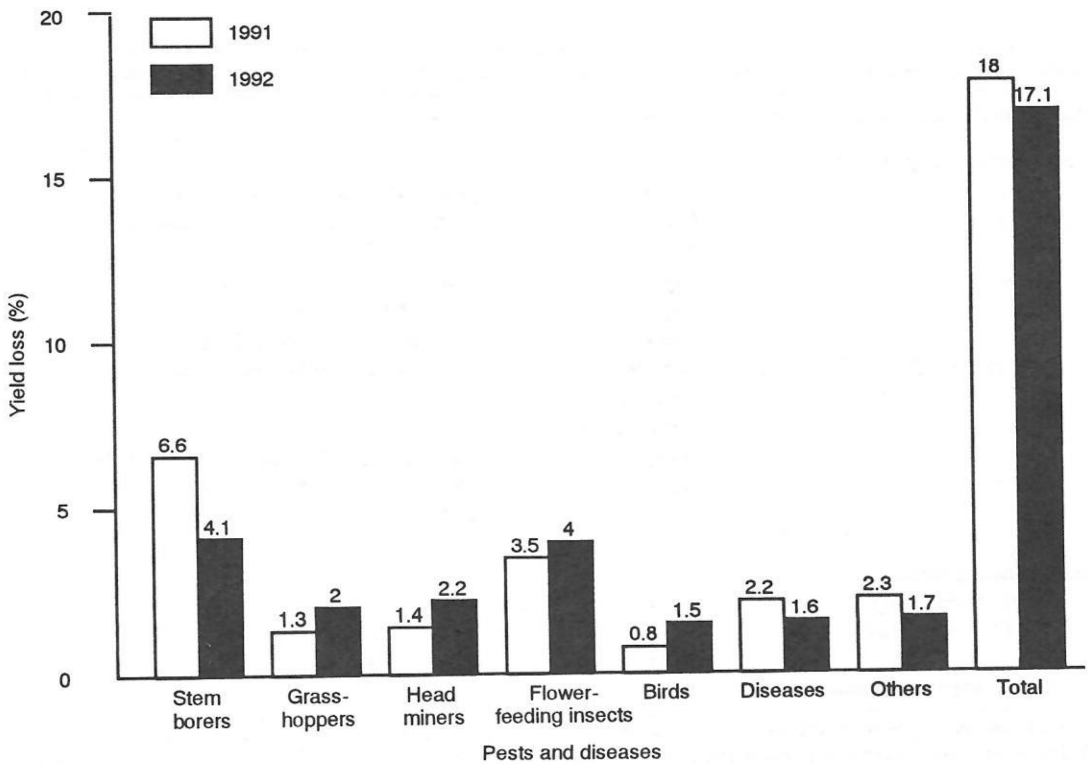

Figure 1. Pearl millet yield losses due to different pests and diseases, rainy seasons 1991 and 1992, Niger.

b) Whole plants

Flower-feeding insects in Niger. Krall (unpublished) studied the pest status of the insect species listed above and the damage potential and feeding pattern. Yield losses due to flower-feeding insects were 3.5 in 1991 and 4% in 1992 (Fig. 1).

Potential yield losses due to *R. infuscata* are shown in Table 2. Yield losses in the cage studies were lower than in the field samples, but in both cases, major losses occurred with 21 and 54% in cages and field experiments, respectively, at damage levels greater than 25%. Mean yield losses on the field samples ranged from 37 to 57%.

Field studies on the use of insecticides in pearl millet in Mali

Investigations in Mali showed that insecticide treatments were economically beneficial only in dry years, if at all, and only with inexpensive or subsidized products; instead, integrated pest management has been recommended for millet. Generally speaking, insecticide treatment cannot be recommended at the level of the individual small farmer in the Sahel zone (Matthews and Jago 1993).

Adjusted length method

Results of investigations carried out between 1983 and 1990 (Dively and Coop 1993) are summarized in Figure 2. The adjusted length method and the GTZ method have their own advantages and disadvantages, but both are suitable for large-scale use (Sidibé 1992).

Crop loss estimation in Niger

Pantenius and Krall (1993) continuously recorded data on the level of damage by individual pests. Both the methodology as well as the training of the field observers have been constantly improved. As representative data, the yield losses measured for the years 1991 and 1992 are presented in Figure 1. Based on a country-wide survey, results showed some variability in pest incidence. In comparison with Table 2, losses seem to be much lower and suggest that more accurate information on losses can be secured when better and improved methods are developed.

Table 2. Reported losses in pearl millet yields due to *Heliocheilus albipunctella* and *Rhinyptia infuscata*.

Loss (percentage of grain mass)	Location	Author
Heliocheilus albipunctella		
13–35	Senegal	Vercambre 1978 (in Bernardi et al. 1989)
29–82	Senegal	Gahukar 1982, 1983 (in Bernardi et al. 1989)
8–41	Niger	Nwanze 1988
3.5–44.8[1]	Niger	ICRISAT Sahelian Center 1988
8–47	Niger	ICRISAT Sahelian Center 1990
15	Niger	Brenière 1974 (in Nwanze 1988)
3–82 and 15–20	Senegal	Gahukar et al. 1986 (in Nwanze 1988)
16–85	Burkina Faso Gambia, Mali Senegal	Anonymous 1990 (Sahel PV Info 1990)
0.8–14.9	Niger	Nwanze and Sivakumar 1990
7–20	Senegal	Bal 1992
Rhinyptia infuscata		
38–97[2] (field, ranges) (37–57, field means)	Niger	ICRISAT 1990
1–70 (cages, ranges from main stems)	Niger	ICRISAT 1990

1. 1–2 larvae caused 3.5% grain yield loss, 3–4 larvae caused 20.7%, 5 larvae caused 34.5%, and >5 larvae caused 44.8% grain yield loss.
2. Damage of 1–25% resulted in 38% grain yield loss, 26–50% resulted in 64% grain yield loss, 51–75% resulted in 80%, and 76–100% damage resulted in 97% yield loss.

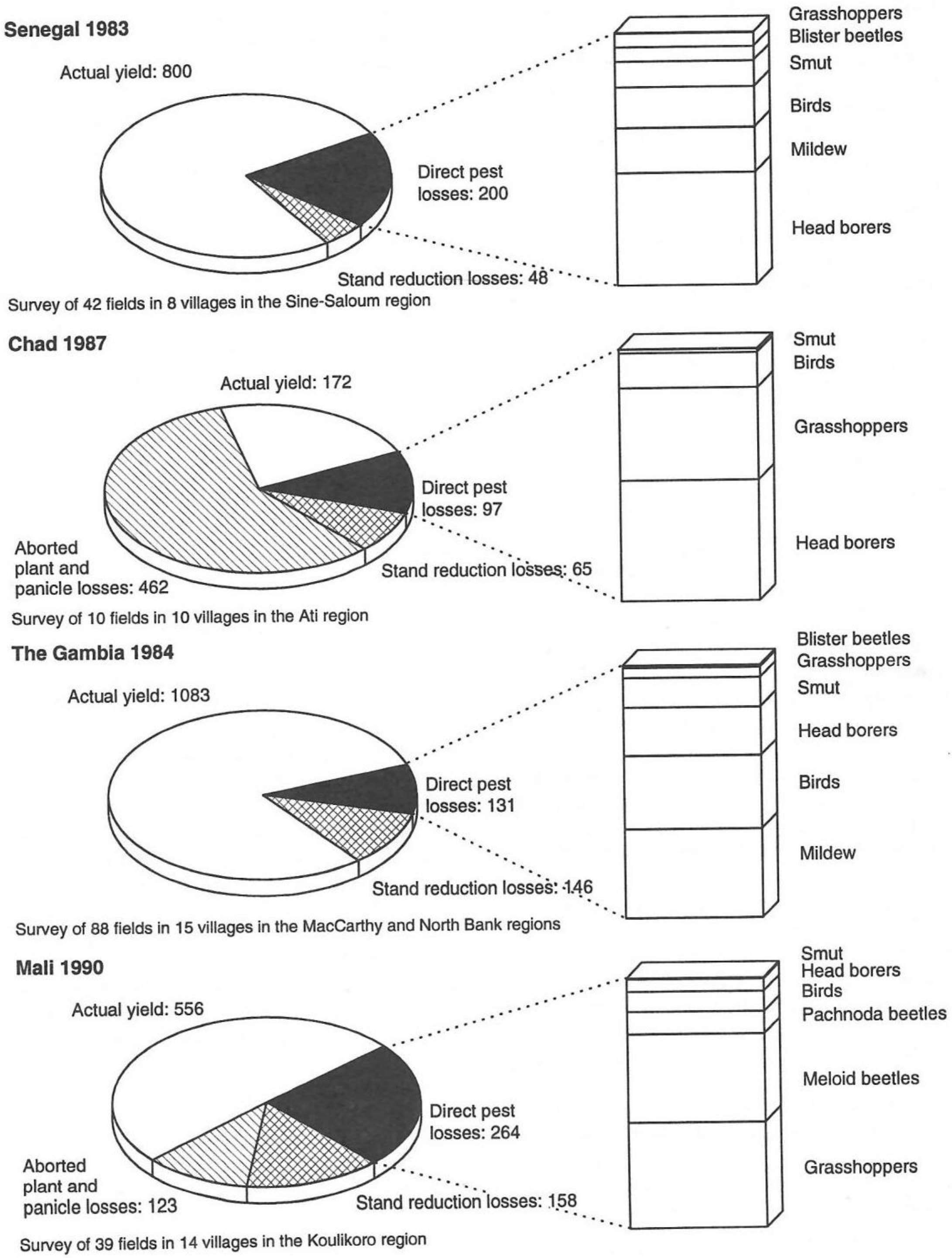

Figure 2. Yield loss profiles from loss assessment surveys in West Africa (Yield and losses are in kg ha^{-1}. Source: Dively and Coop 1993).

Investigations on the millet head miner

The head miner is considered one of the most serious pests of pearl millet, and has been extensively studied. A summary of these results on *Heliocheilus albipunctella* is given in Table 2. It is obvious that high variability exists here in both results and methodologies. For example, results on yield loss estimation due to millet head miner was 3.5% for 1–2 larvae $panicle^{-1}$, 20.7 for 3–4 larvae $panicle^{-1}$, 34.5% for 5 larvae $panicle^{-1}$, and 44.8% for >5 larvae $panicle^{-1}$ (ICRISAT Sahelian Center 1988). Estimation of losses due to the millet head miner was based a variety of methods. Results (Table 2) call for simple standardized methods so that data can be compared across regions and locations.

Advantages and limitations of techniques

Experiments on individual panicles alter natural conditions so much that reliable conclusions about the behavior of the pest in the field are difficult to make. Since the introduced insects cannot behave according to their biology, their feeding behavior can be disturbed. In addition, the test insect on an isolated panicle has no choice but to feed, and feed on that panicle. Nevertheless, these experiments do provide interesting results in some cases.

Experiments with cages in which at least one plant stand is present are more accurate than those involving individual panicles, because the climatic conditions are almost identical inside and outside the cage and panicles in different developmental stages are available. However, a purely quantitative evaluation is already made impossible by the fact that standard conditions are not involved. Moreover, in such cages undesirable pests can be present but remain unnoticed at the start of the trial. Field-cage studies are, however, well suited for detailed observations and photography or filming of individual pests and semi-quantitative evaluations.

Experiments based on paired plot analysis have a number of disadvantages (Settle 1983): (a) distinction between different pests is not possible, (b) loss estimation is inexact, since all insect species are not completely controlled (e.g., stem borers), (d) errors occur, e.g., when insecticides drift onto the untreated plots, (e) there is possibly an influence of the insecticide on plant growth, (f) fungal diseases are not prevented, since only insecticides are applied, (g) the procedure is very expensive, time-consuming, and laborious. In addition, it has been found that even weekly insecticide treatments are sometimes insufficient to keep the control plots pest-free (Settle 1981).

Field studies or surveys such as those in Mali and Niger, can lose precision when conducted on a large scale. However, they become more interesting due to greater representation as country-wide studies. In this case one is dealing with a number of factors. For example, accurate observations require scientifically trained personnel, which is almost always a resource of limited availability. Thus one can only evaluate a small number of samples. In country-wide surveys as in Niger, reliance is made on ordinary field observers. Accordingly, the level of accuracy can depend on the person, but the advantage is that the number of fields evaluated is large.

Implications and Recommendations for Future Research

Techniques for investigating losses due to panicle pests are available in principle but need to be refined and in some cases standardized. For some pests, investigations are very difficult and remain completely lacking (e.g., *G. penniseti*). Programs which are economical and can be carried out region- or even country-wide have been developed and conducted in Niger and Mali. However, they must be tested under different conditions and in different countries before they can be regarded as standard methods. Most importantly, identification of pests remains critical. Accurate description of pest damage and estimation of the resulting losses is paramount. Future studies should (a) develop methodologies for accurate pest and damage identification, (b) provide efficient and rapid standardized methods for pearl millet yield loss assessment, and (c) compare and further refine existing crop loss estimation techniques. Finally, training on techniques in field surveys and yield loss assessment remains a high priority.

Synthèse

Dégâts et pertes de rendements causés par les insectes des panicules du mil (*Pennisetum glaucum*). Le mil, *Pennisetum glaucum* (L.) R. Br., une importante culture de soudure dans la zone sahélienne de l'Afrique de l'Ouest, est attaqué par plusieurs insectes nuisibles. Au Nigéria, 161 espèces ont été recensées (Ajayi 1987), au Niger 84 (Guevremont 1982) et au Sénégal 81 (Ndoye 1979). La majorité des insectes attaquant le mil, en particulier ceux qui se nourrissent des panicules, ont été insuffisamment étudiés dans bon nombre de cas. Par conséquent, l'information sur certains de ces insectes n'est pas suffisante pour déterminer leur importance économique.

Un bon nombre de méthodes d'estimation des pertes de rendement a fait l'objet d'une récente revue critique (Wewetzer et al. 1993). Bien que les avantages et les inconvénients varient d'une méthode à l'autre, il est évident que le développement de telles méthodes revêt une importance primordiale.

L'objet de cette communication est de donner un aperçu général sur l'état des connaissances concernant l'identification des dégâts et les pertes de rendements causés par les insectes nuisibles aux panicules de mil. Cette communication décrit les dégâts causés par la mineuse de l'épi (*Heliocheilus albipunctella* de Joannis), *Pachnoda interrupta* (Olivier), les méloïdes [*Psalydolytta* spp; *Cylindrothorax* spp, *Mylabris* (=*Decapotoma*) affinis (Olivier)], *Rhinyptia infuscata* Burmeister, le moucheron du mil, les sauteriaux, les punaises des épis, et les forficules. Les dégâts causés par ces insectes sont sévères pour certains (exemple la mineuse de l'épi) et négligeables pour d'autres (exemple *Pseudocolaspsis setulosa* Lefèvre).

Les techniques d'estimation des pertes peuvent se faire par les méthodes de mise en cage, (des panicules individuelles, ou des plantes entières); par la méthode d'échantillonnage des plantes dans les champs, par comparaison de plantes ou de parcelles protégées avec celles non protégées. Bien que ces techniques ne soient pas toujours parfaites, elles permettent néanmoins de déterminer les pertes de rendements causées par certains insectes de panicules. Par exemple, les pertes dues à *P. interrupta* étaient passées de 9,7% avec un niveau d'infestation d'un insecte par panicule à 48,7% si le niveau d'infestation est de 10 insectes par épi. Les dégâts causés par les insectes floricoles étaient de 3,5 à 4% selon la saison.

Pour la mineuse de l'épi, les pertes étaient de 3,5% avec un niveau d'infestation de 1–2 larves par panicule, 20,7% pour 3–4 larves, 34,5% pour 5 larves par panicule, et 46,8% pour >5 larves par panicule. D'après les résultats présentés dans cette communication, il ressort une variabilité aussi bien au niveau des résultats que des méthodologies d'estimation des pertes.

Ces techniques comportent aussi bien des avantages que des inconvénients. Les essais de mise en cage des panicules modifient les conditions naturelles si bien que les conclusions sur le comportement de l'insecte au champ deviennent difficiles du fait d'une éventuelle perturbation de leur comportement dans ce microenvironnement. Par contre, les essais menés en cages contenant les plantes entières semblent convenir le mieux. Cependant, dans de telles situations d'autres insectes pourraient déjà être dans les cages avant les expériences, et de ce fait peuvent influencer les résultats.

Les inconvénients des méthodes comparant les parcelles protégées (par insecticide) et non protégées pour estimer les pertes sont multiples. On peut citer entre autres (a) la difficulté de distinguer les différents ravageurs, (b) la difficulté de maîtriser tous les insectes présents dans les parcelles, (c) les erreurs dues à la dérive des insecticides sur les parcelles non traitées. En plus, c'est une procédure coûteuse qui requiert beaucoup de temps et d'efforts.

A la suite de cette revue sur l'état des connaissances sur les méthodologies concernant l'évaluation des pertes, les recommandations suivantes en découlent: (a) les techniques disponibles sur l'estimation des pertes nécessitent une amélioration et une standardisation; (b) ces techniques doivent être évaluées dans différents pays, sous plusieurs environnements; (c) des efforts sur l'identification fiable des ravageurs et leurs dégâts doivent être renforcés; (d) de nouvelles méthodes standardisées, efficaces et rapides d'estimation de pertes doivent être mises au point; e) et enfin la formation dans les techniques d'enquêtes et d'estimation des pertes de rendement reste un domaine prioritaire.

References

Ajayi, O. 1987. The status of millet entomology in Nigeria. Pages 295–296 *in* Proceedings of the International Pearl Millet Workshop, 7–11 Apr 1986, ICRISAT Center. Patancheru, AP 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Anonymous. 1990. Rapport des groupes de travail: Mil. Sahel PV Info 19:4–6.

Anonymous. 1988. Principaux ennemis du mil au Niger et leur contrôle. Niamey, Niger. Direction de la Protection des Végétaux. 28 pp.

Anonymous. 1991. Colloque sur le profil des pertes sur le mil au Sahel. Sahel PV Info 31:7–22.

Bal, A.B. 1992. Les principaux insectes du mil au Sénégal: Importance du parasitisme et méthodes de lutte. Sahel PV Info 41:2–10.

Bernardi, M., Mishoes, J.W., and **Jones, J.W.** 1989. *Raghuva*: a computer simulation of *Raghuva albipunctella* population dynamics and *Pennisetum americanum* and *P. typhoides* phenology. Ecological Modelling 44:275–298.

Coop, L., and **Croft, B.A.** 1992. Damage rates to pearl millet by adults of five grasshopper species and *Psalydolytta* blister beetles in Mali. Tropical Pest Management 38(2):201–205.

Coop, L., and **Croft, B.A.** 1993. Pearl millet injury by five grasshopper species (Orthoptera: Acrididae in Mali. Journal of Economic Entomology 86(3):891–898.

Coutin, R., and **Harris, K.M.** 1968. The taxonomy, distributions, biology and economic importance of the millet grain midge, *Geromyia penniseti* (Felt.), gen.n., comb.n. (Diptera, Cecidomyiidae). Bulletin of Entomological Research 59:259–273.

Dively, G.P., and **Coop, L.** 1993. Millet loss assessment project Mali, 1990. Washington, DC, USA: United States Agency for International Development. 29 pp.

Doumbia, Y.O. 1992. Les méloïdes ravageurs du mil (*Pennisetum americanum* (L.) Leeke) dans les régions sahéliennes de l'Afrique de l'Ouest: Bioécologie et moyens de lutte. Sahel PV Info 42:10–15.

Gahukar, R.T. 1989. Insect pests of millets and their management: a review. Tropical Pest Management 35 (4):382–391.

Grunshaw, J.P. 1992. Field studies on the biology and economic importance of *Pachnoda interrupta* (Coleoptera: Scarabaeidae) in Mali, West Africa. Bulletin of Entomological Research 82:19–27.

Guevremont, H. 1982. Etudes sur la mineuse de l'épi et autres insectes du mil: Rapport annuel de recherches 1981. Maradi, Niger: Centre National des recherches agronomiques de Tarna.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1990. Annual Report 1989. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Sahelian Center 1988. ICRISAT West African Programs Annual Report 1987. BP 12404, Niamey, Niger: ICRISAT Sahelian Center.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Sahelian Center 1990. ICRISAT West African Programs Annual Report 1989. BP 12404, Niamey, Niger: ICRISAT Sahelian Center.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Sahelian Center 1992. ICRISAT West African Programs Annual Report 1991. BP 12404, Niamey, Niger: ICRISAT Sahelian Center.

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

Jago, N.D. 1993b. Millet crop-loss assessment methods. NRI Bulletin 62, Chatham, UK: Natural Resources Institute. 61 pp.

Jago, N.D., Kremer, A.R., and **West, C.** 1993. Pesticides on millet in Mali. NRI Bulletin 50, Chatham, UK: Natural Resources Institute. 45 pp.

Krall, S., and **Dorow, E.** 1993. Brochure de référence sur les dégâts causes aux épis de mil. Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit. 35 pp.

Matthews, M., and **Jago, N.D.** (eds.). 1993. Millet pests of the Sahel—an identification guide. Chatham, UK: Natural Resources Institute. 80 pp.

Ndoye, M. 1979. L'entomofaune nuisible au mil à chandelle (*Pennisetum typhoides*) au Sénégal. Pages 515–530 *in* Compte rendu des travaux, Congrès sur la Lutte Contre les Insectes en Milieu Tropical, 13–16 Mar 1979, Marseilles, France. Part 1. Marseilles, France: Chambre de Commerce et d'Industrie.

Ndoye, M. 1989. Les insectes ravageurs du mil à chandelles dans le Sahel. African Journal of Plant Protection 4 (2):1–43.

Nwanze, K.F. 1988. Assessment of on-farm losses in millets due to insects pests. Insect Science and its Application 9(6):673–677.

Nwanze, K.F. 1991. Components for the management of two insect pests of pearl millet in Sahelian West Africa. Insect Science and its Application 12(5/6): 673–678.

Nwanze, K.F., and **Sivakumar, M.V.K.** 1990. Insect pests of pearl millet in Sahelian West Africa—II. *Raghuva albipunctella* de Joannis (Noctuidae, Lepidoptera): distribution, population dynamics and assessment of crop damage. Tropical Pest Management 36(1):59–65.

Nwanze, K.F., and **Harris, K.M.** 1992. Insect pests of pearl millet in West Africa. Review of Agricultural Entomology 80(12):1133–1155.

Pantenius, U., and **Krall, S.** 1993. A new method for determining yield losses caused by damage to the heads of pearl millet (*Pennisetum glaucum* (L.) R. Br.) due to diseases and pests. Journal of Plant Diseases and Protection 100(5):522–529.

Settle, W. 1981. Yield loss assessment trials: millet. Dakar, Senegal: United States Agency for International Development. 23 pp.

Settle, W. 1982. Yield loss assessment trials: millet. Dakar, Senegal: United States Agency for International Development. 15 pp.

Settle, W. 1983. Millet loss assessment report: results and discussion of procedure. Dakar, Senegal: United States Agency for International Development. 35 pp.

Sharma, H.C., and **Davies, J.C.** 1988. Insect and other animal pests of millet. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 147 pp.

Sidibé, B. 1992. Comparaison de deux méthodes d'estimation des pertes sur le mil. Sahel PV Info 43:11–16.

Wewetzer, A., **Krall, S.**, and **Schulz, F.A.** 1993. Methods for the assessment of crop losses due to grasshoppers and locusts. TZ-Verl.-Ges., RoBdorf, pp. 54.

Zethner, O., and **Laurense, A.A.** 1988. The economic importance and control of the adult blister beetle, *Psalydolytta fusca* Olivier (Coleoptera: Meloidae). Tropical Pest Management 34:407–412.