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Assessment of On-Farm Losses in Millets Due to Insect Pests*

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Abstract—Pearl millet *Pennisetum americanum* L occupies a large proportion of the area growing millets in Africa Consequently the insect pests that attack this species have received attention over other millets A list of the major species is presented Actual data on losses due to insect pests on pearl millet are not readily available Crop loss assessment methods using incidence and damage ratios are discussed Quantitative losses determined from insecticide trials at research station are also presented

Key Words Africa pearl millet *Raghuva albipunctella Acigona ignefusalis* insect damage crop loss assessment incidence ratio paired comparisons

Résumé—Le petit mil *Pennisetum americanum* L occupe une grande partie de la region emblavée en mils en Afrique Les insectes nuisibles qui s attaquent a cette culture ont retenu plus d attention de ce fait que ceux d autres mils Une liste des importantes especes est presentee dans l article Les donnees reelles sur les pertes provoquees par les insectes nuisibles sur le petit mil ne sont pas facilement disponibles Les methodes d evaluation des pertes de rendement a l aide des rapports d incidences et ceux de dégâts sont discutees Les pertes quantitative determinees a partir des essais insecticides en ferme expérimentale sont egalement presentees

Mots Clefs Afrique petit mil *Raghuva albipunctella Acigona ignefusalis* dégats evaluation des pertes de rendement rapport d incidence comparaison appariee

INTRODUCTION

The millets constitute a major food source in the warmer regions of the Old World particularly in southern Asia and Africa where they provide sustainable yields under extreme environmental and biotic stress conditions The four major food millets in these regions are Pearl millet *Pennisetum americanum* L foxtail millet, *Setaria italica* Beauv proso millet, *Panicum miliaceum* L and finger millet, *Eleucine coracana* Gaertn Of these, pearl millet and finger millet are the most commonly grown Pearl millet covers an estimated 26 M ha of cultivated land in Africa and India In West Africa where it constitutes the major staple crop in the Sahelian zone, over 12 M ha of the crop is grown Almost the entire production of finger millet is confined to Africa and Asia India produces over 50% of the total world production and most of the rest is produced in central Africa (Cameroon), eastern Africa (Uganda and Tanzania) and southern Africa (Zimbabwe, Malawi and Zambia) where, depending on the country, it makes up between 20–60% of the total area grown to millets

Finger millet is relatively free of insect pests and although it may harbour a range of pest species, the need for control is much less a problem when compared to pearl millet For the same reason the literature on finger millet is rather scarce The range of insects that attack the millets is perhaps relatively narrow when compared to other cereal crops such as rice wheat corn and sorghum and the most frequently occurring species are also pests of other crops These include

(a) Seedling pests Shootflies, *Atherigona* spp and leaf beetles, *Lema* spp, *Chaetocnema tibialis* Illig

(b) Foliage pests Several species of armyworms, *Spodoptera* spp , hairy caterpillars *Amsacta moloneyi* Druce, and aphids, *Rhopalosiphum maidis* Fitch

(c) Stem borers *Acigona ignefusalis* Hmps , *Eldana saccharina* Walker and *Sesamia calamistis* Hmps

(d) Panicle pests Midge, *Geromyia penniseti* Felt earhead caterpillars, *Raghuva albipunctella* De Joannis, *Heliothis armigera* Hbn and *Eublemma gayneri* Roths, and blister beetles, *Cylindrothorax westermanni* Mkl , *Mylabris holosericea* Klug and *Psalydolytta fusca* Oliv

Gahukar (1984) and Ndoye and Gahukar (1986) have provided comprehensive lists of the pests of millet in West Africa Some species such as grasshoppers and locusts, although not specifically confined to millet, cause spectacular losses and are often more important than the more frequently occurring species listed above

There are few insect pests for which accurate data are available on crop losses in farmers' fields in Africa In most cases, the evidence provided is only one indicating levels of pest infestations as opposed to actual losses (Davies, 1982) Among the several species that are reported to attack pearl millet, actual data on losses are available for only two, namely *Acigona ignefusalis* and *Raghuva albipunctella* The

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FAO manual on crop loss assessment methods (FAO, 1971) does not list millet nor any of its major pests Only two cases are provided on a related crop—sorghum midge and greenbug This paper provides information from on-station research trials, on-farm pest surveys and on-farm trials that have been used in West Africa to assess damage and/or losses due to attacks by *Acigona* and *Raghuva* It also discusses areas where future emphasis is needed

ASSESSMENT METHODS

Crop damage from an insect attack may not always result in yield loss and the intensity of damage is not often proportional to the incidence of a pest To distinguish between the different methods of measurement, in this paper crop loss assessment methods are discussed under (1) incidence ratio, (2) visual score paired analysis, (3) damage intensity loss ratio and (4) quantitative assessment (insecticide trials)

Incidence ratio

The incidence ratio technique is a quick and easy method for assessing crop damage by pests However, it does not give actual loss values sustained by a crop, but an indication of the presence or the frequency of occurrence of a pest in an area It is usually expressed in percentages derived from actual counts of individual insects (usually crop infesting stages, such as larvae) or damage symptoms However, the incidence ratio becomes a vital tool in crop loss control where economic thresholds have been established for an insect on a crop in a particular area It also serves for comparisons of pest infestations between zones and years

Example 1 (*ICRISAT*, 1981, 1984) ICRISAT conducted a series of pest surveys from 1980–1983 in Burkina Faso and Niger The surveys involved a total of 379 farms and observations were made on *Acigona* and *Raghuva* incidence

Fields were selected at random at 10–40 km intervals The incidence of *Acigona* was assessed by splitting millet stems and examining for borer damage Usually up to 25 stems/farm were sampled For *Raghuva*, 150–250 randomly selected panicles per farm were observed for the presence of the characteristic spiral damage A total of 2727 stems and 37,689 panicles were observed

The following ratios were developed

Acigona

(a) % infested stems

$$= \frac{\text{no of stems with borer damage}}{\text{total number of stems sampled}} \times 100$$

(b) % tunnelled internodes

$$= \frac{\text{no of tunnelled internodes}}{\text{total number of internodes of stems sampled}} \times 100$$

Raghuva

(c) % infested panicles

$$= \frac{\text{no of panicles with Raghuva damage}}{\text{total number of panicles sampled}} \times 100$$

In Burkina Faso, the highest stem borer incidence was observed in the wetter southern Sudanian Zone of Bobo Dioulasso (Table 1), whereas *Raghuva* incidence was highest in the drier northern Sahelian Zone Infestations of pearl millet by *Raghuva* were not observed in the southern parts of Burkina Faso In Niger both *Acigona* and *Raghuva* incidence were most severe in the districts of Niamey (east at Filinque) and Maradi Stem borer damage at Dosso was also high The studies also showed a decline in

Table 1 Crop infestation of pearl millet by *Acigona ignefusalis* and *Raghuva albipunctella* in farmers fields in Burkina Faso and Niger West Africa

Species	Location				
	Burkina Faso* (regions)				
	North	South	Central	East	West
Stem borers					
% Infested fields	100 0	100 0	100 0	100 0	—
% Infested stems	51 0	72 0	66 3	44 6	—
% Tunnelled internodes	27 1	35 4	22 3	19 7	—
% Frequency of borer species					
A ignefusalis	100 0	81 4	99 7	100 0	—
E saccharina	0 0	14 0	0 3	0 0	—
S calamistis	0 0	4 6	0 0	0 0	—
Raghuva albipunctella					
% Infested fields	80 0	0 0	6 7	0 0	0 0
% Infested panicles	17 9	0 0	3 5	0 0	0 0
Mean damage score†	3 5	0 0	2 0	0 0	0 0
	Niger‡ (districts)				
Stem borer	Niamey	Dosso	Tahoua	Maradi	Zinder
(*Acigona ignefusalis*)					
% Infested fields	67 2	100 0	94 0	100 0	89 0
% Infested stems	35 2	69 1	48 2	58 0	61 5
% Tunnelled internodes	17 1	33 4	16 9	25 3	28 6
Raghuva albipunctella					
% Infested fields	52 9	12 0	77 4	70 1	60 0
% Infested panicles	30 7	4 2	7 5	30 5	16.8
Mean damage score	3.2	1 0	1.5	2.8	2.0

*Surveys conducted in 1980 and 1981
†Measured on a 1–5 scale, where 1 = zero to low damage and 5 = severe damage
‡Surveys conducted in 1982 and 1983

Table 2. Summary of experiments assessing the effect of stem-borer attack on the yield of early millet*

Experiments		Number of stems assessed	Stems bored (%)	Mean yield of grain per stem [Lb] Bored stems	Stems not bored
Samaru					
SBE	1957	4202	37.3	0.013	0.012
BP 7	1958	4865	20.7	0.044	0.030
BM 1	1960	8725	13.5	0.065	0.061
W 2a	1960	1906	9.4	0.057	0.073
W 2b	1960	2565	9.1	0.047	0.063
Kano					
K 1	1957	6123	60.6	0.084	0.107

*Adapted from Harris (1962).

stem borer and *Raghuva* infestation from 1980 to 1983.

Example 2 (*Vercambre*, 1978). Studies were conducted in Senegal from 1974 to 1976 on *Raghuva* infestation. In each farm, 50–100 panicles were examined. Twenty farms were evaluated in 1974, 42 each in 1975 and 1976. The incidence ratio was used to determine levels of infestation. Results indicated a decline from 1974 to 1976 with the most severe infestation occurring in northern Senegal. It was also found that maximum panicle damage did not exceed 50–60% of production even when 100% of the panicles were infested.

Visual score paired analysis

This method is a modified form of the incidence ratio method and uses the presence of pest attack in a paired analysis for comparing the yielding capacity of undamaged samples. In other words, the undamaged samples within the plant population are treated as the control against damaged samples.

Example 1 (*Harris*, 1962). Harris used three methods to study the effect of stem borer attack on maize, sorghum and millet in northern Nigeria. The insecticide treatment trial and the damage intensity/loss ratio were not applied for millet. However, in his visual score method, detailed assessments of borer attack and the yielding capacity of individual stems were made. The assessment of early millet at harvest was done by classifying stems into bored and unbored groups and evaluating their yield capacities. Bored stems yielded less than unbored stems in three cases and more in two (Table 2). In the latter case, borer attack was associated with better growth and hence higher yields. Only in one case in Kano where infestation was heavy, was the loss projected at 15%. For late millet, infestation was so severe that virtually no grain could be harvested and loss was estimated at 100%. In another trial, 90% of the stems were attacked and yields were reported low.

Example 2 (*ICRISAT*, 1983). In 1982, five pearl millet cultivars (CIVT, Ex-Bornu, Nigeria Composite, Souna III and a local) were sown in large blocks of 20 × 20 m. At first indication of head exsertion, 500 randomly selected panicles (four replicates of 125) were covered with pollination bags to prevent oviposition by *Raghuva*. The bags were maintained for 10 days. A similar number of unbagged panicles were also tagged. At harvest the panicles were scored for *Raghuva* infestation (present or absent) and grain yield was recorded. Grain loss was calculated as follows:

$$Y = \frac{y_1}{n_1} \times (n_1 + n_2)$$

$$\% YL = \frac{Y - (y_1 + y_2)}{Y} \times 100$$

where

Y = calculated attainable grain yield at no infestation
YL = yield loss
n_1 = number of bagged (control) panicles
n_2 = number of unbagged (infested) panicles
y_1 = grain yield from n_1
y_2 = grain yield from n_2.

The highest yield loss (14.9%) was recorded on CIVT and the lowest (0.8%) on the local cultivar.

Example 3 (*ICRISAT*, 1984). The visual score method was adopted in ICRISAT's farm level studies of yield loss factors using over 600 plots of 2000 m² each in farm fields of four villages in western Niger in 1981–1983. These factors included the millet stem borer and the earhead caterpillar. For stem borer, observations were taken at harvest by stem-splitting 50 stems/plot and recording the presence or absence of damage. The yielding capacity of stems were classified in accordance with stem damage.

For *Raghuva*, 250 panicles were randomly selected at harvest in each farm and separated into infested and uninfested lots. Head weight and grain yield were recorded respectively before and after threshing. Analysis of variance and χ^2-tests were made.

Table 3. Assessment of crop loss caused by infestation of *Raghuva albipunctella* in three millet cultivars. Chikal, Niger, 1986

Entry	Treatment	Days to 50% panicle exsertion	Panicles with eggs (%)	Damaged panicles (%)	Damage severity*	Yield (kg/ha)	Yield loss (%)
HKBtif	Protected control†	46	4	9	1.0	1840	41
	Unprotected	44	54	53	4.2	1090	
CIVT	Protected control	48	4	9	1.0	2310	17
	Unprotected	46	33	22	2.8	1920	
Local	Protected control	59	2	8	1.2	1650	8
	Unprotected	58	11	15	1.8	1520	
Mean		50	15	19	2.0	1720	
SE		3.7	1.9	3.3	0.1	84	

*Measured on a 1–5 scale, where 1 = zero to low severity and 5 = high severity.
†Treated with Decis, 0.01% EC.

Results indicated that for *Acigona*, except in one farm, in all test farms there was no effect of stem borer damage on yield But *Raghuva* scores were much higher in one village and showed a grain loss estimate of 14% It was low in another where grain loss was also insignificant

Damage intensity loss ratio

This method applies the same measurement parameters as the visual score method but goes one step further by quantifying the degree of infestation (level or amount of damage) and relating this to yield

Example 1 (*Vercambre*, 1978) In the same studies reported earlier, Vercambre (1978) also measured the actual loss arising from the area of panicle destroyed At the beginning of grain maturity, damaged florets were carefully removed from the panicle and the intensity of attack (damage) was calculated as follows

$$\frac{\text{Panicle area destroyed}}{\text{Total panicle surface}}$$

This is a rather difficult method but Vercambre argues that with training and practice, field assistants were able to provide rapid estimates over a large number of farms Between 50 and 100 panicles per farm were sampled

By applying the average percentage drop in production calculated on a regional basis, along with the production statistics from the Ministry of Agriculture (Senegal), it was estimated that a loss of 110,000 t of grain (equivalent to 25% of production from the regions of Sine Saloum and Diourbel of Senegal) occurred in 1974 Breniere (1974) also reported a loss of 74,000 t (15% of total production) in Niger in 1974

Example 2 (*Guevremont*, 1983) An attempt was made to estimate actual loss that occurred in grain weight due to feeding activity of individual larvae of *Raghuva* This involved the measurement of grain weight in panicle area that was mined, and then comparing with grain from non-damaged areas It was found that loss in grain weight corresponded with grain size ($r = 0\ 64$), that it increased with grain size, and that it varied between 0 4 and 1 0 g for a mean yield of 34 g per panicle

Quantitative assessment (insecticide trials)

Insecticide trials are almost always conducted a research stations These experiments employ pairec plot comparisons with one of each pair of plot being protected by insecticide The results are ofter exaggerated estimates of actual losses due to insec damage since these trials are carried out under close spaced, well-fertilized and mono-cropped conditions Most farmers' crops are wide-spaced, non-fertilized and intercropped Unfortunately, in Africa, insecticide trials for estimating yield losses are still the simplest approach to measure crop losses and some studies have been reported on millet in recent years

Example 1 (*Guevremont*, 1982, 1983) In experiments conducted in 1981 in Niger, Guevremont evaluated seven insecticides for their efficiency in controlling *Raghuva* A short maturity cycle cultivar (IVSP 78) was used The highest yield loss recorded was 6%, calculated from yield differences between the control plots where almost 50% of the panicles had *Raghuva* damage and the most efficient insecticide (Dipterex + SIR 8514) with only 3% panicles infested In a subsequent study conducted in 1982, using three varieties (HKP, HKP3 and IVSP), yield loss was estimated at only 1–2% for HKP and was unreliable for HKP3 and IVSP

Example 2 (*Gahukar* et al , 1986) The results of several insecticide trials conducted from 1982–1985 by the Integrated Pest Management Project of the Institut du Sahel are not readily available However, Gahukar *et al* (1986), in their review have summarized yield loss estimation for *Raghuva* and the results showed considerable variation In Senegal, in 1981 and 1982 losses varied from 3–82% in Sine Saloum and 15 20% in the region of Louga in 1982 Several correlations were also established between egg or larval incidence, grain damage and yield loss The authors, however, concluded that damage severity could not be associated with infestation rate and lamented the lack of information on actual losses on farmers' fields

Example 3 (*ICRISAT*, 1987) (a) *Raghuva* Insecticide trials were conducted in 1984 and 1985 at Chikal (Filinque), Niger using three millet cultivars (HKBtif, CIVT and a local) and Decis (deltamethrine, 0 01% EC) Estimated grain yield loss was

Table 4 Assessment of crop loss caused by infestation of *Acigona ignefusalis* in two millet cultivars Sadore Niger 1985

Parameters measured	Cultivars treatment				
	Protected control	Unprotected	Protected control	Unprotected	Mean ± SE
No larvae stem (50 DAS)*	1 5	3 0	0 0	0 2	1 2 ± 0 73
% Infested stems (50 DAS)	8 3	10 0	1 7	3 3	5 8 ± 2 10
% Internodes tunnelled (50 DAS)	1 4	2 6	0 3	0 6	1 2 ± 0 60
No larvae/stem (at harvest)	11 5	11 2	6 3	7 5	9 1 ± 1 49
% Infested stems (at harvest)	28 0	37 3	17 3	23 0	26 4 ± 2 87
% Internodes tunnelled (at harvest)	4 9	8 5	2 6	3 4	4 8 ± 0 52
Grain yield (kg/ha)	1856	2076	1414	1432	1720 ± 377
Yield loss (%)		11 9†		1 3†	

*DAS = Days after sowing

†Indicates yield advantage of unprotected over protected control

highest in HKBtif (41%) and lowest in the local cultivar (8%), while in CIVT it was 17% (Table 3) Crop damage was associated with crop phenology and maturity cycle

(b) *Acigona* Two cultivars (Nigeria Composite and a local), treated with Rogor (dimethoate, 500 g a i /ha) were used to estimate losses due to borer damage at the ICRISAT Sahelian Center, Sadore, Niger The results showed that low levels of borer infestation resulted in an increase in yield of unprotected plots over the protected control plots (Table 4) Harris (1962) also indicated a similar trend in his experiments

CONCLUSION

There are very few reliable estimates of crop losses to insect pests in the developing world and the situation is less encouraging for crops like the millets which provide major caloric inputs for millions of Africans The generality of the evidence that is provided for crop losses in Africa are often estimates that use techniques that have been developed for developed country agriculture For example, the National Academy of Sciences (USA) in 1978 estimated that post-harvest losses in the developing countries averaged between 10 and 20% and much of this loss was caused by insects (Reed, 1984) While these estimates may in part provide enough evidence to justify national investment in pest control research, often at times the resultant effect is negative

Research on pearl millet is only a few years old compared to other cereal crops like rice, maize and wheat Very little is known of the insect pests of finger millet Yet these two crops constitute about 50% of the total area cultivated to sorghum and millet in Africa It is unlikely that reliable data on losses due to insects will be available in the near future The best we can hope for is that surveys will be undertaken on farmers' fields to provide the basis for future research on these crops As agricultural production in the developing world continues to change, both in crop preferences and in technological inputs, pest status will change and so will the losses they cause Detailed studies of their biologies and ecologies will be needed and along with these, crop loss estimates and economic thresholds

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