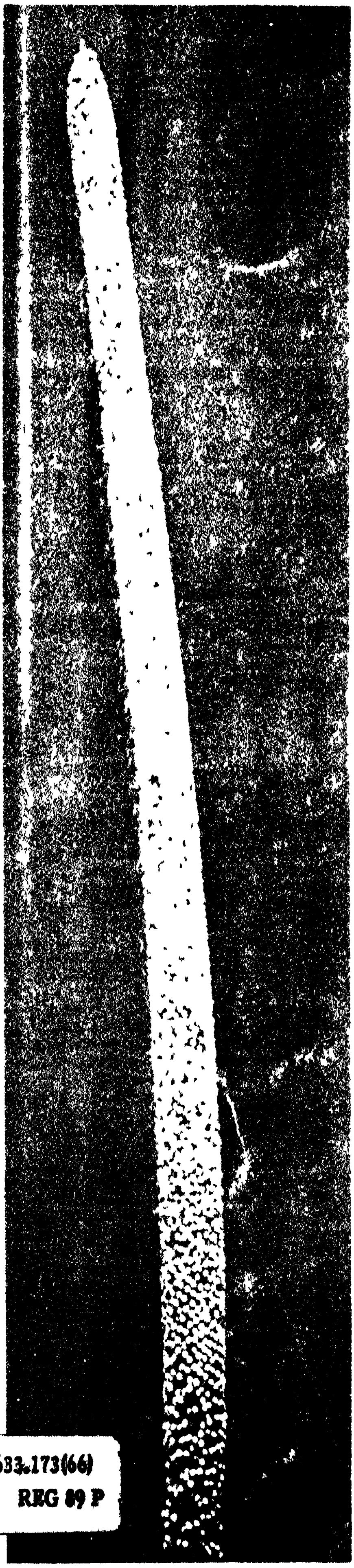
# Proceedings of Regional Pearl Millet Improvement Workshop





International Crops Research Institute
for the Semi-Arid Tropics

Sahelian Center

Sadoré, Niger
4-7 September, 1989

Proceedings of the

# Regional Pearl Millet Improvement Workshop

4-7 September 1989
ICRISAT Sahelian Center
Sadoré, Niger


*Editors*

L.K. Fussell
J. Werder



ICRISAT Sahelian Center
Pearl Millet Improvement Program
B.P. 12404, Niamey
République du Niger
1989

## CONTENTS

Networking Session

# BIOLOGICAL FACTORS AFFECTING PRODUCTION

# Blister Beetles (*Coleoptera: Meloidae*) as a Millet Pest in the Sahel Region of West Africa[1]

Alida Laurense[2]

**Abstract**

*Blister beetles of the genus* Psalydolytta *are serious pests of flowering and maturing millet in the Sahel. A brief description of the two major species,* P. fusca *and* P. vestita, *is given as well as the biology of the immature stages. Larvae are predators on grasshopper egg-pods. Bionomics and population dynamics of the two species are reviewed. Damage and loss depend on the coincidence of the insect peak population and the vulnerable flowering stage of the crop. Adult emergence seems to be independent of the onset of the rains, its intensity of cumulative amount. Infestation levels up to 80% of the crop have been recorded in Mauritania and average losses of 4-48% in The Gambia. Complete crop failures are not uncommon.*

*Use of varieties with long, stiff involucral hairs may be an effective control method; comparative trials in The Gambia and Mali resulted in significantly less attack of 'bristled' varieties. Of the traditionally used control methods only the repelling action of heavy smoke generating fires in the field seems to be effective. Practical application needs thorough organization at village level. Proper thinning and weeding seem to reduce the attractiveness of the crop due to lack of hiding places for the beetles during daytime. Most contact insecticides appear to be useful chemical control when applied to the plants foliar base.*

**Résumé**

**Les cantharides (*Coleoptera: Meloidae*), ravageurs du mil dans la région sahélienne de l'Afrique de l'Ouest**: *Les cantharides du genre* Psalydolitta *sont des insectes nuisibles importants affectant le mil aux stades adulte et de floraison dans le sahel. Une brève description des deux espèces majeures,* P. fusca *et* P. vestita, *est faite ainsi que la biologie des différents stades de leur jeune âge. Les larves sont des prédateurs de gousses d'oeuf de sauterelles. La bioéconomie et la dynamique des populations de ces deux espèces ont été revisées. L'importance des dégats et des pertes dus à ces insectes est liée à une coincidence d'une population optimale et le stade vulnérable de la floraison de cette culture. L'émergence de la population adulte est apparemment indépendante de l'installation de la saison pluvieuse et de l'intensité de son cumul. Des infestations des cultures jusqu'à 80% en Mauritanie et des pertes moyennant 4-48% en Gambie, ont été enregistrées. On en témoigne couramment des échecs entiers de la culture.*

*L'utilisation de variétés ayant des poils involucres, longs et raides peut être une méthode efficace de contrôle; des essais comparatifs en Gambie et au Mali ont résulté à une réduction significative de l'attaque des cantharides. Dans les méthodes traditionnelles de contrôle, seule l'action répugnante des feux dégageant d'importantes fumées dans les champs semble être efficace. Toute application pratique de cette méthode nécessite une étude minutieuse au niveau des villages. La plante attire difficilement les cantharides pendant le jour par manque de cachettes pour celles-ci dû à de bons démariage et sarclage. L'appliquation de la plupart des insecticides à la base foliaire des plantes paraît une méthode utile pour le contrôle chimique.*

## Introduction

Blister beetles of the subfamily Meloidae are widely known as flower beetles or pollen beetles feeding on cereals, grain legumes and Malvaceae (Hill 1983). Genera involved are: *Psalydolytta*, *Mylabris*, *Decapotoma*, *Coryna*, *Cylindrothorax*, *Cyanopytta* etc. Several species of these genera have been observed on millet (*Pennisetum glaucum* (L.) R. Br.) heads in the Sahel (Magema and Delhove 1985, Bonzi and Doumbia 1986, Zethner and Laurense 1988).

Though *Mylabris* spp, *Coryna* spp and other genera may be occasionally numerous on millet heads, the most devastating species belong to the genus *Psalydolytta*, of which *P. fusca* and *P. vestita* are the most important.

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Entomologist, Département de Formation en Protection des Végétaux, Centre AGRHYMET, B.P. 12625, Niamey, Niger.

Blister beetles have been described as early as 1700 (Cros 1981 *in* Bonzi and Doumbia 1986); their agricultural importance as one of the major crop loss factors in millet production in the Sahel has received serious attention only in the past decade and research has started even more recently. This paper is based on research results of the CILSS-USAID project on Integrated Pest Management for Basic Foodcrops in the Sahel, carried out between 1983 and 1986. On the subject, most work has been done by the FAO entomologists Zethner and Laurense, in the Gambia, Magema and Delhove in Mauritania and Doumbia and Bonzi in Mali. Detailed information can be obtained from their respective annual project reports.

Although this paper will focus on blister beetles as millet pests, there are two additional features which make them interesting subjects for further investigation. From the literature, blister beetle larvae are known to be predators of insects as well as grasshopper eggs. Fletcher (*in* Selander and Laurense 1987) reported in 1941 predation of eggs of the Pyrgomorphid *Colemania sphenarioides* by young larvae of *Psadylolytta rouxi* in India and Popov (*in* Bonzi and Doumbia 1986) found larvae of *Mylabris* spp in eggpods of *Oedaleus senegalensis* in Mali. As reported by Selander and Laurense (1987), larvae of *Psalydolytta fusca* have been confirmed as predators on *Cataloipus fuscocoeruleipes* (Sjönstedt) eggs in the Gambia.

A second feature, and maybe the most ancient and commonly known, is the excretion by the adult beetle of the acid cantharidin, provoking blisters on human skin. The name, cantharidin, refers to the systematically incorrect name given to this family of blister beetles. The family *Cantharidae* refers to the Soldier Beetles. Unfortunately, the french literature still uses the confusing term 'cantharides' when referring to the Meloidae.

## Description and Biology

Based on description by Kazab (1954) and own observations on *P. fusca* and *P. vestita* (Magema and Delhove 1985) the following general description of the two major species of *Psalydolytta* can be given:

General: Long, elongated beetles with a flexible head and long, 11 segmented antennae. Legs longer than body with 2 firm claws. Mandibles long with sharp point, bent back/downwards not overlapping distally as in most Meloidae. Elytra totally covering abdomen.

*P. fusca*: Ground color of head and pronotum black, elytra brown. Legs and antennae reddish-brown. Insect covered with a gray pubescence. Elytra characterized by a longitudinal lighter stripe over the middle due to a denser pubescence. Antennae filiform: antennae of male with first segment broadened and segments 3 to 11 bear brownish long hairs. Size: 28-35 mm (Kazab 1954); 20-31 mm with an average of 26.5 mm for the male and 27.0 mm for the female.

*P. vestita*: Head, elytra, legs and antennae reddish-brown, pronotum and underside black. Pubescence of upper and lower side thick, gray white (Kazab 1954). Insect covered with a straw-yellow thick pubescence (Magema and Delhove 1985). Antennae male: first segment very thick, other segments weakly broadened (serrate) without hairs. Middle of the metathorax as well as middle of abdomal segments in the male with protruding gold-yellow hairs (instead of thick pubescence). Size: 19-27 mm. Average: 22 mm, male smaller than female (Magema and Delhove 1985).

Around two weeks after first appearance of the adults the females start oviposition on the soil surface or in cracks in the soil. The eggs of *P. fusca*, creamish-white, 3.5 mm long and around 1.2 m wide, are laid in batches from 36 to 225 eggs (125 on average). Incubated in darkness at 100% RH at 30°C, hatching occurred after around 22 days (Selander and Laurense 1987).

The eggs give rise to the first type of meloid larvae, the triungulin. The triungulin of *P. fusca* is 5.2 mm long and the largest yet discovered in the meloidae (for detailed description see Selander and Laurense 1987).

The Meloidae are hypermetabolic. The different phases and larval instars (Table 1) can be identified using the nomenclature introduced by Selander and Mathieu:

Triungulin: $L_1$ : Slim; very mobile; feeding.

First grub: $L_2$ - $L_5$ : Scarabaeiform but with reduced legs, at least $L_5$ mobile, feeding

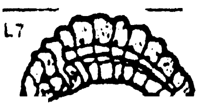
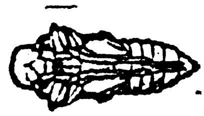
Coarctate: $L_6$ : Resembling a dipteran puparia, reduced legs, not feeding. Diapause phase.

Second grub: $L_7$ : As first grub, legs and mandibles present, unknown whether feeding or mobile.

Pupa

In the Gambia, eggs, triungulins, first grubs and coarctate larvae of *P. fusca* have been found (Selander and Laurense 1987), in Mali, Doumbia and Bonzi (1985) reported the observation of eggs, triungulins, coartacte and second grub larvae and pupae of *P. vestita* (Table 1).

**Table 1. Development of the Meloidae. After: Bonzi and Doumbia (1986). Data on The Gambia from Selander and Laurense (1987) and Laurense (pers. comm.).**

| Phase | Larval instar | Feature[1] | Remarks | Presence Mali 1984 | Presence Gambia 1985-86 |
|---|---|---|---|---|---|
| Triungulin T1 | L1 |  | Mobile feeding | Sep/Oct | Sep/Nov |
| First grub FG2 | L2 |  | Immobile, feeding, in eggpod | Nov | Oct |
| FG3 | L3 | | | | |
| FG4 | L4 | | | | |
| FG5 | L5 | | Mobile, in eggpod and soil | | |
| Coarctate C6 | L6 |  | Immobile, non-feeding, diapause in soil | Jun/Jul | Nov, Feb. |
| Second grub Grub SG7 | L7 |  | Mobile (?), feeding (?), in soil. | Aug | |
| Pupa P | |  | In soil | Aug | |
| Adult | | | On vegetation | Aug/Oct | Aug/Nov |
| Eggs | | | On or in soil | Sep/Oct | Sep/Nov |

[1] From Horsefall (1983).

In the Gambia two coarctate larvae were obtained after releasing triungulins reared from *P. fusca* eggs on moist sand containing egg-pods of *Cataloipus fuscocoeruleipes*.

The life cycle of the larvae is the triungulins search actively for grasshopper egg-pods. With their sharp, dented mandibles they make an entrance in the egg-pod and slit open the eggs. Inside the egg-pod the triungulins moult into the first grub phase larvae which feed on the eggs. The last first grub larvae ($FG_5$) leave the egg-pod and the next, coarctate phase is found in the soil near the empty egg-pod. After the onset of the rains the last larval phase second grub and the pupa are found.

## Distribution and Abundance

*Psalydolytta vestita* and *P. fusca* have been reported from the Sahel region from the west coast (Guinée Bissau, Sénégal, the Gambia) to the east of Niger. However, the abundance and relative importance differs with the location: in Guinée Bissau, southern Sénégal and the Gambia *P. fusca* is reported as the most important species, *P. vestita* is the predominant species in Mauritania and Mali. This may indicate a relationship between the species and the climate in which *P. fusca* may have a preference for the wetter regions.

Light-trap catches in The Gambia in 1984, 1985 and 1986 have revealed a first appearance of the adult *P. fusca* at the end of Aug (27th, 29th and 30th respectively). No relation with dates of onset of the rains, total amount of rainfall or intensity could be established (Table 2).

**Table 2. Rainfall data 1984-86 as measured at Yundum Airport, The Gambia and first catches of *Psalydolytta fusca* adults in light-trap at the Crop Protection Service at Yundum.**

| Year | Date first rainfall | Cumulative rainfall 100 mm | 150 mm | 200 mm | First shower >10 mm | >20 mm | First *P. fusca* |
|---|---|---|---|---|---|---|---|
| 1984 | 02/06 | 26/06 | 27/06 | 09/07 | 02/06 | 07/06 | 27/08 |
| 1985 | 22/06 | 15/07 | 18/07 | 22/07 | 27/06 | 15/07 | 30/08 |
| 1986 | 27/06 | 01/08 | 03/08 | 03/08 | 29/06 | 29/06 | 29/08 |

Last light-trap catches were obtained at the beginning of November. Between the end of August - beginning November two peaks in population densities were observed: the first at the end of September, the second around two weeks later at the beginning of October.

The presence of two distinct peak populations has also been reported for *P. vestita* in Mauritania (Magema and Delhove 1984, 1985). The dates of first and last observations of *P. vestita* adults in Mauritania differ slightly from the ones of *P. fusca* in the Gambia: *P. vestita* has been collected in 1984 and 1985 between the beginning of Aug until the beginning of Oct with peak populations at the end of Aug and the beginning of Sep.

At Samé, Mali, the first adult *P. fusca* was observed in 1984 in nature on 18 July and the first *P. vestita* on 23 July. The first light-trap catches were obtained on August 1st and 8, respectively. Observations at Bema in the same country showed a delay of 2 weeks in the first light-trap catches (Doumbia and Delhove 1985). In The Gambia 10-30 adults of *P. fusca* $hill^{-1}$ have been recorded and random sampling of millet fields between 1981 and 1984 gave averages between 0.2 and 2.4 adults hill$^{-1}$ (Zethner and Laurense 1988). Pre-treatment sampling of a heavy infested field in 1985 gave an average of 4.2 beetles hill$^{-1}$ (Zethner et al. 1985). Population increases occur very fast in fields.

## Biology of Adult Beetles

Unlike meloidae of the genera *Mylabris*, *Decapotoma*, *Coryna* etc., the *Psalydolytta* adults are predominantly active during evening, night and early morning, when they are found feeding on the host plant. Maximum feeding activity in millet fields has been observed between 0300 and 0500 (Zethner et al. 1985). When feeding on spikes of flowering millet, the beetle pulls out and eats the ovaries, anthers and stigmas. On spikes in the milky stage it cuts off the tips of the grains and consumes the content. During daytime almost the complete beetle population is found at the base of the host plants or under weeds, seeking shade (Zethner and Laurense 1988).

In The Gambia *P. fusca* has been reported on pearl millet (*Pennisetum glaucum*), wild millet (*Pennisetum pedicellatum*), *Digitaria ciliaris* and maize (*Zea mays* L.) (Zethner and Laurense 1988). In Mali it was also found on *Andropogon gayanus*, *Digitaria exilis* and sorghum (*Sorghum bicolor* (L.) Moench) (Doumbia and Bonzi 1984). *Psalydolytta vestita* has the same host plants.

## Crop Damage and Loss

Screenhouse trials in The Gambia in 1984 and 1985 have shown a potential total destruction of the yield with populations of 5 beetles hill$^{-1}$, present on the crop during the vulnerable flowering stage (Zethner and Laurense 1988). Observations from The Gambia and Mauritania show that total crop destruction is not uncommon at farm level. In The Gambia crop losses were found to be 4 to 48% between 1981 and 1984 (Zethner and Laurense 1988). For Mauritania infestation levels at 15 days before harvest of 4-60% (1983), 8.5-15% (1984), 2-80% (1985) and 0.5-50% (1986) have been reported with losses up to 100% (Magema and Delhove 1984 and 1985, Magema and Beye 1986).

Damage and loss are most serious if the appearance of the beetles in the field coincides with the flowering stage of the crop. This depends both on planting date and variety of the crop and date of appearance of the beetles. A timely sown 90-day variety of millet in The Gambia will escape attack due to its very early flowering (Aug) in relation to the population peak of *P. fusca* (Sept/Oct). However, for timely sown 90-day varieties in Mauritania, flowering may just coincide with the maximum populations of *P. vestita* of beginning September.

## Control Methods

### Resistant varieties

In both The Gambia and Mali, it has been observed that millet varieties with rather long involucral hairs on the spike, so called 'bristled' varieties, were less attacked than spikes with short involucral hairs. Confirmation was sought in field trials. Experiments were carried out in The Gambia in 1985 with bristled and non-bristled 90-day (early) and 130-day (late) millet varieties. There was a significant difference in *P. fusca* populations between the bristled and non-bristled varieties (Table 2). In 1986 experiments were repeated under farm conditions with local bristled and non-bristled 90-day millet varieties (Table 4).

**Table 3. Numbers of *Psalydolytta fusca* adults on two bristled and two non-bristled varieties of millets in 1985 experiments in The Gambia.**

| Variety | Mean number per 10 hills |
|---|---|
| Early millet - bristled | 2.8 |
| Early millet - non-bristled | 4.6[1] |
| Late millet - bristled | 0.7 |
| Late millet - non-bristled | 26.7[1] |

1. Difference statistically significant (P<0.01)

**Table 4. Performance of bristled and non-bristled varieties of early millet in demonstration trials 1986 (Zethner and Laurense 1988).**

| | Sapu M.I.D | | | | Karantaba L.R.D. | | Kuntaur M.I.D. | | Wellingara N.B.D. | | Sarajaje U.R.D. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Early sowing | | Late sowing | | | | | | | | | |
| Pests and disease | B | NB | B | NB | B | NB | B | NB | B | NB | MB | FB |
| *P. fusca* | | | | | | | | | | | | |
| av. no. beetles $hill^{-1}$ | 0.03 | 0.16 | 0 | 0 | 0.61 | 1.45 | 0 | 0 | 0 | 0 | 0.9 | 2.0 |
| Millet spike borer[1] | | | | | | | | | | | | |
| av. no. galleries/spike | 0.29 | 0.66 | 0.08 | 0.17 | 0.55 | 0.97 | 0.90 | 1.76 | 0.75 | 1.09 | 0 | 0 |
| Weaverbird damage, % | 3.7 | 7.4 | 3.3 | 12.3 | | NA | 2.4 | 13.1 | 2.9 | 11.8 | 5.6 | 5.2 |
| Smut[2] severity, % | 6.7 | 4.4 | 2.8 | 9.2 | | NA | 2.2 | 8.9 | 2.3 | 5.4 | 4.0 | 5.0 |
| Yields, kg grains $ha^{-1}$ | 855 | 681 | 612 | 563 | 756 | 540 | 707 | 662 | 1670 | 1359 | 1598 | 1670 |

1. *Heliocheilus (Raghuva) albipunctella*
2. *Tolyposporium penicillariae*

B = bristled millet variety
NB = non-bristled millet variety
NA = data not available
MB = most spikes with bristles
FB = fewer spikes with bristles

Not only were the bristled varieties less attacked by *P. fusca*, attack by *Heliocheilus albipunctella*, weaverbirds and smut were reported of lower incidence. In all but one of the cases yields of the bristled varieties were higher than non-bristled varieties. In Mali in 1985 bristled and non-bristled early varieties were compared. Non-bristled variety carried a *P. fusca* population 1.8-2.6 times higher than the bristled variety. Yields were 220-420 kg $ha^{-1}$ for the bristled and 153-201 kg $ha^{-1}$ for the non-bristled varieties (Doumbia and Bonzi 1985).

Two restrictions may hamper practical suitability of the bristled varieties. The bristle character may not be 100% genetically inherited and the performance of the bristled varieties has not been analyzed in no-choice conditions.

## Traditional control methods

Three traditional methods of bister beetle control have been observed in the Sahel. The simplest method is to collect and destruct the beetles by hand. Due to the toughness of the skin of hand (and foot) the cantharidin hardly causes blisters to the collecting farmer. In some regions people grease their skin with juice of crushed cowpea (*Vigna unguiculata* (L.) Walp) leaves as a protection against the acid (Bonzi and Doumbia 1986).

A second method is to attract the beetles to split baobab (*Adansonia digitata*) fruits. Experiments in The Gambia showed very limited effect (Zethner et al. 1985). In Sénégal slightly better results were obtained in 1986 with the application of some vinegar drops to the fruits (CILSS 1987).

The most effective and promising method is the lighting of fires at night in millet fields. In The Gambia, trials at farm level were conducted in 1985 and 1986 (Zethner and Laurense 1988). The results showed that the effect depends primarily on the quality of the smoke and, consequently, on the material used as fuel (Table 5). Groundnut shells appeared to be particularly good, whereas dry wood and grass neither produced heavy smoke nor did the fires appear to attract beetles. Practical application of the method was found to be possible only when repeated a few times during the vulnerable flowering stage of the millet, provided the whole village participates.

Table 5. Effect of smoke on abundance of *Psalydolytta fusca* in fields of early millet, 1985-86 (Zethner and Laurense 1988).

| Fields | No. *fusca* hill$^{-1}$ before smoking | No. *fusca* hill$^{-1}$ after smoking | % reduction after on burning | Source of fire[1] | Smoke | Date |
|---|---|---|---|---|---|---|
| **Western Divisions** | | | | | | |
| Tumani Tenda | 1.84 | 0.03 | 98[2] | Groundnut shells | Much | 10/09/85 |
| Tumani Tenda | 1.96 | 0.02 | 99[2] | Groundnut shells | Much | 12/09/85 |
| Sincho Alhagi | 2.82 | 1.34 | 52[2] | Palm leaves & tyre | Much | 10/09/85 |
| Sincho Alhagi | 1.67 | 1.07 | 36[3] | Palm leaves & tyre | Some | 12/09/85 |
| **Lower River Division** | | | | | | |
| Karantaba | 0.44 | 0.00 | 100[2] | Wet wood | Much | 04/09/85 |
| Sambunda | 0.72 | 0.04 | 94[2] | Wet wood | Little | 07/09/85 |
| Fonkoi Kunda | 1.02 | 1.02 | 0 | Dry grass and wood | None | 03/09/85 |
| **North Bank Division** | | | | | | |
| Kubandar | 1.33 | 0.78 | 41[3] | Wood and grass | Some | 04/09/85 |
| Kubadar | 1.02 | 0.73 | 28[3] | Wood and grass | Some | 07/09/85 |
| Chamen, 1985 | 1.32 | 0.90 | 32[3] | Wood and grass | Some | 09/09/85 |
| Chamen, 1986 | | | | | | |
| Farmer 1 | 2.03 | 1.18 | 42[2] | Wood and grass | Some | 13/09/86 |
| Farmer 2 | 2.40 | 1.35 | 44[2] | Wood and grass | Some | - |
| Farmer 3 | 2.87 | 1.50 | 48[2] | Wood and grass | Some | - |
| Farmer 4 | 2.51 | 1.24 | 51[2] | Wood and grass | Some | - |
| Farmer 5 | 3.39 | 1.86 | 45[2] | Wood and grass | Some | - |
| Total, Chamen 1986 | 2.64 | 1.43 | 46[2] | | | |

1 *P. fusca* thrown upon fires
2 Difference in *P. fusca* significant $P<0.05$
3 Difference in *P. fusca* significant $P<0.01$

## Cultural control

Qualitative observations in The Gambia indicate that during daytime *P. fusca* is commonly found in largest numbers at the base of the more dense millet stands and under broad-leaved weeds. A clear and open millet field may therefore reduce the attractiveness of the crop to the beetles.

Manipulation of the sowing date of the millet may avoid the coincidence of susceptible crop stage and high beetle populations. Under the erratic Sahelian climate, however, not much opportunity for such manipulation is available.

## Chemical Control

Based on research results concerning potential damage by the beetles, an economic threshold of one beetle per two hills has been established. In Mauritania a threshold of two beetles per spike has been used (CILSS 1987).

Trials with pesticides in The Gambia, Mali and Mauritania have resulted in the following recommendations (CILSS 1986 and 1987):

Carbaryl 85% WP at a dose of 1275 g a.i. $ha^{-1}$
Trichlorphon 80% SP at a dose of 400 g a.i. $ha^{-1}$
Malathion 50% EC at a dose of 750-1000 g a.i. $ha^{-1}$
Ficam ULV at a dose of 30 g a.i. $ha^{-1}$
Fenitrothion 2% P at a dose of 8 kg $ha^{-1}$

In all cases treatment of the plant base is sufficient to kill the populations due to their hiding behavior at daytime. Treatment of the millet heads is unnecessary and undesirable from toxicological point of view.

## Conclusion

Although *Psalydolytta fusca* and *P. vestita* adults differ in feature and climatic preference, the host plants and damage caused are identical. The biology of the larvae is still obscure. For none of the studied species has the complete life cycle been found in nature. The damage can be to such an extent that farmers abandon cultivation of susceptible early varieties.

Of the possible control methods the use of varieties with long involucral hairs is the most promising, though persistence and performance in no-choice conditions should be studied as well as the effects on other millet pests. Chemical control with contact insecticides applied to the plant base seems to be effective but for most farmers not feasible. Although the effectiveness of the beetle larvae as predators of grasshopper egg-pods is still unknown this quality should be seriously taken into account when opting for chemical control.

Of the traditionally used control methods, the lighting of fires in the fields seems to be effective. The fires should generate a heavy smoke repelling the beetles. However, the method is time and energy consuming since it needs to be repeated several times. Biological control can not be considered yet due to lack of knowledge on the diseases, predators and parasitoïdes of the insect.

## References

Bonzi, S.M., and Doumbia, Y.O. 1986. La situation des meloïdes en Afrique sahélienne. [Not published].

CILSS. 1986. Projet Lutte Intégrée. Synthèse des rapports techniques annuels de la campagne agricole 1985.

CILSS. 1987. Projet Lutte Intégrée. Synthèse des rapports techniques annuels de la campagne agricole 1986.

Doumbia, Y.O., and Bonzi, S.M. 1984. Rapport annuel 1984 - Entomologie. P.L.I. - CILSS. Composante nationale du Mali.

Doumbia, Y.O., and Bonzi, S.M. 1985. Rapport annuel 1985 - Entomologie. P.L.I. - CILSS. Composante nationale du Mali.

Hill, D.S. 1983. Agricultural insect pests of the tropics and their control. Second Edition. Cambridge University Press. 749 pp.

Horsefall, W.R. 1943. Biology and control of common blister beetles in Arkansas. University of Arkansas, Agricultural Experimental Station Bulletin no. 436, 55 pp.

Kazab, Z. 1954. Die Arten der Meloiden Gattun *Psalydolytta* Pér. Acta Zoological. Academiae Scientiarum Hungarica 69-103.

Magema, Na.B., and Beye, C.M. 1986. Rapport annuel 1986. Entomologie. P.L.I.-CILSS. Composante nationale de la Mauritanie.

Magema, Na.B., and Delhove, G.M. 1984. Rapport annuel 1984. Synthèse d'observations. P.L.I.-CILSS. Composante nationale de la Mauritanie.

Magema, Na.B., and Delhove, G.M. 1985. Rapport annuel 1985. Entomologie. P.L.I.-CILSS. Composante nationale de la Mauritanie.

Selander, R.B., and Laurense, A.A. 1987. On the immature stages of *Psalydolytta fusca* (Coleoptera: Meloidae). Proceedings of the Entomological Society, Washington 89:489-499.

ent of The

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

# Note on the Populations Dynamics of *Rhinyptia infuscata* (*Scarabeidae*): a Serious Pest of Pearl Millet[1]

**M.J. Lukefahr and Abdoul Karim Mamalo[2]**

**Abstract**

Rhinyptia infuscata *(Burm.)* (Scarabeidae) *was recognized as a serious pest of pearl millet in 1987 when over 500,000 adults ha$^{-1}$ were observed. The peak period of activity was between 2100-2400 hours. Larvae develop on roots of millet and cowpea from the previous season.*

*Larvae populations were significantly reduced if the root system of millet was destroyed. Cultural control measures may be the most realistic method of population suppression. Additional research is needed before an effective control program can be designed.*

**Résumé**

**Note sur les dynamiques de populations du *Rhinyptia infuscata* (Scarabeidae): un ravageur important du mil:** *Le* Rhinyptia infuscata *(Burm.) (*Scarabeidae*) était reconnu comme un ravageur important du mil en 1987, période pendant laquelle 500.000 adultes ha-1 ont été observés. La période de pointe d'activité était entre 2100-2400 heures. Les larves se développent sur les racines du mil et du niébé pendant l'année précédente.*

*Les populations larvaires pourraient être considérablement réduites si le système racinaire du mil était détruit. Les mesures de contrôle cultural pourrait être la méthode la plus réaliste de suppression de populations. Une recherche supplémentaire est nécessaire si un programme efficace de contrôle doit être conçu.*

## Introduction

During the 1987 growing season at ICRISAT Sahelian Center (located 41 km south east of Niamey, Niger) it was noted that pearl millet (*Pennisetum glaucum* (L.) R. Br.) heads were empty of seed and upon close examination it was found that the anthers and stigmas were absent. However, if the heads had been covered with selfing bags a normal seed set occurred. Therefore the problem could not be environmental or related to agronomic practices. Detailed inspections and observations failed to determine the cause of the problem until nocturnal observations identified high populations of the scarabid beetle *Rhinyptia infuscata* (Burm). While this insect occurs in most West African insect collections, published information on the pest status of this insect is limited.

Guevremont (1983), in an unpublished report from Maradi, Niger, noted that adults were present from early July and maximum number occurred in late September when as many as five adults per head were found. Maiga (1984) also from Maradi, mentioned that large number of adults attacked millet heads.

Gahukar and Pierrard (1983) reported adults of *Rhinyptia* attacking both millet and sorghum (*Sorghum bicolor* (L.) Moench) at Bambey, Sénégal and as many as 15 adults per head were recorded on millet. N'Doye and Gahukar (1986) mentions that *Rhinyptia* was an occasional pest of millet in West Africa.

The objective of this paper is to present results obtained during the 1987, 1988 and 1989 growing seasons on populations of *Rhinyptia infuscata*.

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Principal Entomologist and Senior Research Assistant, respectively, Pearl Millet Improvement Program, ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger.

## Materials and Methods

Population dynamics

During 1987 nocturnal observations were made on seven different dates between August 23 and 14 September at the ICRISAT Sahelian Center (ISC), Sadoré, Niger. Three observers examined 200 linear meters of millet every hour from 1900 to 0700 the following morning and recorded the number of *Rhinyptia* adults.

In 1988 observations were made on 13 different dates between Jul 13 and Sep 17 by three observers who counted adults on 220 linear meters of row. The number of *Rhinyptia* adults were recorded on each observational period. A rechargeable 6 volt battery with a 4.8 volt light bulb was used to illuminate the plants and count the beetle adults.

Beginning in Jan 1988, three light traps with 150 W mercury vapor lights were operated each night and number of *Rhinyptia* adults captured were recorded for five nights of each week.

In 1988 and 1989 numerous soil samples were taken in an attempt to find the location where larvae were developing. The soil from an area one meter square and at least 20 cm deep was sifted through a coarse mesh screen and the number of larvae recorded.

Control methods

At the end of the 1988 growing season a test was begun to study the influence of different cultural control practices on populations millet insects. Each treatment was replicated seven times in plots that were 7.5 x 20.0 m. These plots were sampled on Jun 27-28 1989 by sifting soil from four meter square from each plot through a metal screen. The samples were taken to a depth of 20 cm and number of *Rhinyptia* larvae recorded.

In 1989, Dursban (chloropyrifos) at the rate of 480 gms (a.i.) $ha^{-1}$ was applied with conventional knapsack sprayer when millet was starting to head. Twenty-four hours later the soil surface was examined and the number of dead adults m2 was recorded.

## Results and Discussion

Population dynamics

*Rhinyptia* adult emergence begins soon after the rains have commenced. In 1988 the peak emergence occurred in early August after sustained rainfall, however, smaller numbers were found earlier (Table 1). In 1989 the number of adults declined during late July due to the prolonged drought that occurred from July 10 to July 30. The ability of the adults to synchronize their emergence with rainfall shows a remarkable survival mechanism which has enabled this insect to exist under Sahelian conditions.

The adult shows a very strong aversion to daylight. Their activity does not commence until darkness falls and ceases at daybreak. More than 50% of the total number of adults counted were found between the hours of 2100-2400. During the day adults can be found in the soil and concentrated around the base of the plants. Adults can be found under the ground trash in non-cultivated land if located close to millet fields. Adults captured in light traps cages are strongly repelled by daylight and undergo frantic activity in an effort to find unlighted areas.

As many as 60 adults have been observed feeding on a single head during the

**Table 1. Catches of *Rhinyptia infuscata* adults in three mercury vapor light traps at ISC, Niger 1988 and 1989.**

| | 1988 | 1989 |
|---|---|---|
| May 1-7 | 4 | 0 |
| 8-14 | 0 | 2 |
| 15-21 | 0 | 0 |
| 22-28 | 0 | 371 |
| May 29-Jun 5 | 0 | 0 |
| Jun 6-12 | 0 | 0 |
| 13-19 | 1 | 0 |
| 20-27 | 19 | 2 |
| Jun 28-Jul 4 | 0 | 0 |
| Jul 5-12 | 75 | 115 |
| 13-20 | 53 | 38 |
| 21-27 | 11 | - |
| Jul 28-Aug 3 | 24 | 80 |
| Aug 4-10 | - | 669 |
| 11-17 | 1141 | 632 |
| 18-25 | 1036 | 3319 |
| 26-31 | 2039 | 42,816 |
| Sep 1-7 | 1962 | 41,500 |
| 8-14 | 585 | 140,000 |
| 15-22 | 818 | 70,350 |
| 23-30 | 694 | 41,240 |
| Oct 1-7 | 152 | 7019 |
| 8-15 | 5 | 508 |
| 16-23 | 0 | |

period. Adults feed only on the anthers and stigmas of the millet heads and their feeding is so precise that the remaining structures are undamaged. Therefore, when day-light comes, there is no evidence of beetle attack. The massive numbers of adults present in 1987 resulted in a near crop failure at ISC as yields averaged only 150 kg grain $ha^{-1}$ on the worst attacked fields. Had not late rains occurred in September, after populations had declined, the yields would have been even lower. Farmers' fields located near Sadore also came under attack but the late flowering landraces escaped the peak populations.

During the 1987-88 post rainy season soil samples were taken in non-cultivated areas to determine if larval development was taking place on roots of plants in these undisturbed areas. Particular emphasis was placed on shrubs and trees; however only a few larvae were found from more than 80 $m^2$ of soil samples. During the 1988-89 post rainy season the soil sampling was limited to areas that had been under cultivation during the 1988 growing season. Fields that had been cropped with millet or cowpea had much higher densities of larvae than groundnut and the non cultivated areas (Table 4). Farmers fields that had been cropped to millet during the 1988 growing season had fewer larvae than at ISC. These differences were probably due to differences in plant density as farmers normally have about 10,000 hills $ha^{-1}$ while at ISC the density is about 33,000 hills. Since the larvae feed on the root system of plants from previous crop season, the fields utilized for groundnuts would have reduced number of roots following harvest, therefore this probably explains the low larval populations on groundnut fields.

Table 2. Activity period of *Rhinyptia infuscata* adults on millet heads during noctural hours at ISC, Niger 1987and 1988.

| Mean no. of adults at: | | |
|---|---|---|
| 1900 | 1160 | 36 |
| 2000 | 3000 | 2118 |
| 2100 | 4122 | 1816 |
| 2200 | 3830 | 1677 |
| 2300 | 3839 | 1642 |
| 2400 | 3449 | 1603 |
| 0100 | 2495 | 1323 |
| 0200 | 2346 | 1192 |
| 0300 | 2113 | 1056 |
| 0400 | 1911 | 902 |
| 0500 | 1518 | 539 |
| 0600 | 1134 | 319 |
| 0700 | 150 | 32 |
| Total | 29,171 | 13,295 |
| % adults present from 2100-24000 | 52.6 | 50.6 |

Table 3. Estimated adult population $ha^{-1}$ of *Rhinyptia infuscata* on millet heads between hours of 2100-2300 at ISC, Niger 1987, 1988 and 1989.

| | 1987 | 1988 | 1989 |
|---|---|---|---|
| Before Jul 14 | - | 7350 | - |
| Jul 5-22 | - | 68,200 | - |
| Jul 23-30 | - | - | - |
| Aug 1-7 | - | 49,300 | - |
| Aug 8-15 | - | 25,600 | - |
| Aug 16-22 | - | 235,000 | - |
| Aug 23-30 | 525,000 | 357,000 | 457,520 |
| Sept 1-6 | 415,120 | 384,000 | 689,307 |
| Sept 7-13 | 166,785 | 191,000 | 863,102 |
| Sept 14-21 | 18,601 | 77,800 | 832,280 |
| Sept 22-28 | - | - | 319,600 |

Density of millet (as hills per ha): 33,000

## Control methods

Of the different cultural practices, only the plots in which the stalks were buried resulted in reduced larval populations (Table 5). Reductions are probably due to the partial destruction of the root system during the burial of the stems. This suggests that control of *Rhinyptia* may be achieved by tillage practices and may be the most practical method of control. Actually, many farmers up-root the millet plants soon after harvest which should result in reduced populations; however this is not practiced by all farmers.

Chemical control of adult populations could be achieved by use of Dursban at the 480 g (a.i) $ha^{-1}$. In 1987, 144 dead adults $m^{-2}$ were recorded 24 hours after insecticide application. However, as flowering is spread over a two week period repeated applications would be needed to protect newly emerging heads. Moreover, the difficulty in applying insecticide to millet heads on plants that are 2 m or higher makes chemical control an unrealistic option.

## Conclusion

In conclusion we believe that *Rhinyptia* occurs in numbers that result in measurable yield losses but because of its nocturnal feeding habits has not been considered as a pest of millet. This insect probably occurs in damaging numbers each year and should receive increased attention in a millet entomology research program. In particular information is needed on: (1) life history (2) distribution in West Africa (3) cultural control and (4) yield losses resulting from different population densities.

## References


**Gahukar, R., and Pierrard, G.** 1983. Chafer beetles as a pest of sorghum and pearl millet. FAO Plant Protection Bulletin 11(4):168-69.

**Guevremont, H.** 1983. Rapport annuel de recherches pour 1982. INRAN, Maradi, Niger, pp. 10-11. [Unpublished]

**Maiga, S. D.** 1984. Premier séminaire régional de formation. Projet Amélioration des mil, sorgho, niébé et mais, INRAN, Maradi, Niger. [Unpublished]

**NDoye, M., and Gahukar, R.** 1986. Insect pests of pearl millet in West Africa and their control. Proceedings of the International Pearl Millet Workshop ICRISAT Center Hyderabad, India, pp 195-205.


**Table 4.** Larval populations of *Rhinyptia infuscata* following different crops from the 1988 growing season, ISC, Niger, June 1989.

| Crop in 1988 | Area $m^2$ sampled | Estimated larval population $ha^{-1}$ |
|---|---|---|
| Cowpea | 8 | 23,000 |
| Millet | 9 | 20,100 |
| Groundnut | 20 | 7,500 |
| Non-cultivated | 10 | 6,000 |
| Farmers' field | 16 | 10,700 |

**Table 5.** Influence of different cultural control practices on larval populations of *Rhinyptia infuscata*, ISC, Niger, 1988 and 1989.

| Treatment | Larval populations $ha^{-1}$ |
|---|---|
| Stalks left standing | 11,400 |
| Stalks cut Dec. 1 and left on soil surface. | 11,400 |
| Stalks cut Dec. 1 and partially buried. | 15,200 |
| Stalks cut and buried 5-cm on Dec 1 | 3,500 |
| Stalks cut down on Mar 1 | 11,600 |
| CV (%) | 47.9 |

# Chemicals for Control of Stem borers of Pearl Millet in the Nigerian Savanna[1]

**I.I. Uvah[2] and O. Ajayi[3]**

**Abstract**

*The efficacies of some seed dressings and other chemical formulations for control of the millet stem borer,* Coniesta (Acigona) ignefusalis, *were compared with that of granular carbofuran at the Institute for Agricultural Research, Samaru, Nigeria during 1985-1988. The seed dressings, Furadan 35ST, Marshall 25 ST and Fernasan D failed to give satisfactory control of the millet stem borer whether applied alone or in sequential combination with other insecticides. Miral 3G at 15 kg granules ha⁻¹, Apron-plus 50DS seed dressing at 5 g kg⁻¹ seed and Talstar 10ec applied twice at 20 and 35 days after planting were found to be promising alternatives to granular carbofuran for* Coniesta ignefusalis *control. An integrated approach to millet stem borer control is suggested.*

**Résumé**

**Produits chimiques pour le contrôle du foreur de tiges du mil dans la savane nigériane.** *L'efficacité des traitements de certaines semences et autres formules chimiques pour contrôler le foreur de tige de mil,* Coniesta (Acigona) ignefusalis, *a été comparée avec celle du carbofuran granulaire à l'Institut de Recherche Agricole, Samaru (Zaria), Nigéria, de 1985-1988. Les traitements de semences, Furadan 35 ST, Marshall 25 ST et Fernasan D n'ont pas abouti à un contrôle satisfaisant du foreur de tige de mil qu'ils soient appliqués seuls ou en combinaison séquentielle avec d'autres insecticides. Le Miral 3G à 15 kg de granules ha⁻¹, le traitement de semences Apron-plus 50DS à 5 g kg⁻¹ de semence et de Talstar 10 ec appliqué à 20 et 35 jours après semis ont prouvé être des alternatives plus promettantes contre le carbofuran granulaire pour le contrôle de* Coniesta (Acigona) ignefusalsis. *Il est suggéré une approche intégrée pour le contrôle du foreur de tige de mil.*

## Introduction

Pearl millet, (*Pennisetum glaucum* (L.) R. Br) is second in importance only to sorghum (*Sorghum bicolor* (L.) Moench) among cereal crops grown in the Nigerian savannas for human consumption. Over 40% of utilized arable land in the Nigerian savannas (about 5 million hectares) is devoted to millet production as a sole crop in the Sudanian and Sahelian areas, and in mixtures involving mostly sorghum but sometimes also cowpea (*Vigna unguiculata* (L.) Walp.), groundnut (*Arachis hypogaea* L.) and cotton (*Gossypium hirsutum* L.) in other areas (Egharevba 1978). Annual production is estimated at 2.4 million tonnes with national mean yields of 580 - 750 kg ha⁻¹ (Egharevba 1978, 1979; Andrews and Kassam 1978). However, yields of over 200 kg ha⁻¹ are obtainable under improved technology (Egharevba 1979).

Insect pests are the most important constraint to millet production in Nigeria (Williams et al. 1975). The more important insects are the millet shootfly (*Delia arambourgi* Seguy), stem borers (mainly *Coniesta (Acigona) ignefusalis* Hampson), midge (*Geromyia penniseti* Felt), headworm (*Heliocheilus (Raghuva) albipunctella* Laporte) and head beetles, (*Meligethes heteropus* Gerstaecker) (Hills 1975, Ajayi 1985a). Of these insect pests, *H. ignefusalis* is the most important and widespread on millet in Nigeria (Ajayi 1985a).

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Entomologist, Department of Crop Protection, Faculty of Agriculture/Institute for Agricultural Research, Ahmadu Bello University, P.M.B 1044, Zaria, Nigeria.

3. Present address: ICRISAT West African Sorghum Improvement Program, PMB 3491, Kano, Nigeria.

Experiments at the Institute for Agricultural Research at Samaru have shown that granular carbofuran applied to the soil at 1.0 kg a.i. $ha^{-1}$ at planting and again at 45 days later effectively controls the millet stem borer (Ajayi and Uvah 1988). The chemical is, however, expensive and often not readily available. The need to identify cheaper alternatives constituted the aim of the present study. Efficacies of chemical seed dressings and other formulations were compared with that of granular carbofuran in a four-year study from 1985 to 1988.

## Materials and Methods

### General conditions

Four experiments were carried out during the wet seasons of 1985 to 1988. The pearl millet variety, Ex Bornu was used in all the experiments. Field agronomic practices conformed with standard recommendations (Anonymous 1985). The field layout for all the experiments was a randomized block design with four replicates on plots measuring 4.5 m (six ridges) x 5 m. Plots were separated by 1.5 m of weed-free fallow. The following parameters were sampled on single plot basis:

(i) germination count at two weeks after planting (WAP)
(ii) count of deadhearts at four WAP
(iii) days to 50% heading
(iv) holes per stem for 10 stems at harvest
(v) tunnel length per stem for 10 stems at harvest
(vi) number of larvae and pupae per stem for 10 stems at harvest
(vii) number and weight of heads per two central rows
(viii) weight of grain threshed from all heads on the two central rows and
(ix) a thousand-grain weight.

Insecticide application varied with formulation. Granules applied at planting were placed in the seed furrow such that they were separated from the seed by a layer of soil. Side dressed granules were placed in furrows 2.5 cm away from the base of plants. Seed dressing concentrates were diluted with 25% volume of water and applied evenly by carefully turning seed using a wooden stirrer in a plastic container. Such treated seed was spread out to dry under shade prior to planting. Seed treatment dusts were evenly applied to seed by stirring the mixture carefully in a plastic dish. Foliar sprays (wp & ec formulations) were applied using a knapsack sprayer. Millet was generally planted from early to mid-June. The insecticide treatments employed in the different years were as below.

### 1985 Experiment

Twelve insecticide treatments comprising various rates and/or frequencies of carbofuran, Marshall seed treatments, granular carbofuran and chlorpyrifos were evaluated in 1985. Vetox 85 wp (85% carbaryl) at 1.7 kg a.i $ha^{-1}$ at 20 DAS and again at 35 days after planting (DAP), Furadan 3G (3% carbofuran granular) at 1.0 kg a.i. $ha^{-1}$ at planting, Furadan 3G at 1.0 kg a.i. $ha^{-1}$ at planting followed by side dressing at 45 DAP, Furadan 3G at 1.0 kg a.i. $ha^{-1}$ at 45 DAP only, Dursban 5G (5% chlorpyrifos granular) at 0.5 and 0.75 kg a.i. $ha^{-1}$ at planting, Dursban 4ec (4% chlorpyrifos) at 0.96 kg a.i. $ha^{-1}$ each at 20 and again at 35 DAP, Furadan 35 ST (35% carbofuran e.c. seed treatment) at 0.75 and 1.0 kg a.i/100 kg seed, Marshall 25 ST (25% dust) at 0.5, 0.75 and 1.0 kg a.i./100 kg seed, and the unprotected control.

## 1986 Experiment

Granular carbofuran was again compared with Marshall and carbofuran seed treatments alone and also in sequence with granular carbofuran. Treatments were: Furadan 5 G (5% carbofuran granular) at 1.0 kg a.i $ha^{-1}$ at (i) transplanting and (ii) 30 DAP, Furadan 5 G at 1.0 kg a.i $ha^{-1}$ at planting followed by side dressing of same at 45 DAP, Furadan 35 ST at 0.75 and 1.0 kg a.i./100 kg seed, Furadan 35 ST at 1.0 kg a.i/100 kg seed followed by Furadan 5 G at 1.0 kg a.i. $ha^{-1}$ side dressing at 30 DAP, the unprotected control, and Marshall 25 ST at 0.5 and 1.0 kg a.i./100 kg seed.

Due to poor performance of sole applications of the two seed dressings tested against millet stem borers, other formulations including Apron-plus 50DS, Fernasan D and Miral 3G were compared with soil-applied granular carbofuran. The treatments were: Furadan 5G at 1.0 kg a.i. $ha^{-1}$ at planting followed by side dressing of same at 45 DAP, Apron-plus 50DS (10% metalaxyl, 6% carboxin and 34% furathiocarb) at 5, 10 and 15 g dust $kg^{-1}$ seed, Miral 3G (3% isazophos) at 10, 15 and 20 kg granules $ha^{-1}$, Fernasan D (20% BHC and 25% thiram) at 10 g dust/3 kg seed, and the unprotected control.

Table 1. The effect of 13 insecticide treatments on stem borer infestation and damage and the yield of millet (ex Bornu) at Samaru, 1985.

| Insecticide | % of stems bored | No. of holes $stem^{-1}$ | No. of borers $stem^{-1}$ | Grain yield ($t\ ha^{-1}$) |
|---|---|---|---|---|
| Vetox 85 WP @ 1.7 kg a.i. $ha^{-1}$ | 30.0 | 1.4 | 0.6 | 1.07 |
| Furadan 3G @ 1.0 kg a.i. $ha^{-1}$ at planting | 43.3 | 4.0 | 1.1 | 1.87 |
| Furadan 3G @ 1.0 kg a.i. $ha^{-1}$ at planting + side dressing at 45 DAP | 6.7 | 0.7 | 0.2 | 1.60 |
| Furadan 3G @ 1.0 kg a.i. $ha^{-1}$ Side dressing at 45 DAp | 13.3 | 0.5 | 0.0 | 0.93 |
| Dursban 5G @ 0.5 kg a.i $ha^{-1}$ | 16.7 | 1.6 | 0.8 | 1.33 |
| Dursban 5G @ 0.75 kg a.i. $ha^{-1}$ | 13.3 | 0.3 | 0.1 | 1.07 |
| Dursban 4 ec @ 960 g a.i. $ha^{-1}$ | 16.7 | 1.5 | 0.6 | 1.60 |
| Furadan 35 ST @ 0.75 kg a.i./100 kg seed | 36.7 | 2.4 | 1.0 | 1.20 |
| Furadan 35 ST @ 1.0 kg a.i./100 kg seed | 36.7 | 3.1 | 2.0 | 1.47 |
| Marshall 25 ST @ 0.5 kg a.i./100 kg seed | 33.3 | 1.3 | 1.6 | 1.47 |
| Marshall 25 ST @ 0.75 kg a.i./100 kg seed | 36.7 | 2.8 | 2.2 | 1.73 |
| Marshall 25 ST @ 1.0 kg a.i./100 kg seed | 20.0 | 1.8 | 2.1 | 1.33 |
| Control, no insecticide | 16.7 | 0.8 | 0.1 | 0.93 |
| SED | ±14.80 ns | ±1.50 ns | ±1.20 ns | ±0.50 ns |

ns = Not significant at P<0.05.

## 1988 Experiment

Granular carbofuran was in 1988 compared with Apron-plus 50 DS and Miral 3G and also with Talstar and sequential applications of seed dressings with either granular or foliar insecticides. The treatments were: Furadan 3G at 1.0 kg a.i. $ha^{-1}$ at planting followed by same at 45 DAP, Talstar 10 ec (10% bifenthrin) at 15, 20 and 30 g a.i. $ha^{-1}$ each applied twice at 20 and 35 DAP, Apron-plus 50DS at 10 g dust $kg^{-1}$ seed, Miral 3G at 15 kg granules $ha^{-1}$ at planting, Furadan 35 ST at 1.0 kg a.i. $ha^{-1}$ at 30 DAP, Furadan 35 ST at 1.0 kg a.i./100 kg seed followed by two applications of Talstar 10 ec at 0.03 kg a.i. $ha^{-1}$ at 20 and 35 DAP, Marshall 25 ST at 1.0 kg a.i./100 kg sed followed by two applications of Talstar 10 ec at 0.03 kg a.i. $ha^{-1}$ at 20 and 35 DAP, and the unprotected control.

**Table 2. The effect of eight insecticide treatments on stem borer infestation and damage and the yield of millet (ex Bornu) at Samaru, 1986.**

| Insecticide | % of stems bored | No. of holes $stem^{-1}$ | No. of borers $stem^{-1}$ | Tunnel length | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| Furadan 5G @ 1.0 kg a.i. $ha^{-1}$ at planting | 63.3 | 8.0 | 2.6 | 20.1 | 1.46 |
| Furadan 5G @ 1.0 kg a.i. $ha^{-1}$ at planting + side dressing at 45 DAP | 40.0 | 2.0 | 1.1 | 35.0 | 1.20 |
| Furadan 5G @ 1.0 kg a.i. $ha^{-1}$ at 30 DAP | 53.3 | 4.8 | 1.4 | 20.4 | 1.18 |
| Furadan 35 ST @ 1.0 kg a.i/100 kg seed | 70.0 | 7.1 | 5.6 | 18.7 | 0.52 |
| Furadan 35 ST @ 0.75 kg a.i./100 kg seed | 53.3 | 4.7 | 4.7 | 13.8 | 0.95 |
| Marshal 25 ST @ 0.5 kg a.i./100 kg seed | 66.7 | 6.6 | 1.7 | 12.3 | 0.83 |
| Marshal 25 ST @ 1.0 kg a.i./100 kg seed | 63.3 | 3.8 | 3.6 | 9.5 | 0.85 |
| Furadan 35 ST @ 0.5 kg a.i./100 kg seed + Furadan 5G @ 1.0 kg a.i. $ha^{-1}$ side dressing at 30 DAP | 56.7 | 4.0 | 1.7 | 16.7 | 0.74 |
| Control, no insecticide | 50.0 | 6.4 | 2.3 | 14.7 | 1.14 |
| SED | ±16.12 ns | ±2.03 ns | ±1.59 ns | ±[illegible].25 ns | ±0.21 ns |

ns = Not significant at P<0.05.

## Results

### 1985 Experiment

Stem borer infestations of millet were very low in 1985 (Table 1). Some of the plots were water-logged and plant growth was adversely affected. These two factors made comparison of the performance of the various treatments difficult. However, the level of stem borer infestation and damage was lower in plots in which Furadan granules were applied twice (at planting and at 45 DAP) or as a side dressing at 5% level. Seed treatment chemicals (as others) did not give any appreciable reductions in stem borer infestations and damage although the yields associated with their use were higher (P<0.05) than the control.

## 1986 Experiment

Furadan 5G at 1.0 kg a.i. $ha^{-1}$ followed by a side dressing of the same at 45 DAP gave the best protection against stem borer and higher yields than most other treatments (Table 2). However, these effects were not significant ($P<0.05$). Again, Furadan and Marshall seed treatments failed to give appreciable reductions in stem borer infestation and damage over the control.

## 1987 Experiment

Plant establishment was significantly improved ($P<0.05$) by all the insecticide treatments (except Miral 3G at 20 kg $ha^{-1}$) relative to the control, with Apron-plus 50DS at 5 g dust $kg^{-1}$ seed being the best (Table 3). Heading was significantly earlier ($P<0.001$) in plots treated with Furadan granules or Miral granules than in those treated with Apron-plus 50DS, and significantly later ($P<0.001$) in control plots than in any of the treated plots. Number of holes per stem and number of larvae and pupae per stem were not significantly different among the treatments ($P<0.05$). Percentage of internodes with borer holes was lower ($P<0.01$) in plots treated with Furadan granules, Apron-plus 50DS at 5 g dust $kg^{-1}$ seed or Miral granules than in control plots and higher ($P<0.01$) in plots treated with Apron-plus 50DS at 10 g dust $kg^{-1}$ seed than all other plots. Grain yield was higher ($P<0.05$) in plots treated with granular Furadan or Miral at 15 kg granules $ha^{-1}$ than control plots or plots that received other treatments. Grain yield associated with Apron-plus 50DS at 5 g $kg^{-1}$ seed was only slightly lower than that associated with granular Furadan or Miral (at 15 kg $ha^{-1}$).

Table 3. The efficacy of seed dressing chemicals in controlling stem borer at Samaru, 1987.

| Treatment | Establishment count | Days to 50% heading | No. of holes $stem^{-1}$ | % of internodes with holes[1] | No. of larvae & pupae $stem^{-1}$ | Grain yield ($t\ ha^{-1}$) |
|---|---|---|---|---|---|---|
| Furadan 5G at 1.0 kg a.i. $ha^{-1}$ at planting + 45 DAP | 74.3b | 42.0a | 0.20 | 13.2a | 0.23 | 3.24b |
| Apron plus 50DS at 5 g dust/kg seed | 78.3b | 43.7b | 0.87 | 25.9a | 0.40 | 2.84ab |
| Apron plus 50DS at 10 g dust/kg seed | 76.3b | 44.0b | 2.07 | 60.2c | 0.83 | 2.49a |
| Apron plus 50SD at 15 g dust/kg seed | 73.3b | 43.7b | 1.00 | 39.7b | 0.40 | 2.17a |
| Miral 3G at 10 kg granules $ha^{-1}$ | 72.7b | 42.0a | 0.70 | 25.3a | 0.47 | 2.40b |
| Miral 3G at 15 kg granules $ha^{-1}$ | 72.0b | 42.7a | 1.40 | 30.2a | 0.47 | 3.47b |
| Miral 3G at 20 kg granules $ha^{-1}$ | 70.7a | 42.7a | 0.70 | 27.4a | 0.30 | 2.63a |
| Fernasan D at 10 g dust/3 kg seed | 72.7b | 43.7b | 1.17 | 30.5a | 0.77 | 2.27a |
| Control, no insecticide | 63.3a | 46.7c | 1.03 | 32.3b | 0.70 | 2.44a |
| SED | ±3.6* | ±0.6*** | ±0.53ns | ±8.3** | ±0.33ns | ±0.33* |

[1] Arc sine transformed data
* Significant at $P<0.05$
** Significant at $P<0.01$
*** Significant at $P<.001$
Means followed by the same letter are not significantly different using Duncan's Multiple Range Test.

## 1988 Experiment

All chemicals tested except Talstar at 20 g a.i $ha^{-1}$ gave significant ($P<0.05$) reduction in deadheart symptoms over the control (Table 4). Millet treated with Furadan granules, Apron-plus and Miral 3G attained 50% heading earlier ($P<0.05$) than most other treatments including the control. Talstar - treated plots had very low or no stem borer infestations and relatively higher yield than most other treatments including the control. Seed dressing treatments, whether alone or followed by other chemicals, reduced deadheart symptoms ($P<0.05$) but not other stem borer symptoms over the control.

**Table 4. Chemical control of millet stem borers at Samaru, 1988.**

| | Dead hearts $plot^{-1}$ | Days to 50% heading | Feeding holes per 10 stems | Larvae & pupae/10 stems | 1000 grain weight (g) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| Vitarax 30T at 500 g/100 g seed + Furadan 3G at 1.0 kg $ha^{-1}$ at planting and at 45 DAP[1] | 1.0a | 50.5a | 5.8a | 11.3ab | 8.5ab | 3.80a |
| Furadan 3G at 1.0 kg a.i $ha^{-1}$ at planting and at 45 DAP | 0.3a | 50.0a | 15.0abc | 4.0a | 8.2ab | 2.65a |
| Furadan 35 ST at 1.0 kg a.i./100 kg seed + Furadan 3G (1.0 kg a.i. $ha^{-1}$) at 30 DAP | 0.0a | 52.8abc | 8.5ab | 4.8a | 9.0ab | 2.77a |
| Marshal 25 ST at 1.0 kg a.i./100 kg seed + Furadan 3G (1.0 kg a.i. $ha^{-1}$) at 30 DAP | 1.0a | 54.0bcd | 16.5abc | 14.0ab | 8.9ab | 2.21a |
| Talstar 10 EC at 20 g a.i. $ha^{-1}$ at 20 & 35 DAP | 1.31b | 57.0de | 0.0a | 0.0a | 8.1ab | 2.88a |
| Talstar 10 EC at 30 g a.i. $ha^{-1}$ at 20 & 35 DAP | 0.8a | 58.3e | 0.3a | 0.3ab | 8.8ab | 2.78a |
| Talstar 10 EC at 15 g a.i. $ha^{-1}$ at 20 & 35 DAP | 0.0a | 53.8bc | 0.0a | 0.0a | 8.3ab | 3.73a |
| Furadan 35 ST at 1.0 kg a.i./100 kg seed + Talstar 10 EC at 30 g a.i. $ha^{-1}$ at 20 & 35 DAP | 0.5a | 54.5cd | 37.3bc | 45.0b | 7.5a | 1.72a |
| Marshal 25 ST at 1.0 kg a.i./100 kg seed + Talstar 10 EC at 30 g a.i. $ha^{-1}$ at 20 & 35 DAP | 0.5a | 53.0abc | 22.5abc | 22.5ab | 9.6b | 2.4a |
| Apron plus 50 DS at 10 g dust $kg^{-1}$ seed | 1.0a | 51.3ab | 24.3c | 38.5ab | 8.6ab | 2.63a |
| Miral 3G at 1[illegible] kg granules $ha^{-1}$ | 1.0a | 51.3ab | 16.8abc | 3.0ab | 8.8ab | 2.18a |
| Control, no insecticide | 2.5b | 58.3e | 21.5abc | 29.5ab | 8.0ab | 2.36a |
| SED | ±0.7[illegible] | ±1.57 | ±14.92 | ±19.33 | ±0.95 | ±1.057 |

Means followed by the same letter are not significantly different using Duncan's Multiple Range Test.

## Discussion

Although the results were not always significant, these experiments show consistent reductions in stem borer infestations and damage in millet by two soil applications of Furadan granules at planting and again at 45 days later. In general, most seed dressing chemicals tested, even though they are more readily available and cheaper than other formulations, failed to control stem borer infestations and damage on millet. However, results of the 1987 and 1988 experiment show that Talstar 10 ec, Miral 3G and Apron-plus 50DS are promising alternatives to Furadan granules. Further investigations are required before firm recommendations can be made.

Finally, effective control of millet stem borers may be achieved by adopting an integrated control approach involving not only chemicals but also such practices as sun-drying, composting or destruction of millet stems after harvest (Hill 1975; Adesiyun and Ajayi 1980; Ajayi and Uvah 1988). Ajayi (1985b) found no resistance to the stem borer in the millet varieties he tested but a further search among a wider range of varieties could be fruitful. Meanwhile, cultural practices and chemical control as outlined here should be employed against *H. ignefusalis*.

## References


Adesiyun, A.A., and Ajayi, O. 1980. Control of sorghum stem borer by partial burning of the stalks. Tropical Pest Management 26:113-117.

Ajayi, O. 1985a. A check-list of millet insect pests and their natural enemies in Nigeria. Samaru Miscellaneous Paper 108. 16 pp.

Ajayi, O. 1985b. The effects of planting date and varieties on stem borer infestation and damage of pearl millet. Nigerian Journal of Entomology 6:71-77.

Ajayi, O., and Uvah, I.I. 1988. Review of research on millet entomology in Nigeria - 1977 to 1987. Proceeding of the Regional Pearl Millet Workshop, 14-19, Aug 1988, IAR, Samaru-Zaria, Nigeria, pp. 21-30.

Andrews, D.J., and Kassam, A.H. 1978. Importance of multiple cropping in increasing world food supply. Pages 1-10 *in* Multiple Cropping (Papendick, R.I., Sanchez, P.A., and Triplett, D.B., eds.) Asia Publication 27, Madison, USA.

Anonymous 1985. The production of millet. IAR-AERLS Extension Guide No. 16. AERLS, Zaria, Nigeria, 7 pp.

Egharevba, P.N. 1978. A review of millet work at the Institute for Agricultural Research, Samaru. Samaru Miscellaneous Paper 77. 17 pp.

Egharevba, P.N. 1979. Agronomic practices for improved sorghum and millet production. Samaru Miscellaneous Paper 90. 21 pp.

Hill, D.S. 1975. Agricultural insect pests of the tropics and their control. Cambridge University Press, London. 516 pp.

Williams, L.B., Thakare, R.B., and Halilu, T.W. 1975. Millet benchmark survey, Kano 1975.

# Cinétique de l'Epidémie du Mildiou en Milieu Réel en Fonction des Facteurs de l'Environnement[1]

D.F. M'Baye, ISRA/CNRA[2]

**Abstract**

**The epidemiology of downy mildew as a function of environmental factors:** *The factors influencing the development of downy mildew (DM)* (Sclerospora graminicola *(Sacc.) Schroet.) on pearl millet have been investigated at Bambey, Sénégal, for two seasons in 1986 and 1988. It has been shwon that the infection and distribution of DM depends on the physiological stage of the host plant, environmental factors like relative humidity, and wind direction and on the presence of inoculum at the beginning of the growing season.*

*Les facteurs qui influencent le développement du mildiou* (Sclerospora graminicola *(Sacc) Schroet)ont été étudiés à la station de recherche de Bambey, Sénégal, pendant les saisons pluviales de 1986 et 1988. Les résultats ont montré que l'infestation et la propagation du mildiou dépendent de l'état physiologique de la plante, des facteurs de l'environnement tels que l'humidité relative de l'air, la direction du vent et de la présence d'inoculum au début de la campagne.*

## Introduction

La culture du mil (*Pennisetum glaucum* (L.) R. Br.) est largement pratiquée en Afrique de l'Ouest où elle occupe plus de 13 millions d'hectares (FAO 1980). Cependant, les rendements à l'hectare restent faibles et sont estimés à 660 kg $ha^{-1}$ environ. Un des principaux facteurs responsables de cette situation est la sensibilité des variétés cultivées aux maladies dont la plus importante est le mildiou (*Sclerospora graminicola* (Sacc.) Schroet.).

Cette maladie sévissant partout où le mil est cultivé, cause annuellement des dégâts relativement importants dans la région : 10% au Nigéria, (King and Webster 1970), 0,2-21% au Sénégal, 0,1-6,8% au Niger, 3,25-20,53% au Mali, 0,9-5,8% en Gambie, 1-10% au Burkina Faso (CILSS 1987). En dépit des nombreux travaux faits sur cette maladie, les connaissances sur sa cinétique au champ, à même de permettre de choisir une méthode de lutte adéquate, demeurent limitées.

L'objet de la présente communication est de livrer les résultats de deux années d'expérimentation portant sur la cinétique de l'épidémie du mildiou au champ en relation avec les facteurs de l'environnement.

## Matériel et Méthodes

L'essai a été implanté dans les parcelles d'expérimentation du service de recherche de bioclimatologie de l'Institut Sénégalais de Recherches Agricoles (ISRA) à Bambey où était installée une station météorologique type CIMEL électrique fournissant onze paramètres métérologiques. La variété utilisée est Souna III (en vulgarisation au Sénégal). L'essai a été mené pendant deux campagnes agricoles 1986 et 1988.

Les observations suivantes ont été effectuées : quadrillage de la parcelle en numérotant les plantes; date d'apparition des premiers symptômes; suivi de

1. Présenté à l'Atelier Régional sur l'Amélioration du Mil, ICRISAT Centre Sahélien, 4-7 Sept 1989 Sadoré, Niger.

2. Phytopathologiste, Centre National de Recherches Agronomiques ISRA/CNRA B.P. 53, Bambey, Sénégal

l'évolution de la maladie dans la parcelle par le marquage des plantes malades, tous les deux jours; relevés des différents paramètres climatiques à chaque observation de la maladie.

## Résultats et Discussion

### Campagne 1986

Les premiers symptômes sont apparus 21 jours après la levée (Fig. 1). Ils sont probablement imputables à une infection d'oospores, car pendant cette période, les conditions météorologiques ont été favorables (température moyenne = 24,8 à 34°C, humidité relative 89%, vent calme) (Fig. 2). En effet, les résultats obtenus en laboratoire par Safeuulla (1975) sur la germination des oospores corroborent cette hypothèse.

Par contre, les attaques du 6 Septembre résulteraient probablement d'une infection secondaire qui proviendrait des pieds de mil atteints de mildiou dans les champs avoisinants à la faveur des vents du sud et du sud-ouest, antérieurs à cette date.

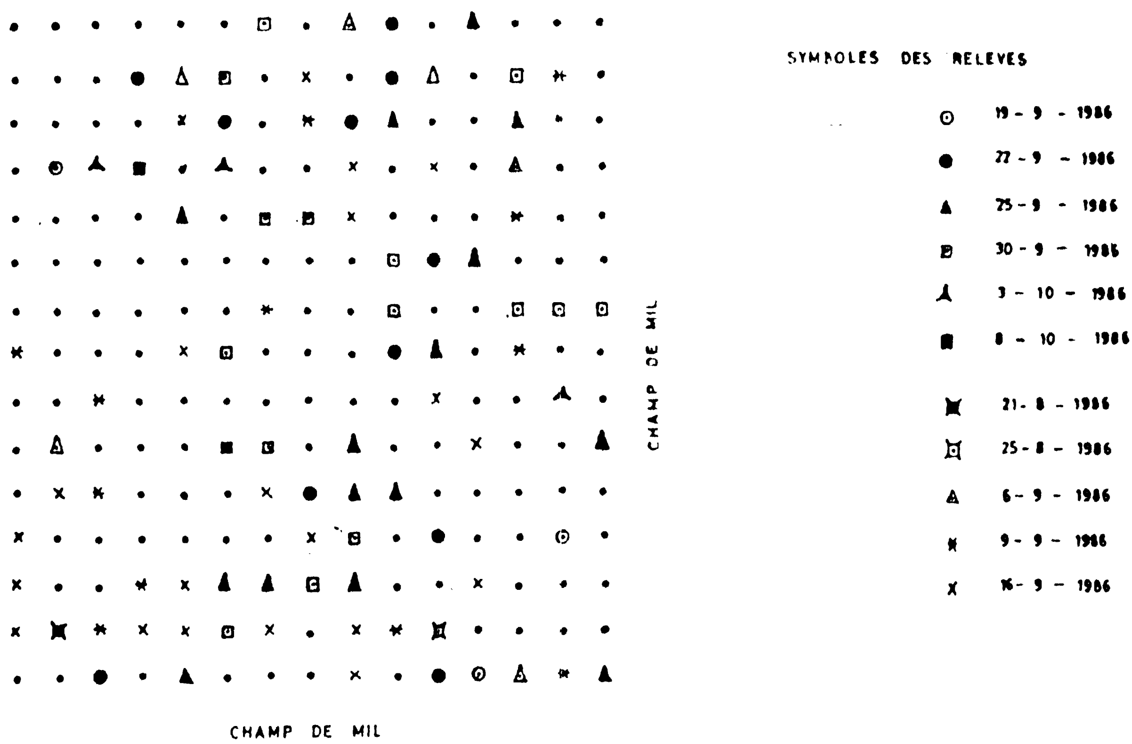



Figure 1. Représentation schématique de l'évolution spacio temporelle du mildiou dans la parcelle d'observation, Bambey, Sénégal, hivernage 1986.

Cependant, l'évolution ultérieure de la maladie semble découler des nouveaux foyers induits par des conditions météorologiques favorables des jours précédents. La cinétique de l'épidémie a continué à progresser autour des foyers existants malgré l'accalmie des vents du 9 au 16 Septembre (Fig. 2). Les pluies presque quotidiennes, la température maximale 33°C, l'humidité relative de l'air presque saturante, sont autant de facteurs qui ont maintenu la pression de la maladie. Le mil est au stade tallage. Pourtant, au-delà du 16 Septembre, l'évolution de la maladie a accusé une forte et brusque dépression bien que les facteurs de l'environnement soient demeurés favorables. Cette baisse de la propagation de la maladie semble être liée au fait qu'en période de pleine montaison, le mil a atteint un stade lui conférant une résistance intrinsèque à la maladie (résistance mécanique et/ou chimique).

A l'issue des relevés effectués les 22, 25 et 30 Septembre, on note une recrudescence de l'épidémie de la maladie. Ce phénomène peut s'expliquer par l'apparition, à la suite des fortes pluies, de talles basales et aériennes formées de jeunes tissus plus sensibles aux attaques de *Sclerospora*.

Les dernières observations des 03 et 08 Octobre ont montré une baisse de pression de la maladie probablement liée, entre autres, à la raréfaction des pluies et à une ascendance des températures.

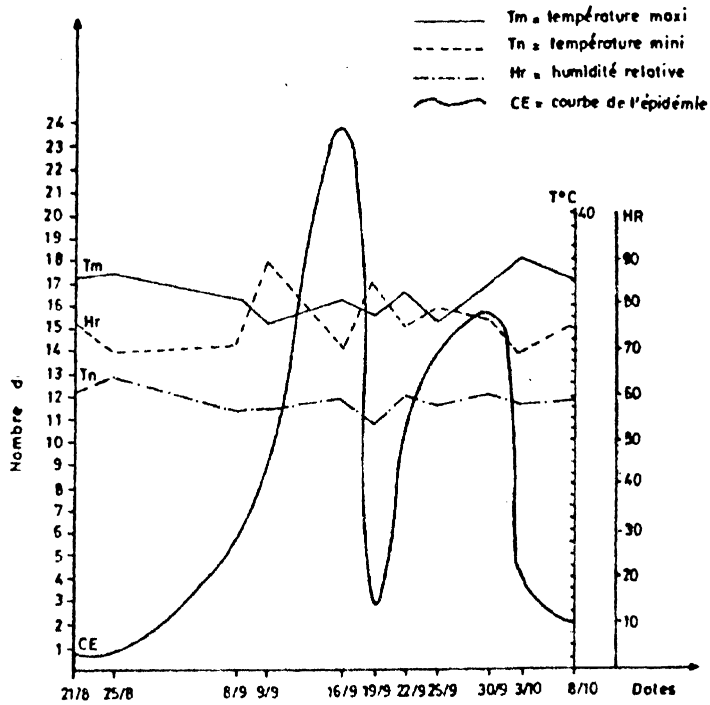



Figure 2. Courbe d'évolution de l'épidémie du mildiou en fonction de la température et de l'humidité, Bambey, Sénégal, hivernage 1986.

Campagne 1988

Les premières attaques ont été observées le 22 Août, au stade "début-tallage" du mil (Fig. 3). Durant les 5 jours qui ont précédé cette observation, les températures minimale et maximale ont varié de 24 à 24,5°C et de 26 à 31,9°C respectivement; les humidités relatives minimale et maximale de l'air ont, quant à elles, varié de 76 à 79 et de 96 à 99%, respectivement (Fig. 4). Ces conditions étaient idéales pour favoriser la sporulation du mildiou. Cependant, deux jours après, on assiste à une chute de l'humidité relative de l'air et à une remontée de la température. Cette péjoration des conditions du mildiou a eu pour conséquence la stagnation de la progression de la maladie et cette tendance s'est maintenue jusqu'au 09 Septembre, période correspondant au stade montaison du mil.

A partir du 10 Septembre, les conditions ci-après ont prévalu : air saturé d'humidité à cause de fortes pluies avant cette date ; vents soufflant dans les directions NW et SW, c'est-à-dire des foyers d'infection (attaques du 22 Août) vers l'intérieur de la parcelle. La maladie a recommencé à se propager dans la parcelle surtout au niveau des talles basales nouvellement formées et les chandelles en initiation.

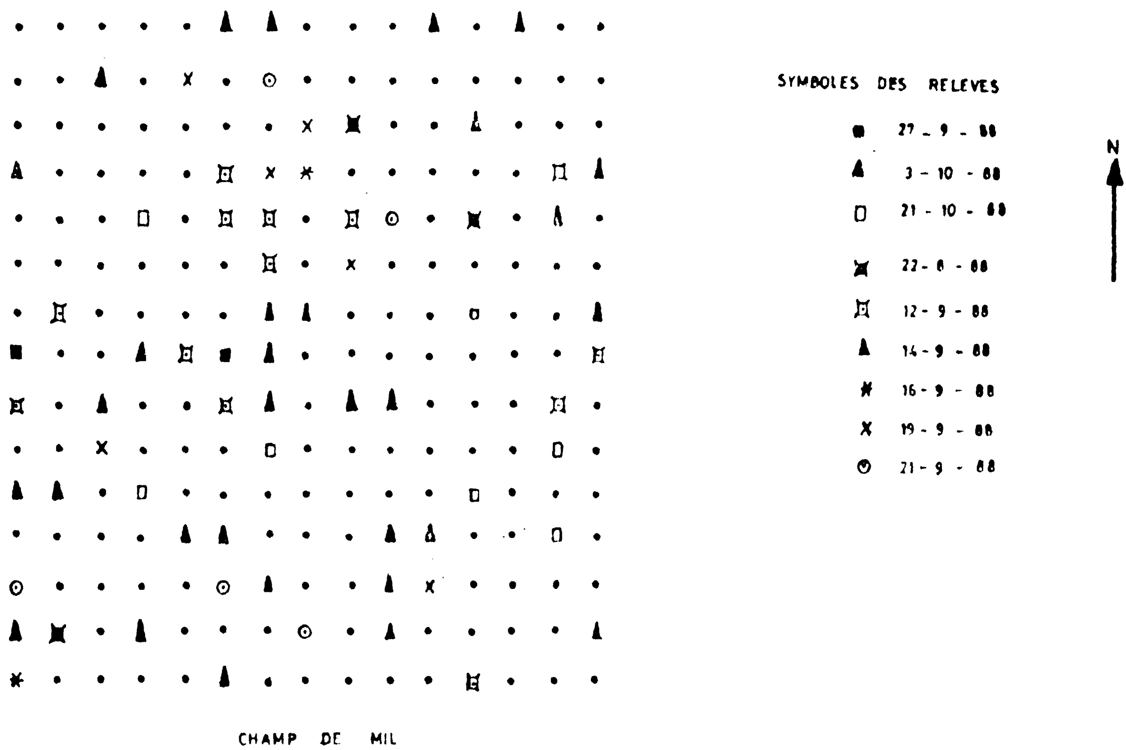



Figure 3. Représentation schématique de l'évolution spacio temporelle du mildiou dans la parcelle d'observation, Bambey, Sénégal, hivernage 1988.

L'arrêt brusque des pluies pendant 10 jours (20-29 Septembre) d'une part et le vieillissement des tissus de l'hôte d'autre part, ont été, sans nul doute, les facteurs inhibiteurs de l'évolution ultérieure de la maladie. En effet, pendant tout ce temps, l'augmentation du nombre de plantes attaquées a été très faible (3 plants).

A partir de cette date jusqu'au stade "grain pâteux" du mil, on assiste à une reprise de propagation de la maladie dans la parcelle. L'émergence tardive de talles aériennes et basales provoquées par les pluies abondantes de fin Septembre, les rosées et les douces températures nocturnes et matinales qui ont prévalu pendant ce temps et l'augmentation progressive de la pression de l'inoculum, sont autant de facteurs qui pourraient expliquer la reprise d'activité de la maladie.

A la maturité du mil, on observe une baisse de pression de la maladie due probablement à la péjoration des conditions climatiques.

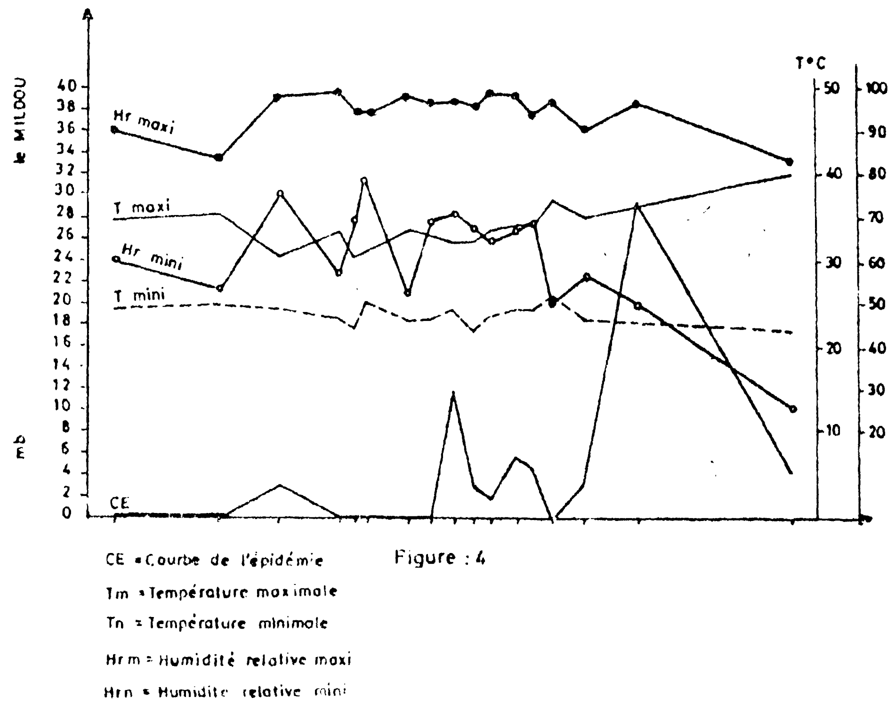



Figure 4. Courbe d'évolution de l'épidémie du mildiou en fonction de la température et de l'humidité, Bambey, Sénégal, hivernage 1988.

## Conclusion et Recommandations

Cette expérimentation portant sur la connaissance de la cinétique de l'épidémie du mildiou en milieu réel, nous a permis de confirmer les résultats obtenus en laboratoire (Mbaye D.F. 1985). En effet, elle nous a montré que l'infection et la propagation du mildiou dépendent, entre autres, de l'état physiologique de la plante (présence ou absence de tissus jeunes), des facteurs de l'environnement tels que l'humidité relative de l'air, la direction du vent, et de l'inoculum (sporulation ou pas, etc).

Par ailleurs, cette expérimentation a permis de révéler que chez le mil, il existe quatre stades, liés à l'apparition de jeunes tissus, pour lesquels il semble plus sensible au mildiou :

1. Apparition du coleoptile
2. Début de formation des talles secondaires
3. Initiation des inflorescences
4. Formation des talles aériennes.

Cependant, seules les attaques intervenant aux 1er et 3ème stades semblent avoir une importance économique car étant capables de péjorer les rendements ; les attaques intervenant aux 2ème et 4ème stades se localisant sur les talles secondaires et aériennes ne présentent que peu d'impact sur le rendement.

Sur la base de ces considérations et des résultats obtenus antérieurement, nous pouvons formuler les premières recommandations suivantes :

o En lutte génétique. Sélectionner des variétés qui ont une bonne rigueur à la levée, tallage et floraison groupés et de courte durée, et peu de talles aériennes.

o En lutte chimique. Protéger la plante aux moments du semis et du tallage-montaison avec un produit systématique.

o En lutte agroculturale. Eviter des retards de semis par rapport aux champs voisins, arracher les plantules précocement attaquées, appliquer judicieusement les engrais qui favorisent la formation importante de matière végétative.

## Bibliographie

CILSS (Comité permanent interétats de lutte contre la sécheresse au Sahel) 1987. Pages 17-29 *in* Recherche et développement de la lutte intégrée contre les principaux ennemis des cultures dans le Sahel. Compte rendu. Réunion technique annuelle des groupes de travail, 2-7 Fév 1987. Banjul, Gambie/Ouagadougou, Burkina Faso. Projet de lutte intégrée.

FAO. 1980. 1979 Production Year books, Rome, Italy: FAO.

King, S.B., and Webster, O.J. 1970. Downy mildew of sorghum in Nigeria. Indian Phytopathology 23:3242-3491.

Mbaye, D.F. 1985. Compte rendu de visite à l'ICRISAT à Hyderabad (Inde) du 18 Jan au 18 Mars 1985. ISRA-CNRA Sénégal: 36 pp.

Safeuulla, K.M. 1970. Investigation on biology and control of downy mildew diseases of sorghum and millets in India. Research Report 1967-1971 (PL 480 Grant FG-In-44). University Mysore, Mysore, India: 37 pp.

# Reaction of *Pennisetum violaceum* to Downy Mildew, Smut, Ergot, and *Striga hermonthica*[1]

J. Werder[2], I. Abdou[3], H. Bissala Yahaya[3], A. Cissé[3] and M. Moussa[3]

**Abstract**

*Sixty-two collections of wild millet (*Pennisetum violaceum*) have been tested for their reaction to downy mildew, smut, and ergot, and 36 collections for the reaction to* Striga hermonthica. *The wild millet tested was collected by ORSTOM in Burkina Faso, Mali, Mauritania, Niger, and Sénégal. Two entries from Sénégal were resistant to downy mildew but all the other collections were highly susceptible. None of the entries was resistant to smut. Four entries were resistant to ergot and two collections were tolerant to* Striga hermonthica *but all the other collections were susceptible.*

**Résumé**

**Réaction du mil sauvage (*Penissetum violaceum*) au mildiou, au charbon, à l'ergot et au *Striga hermonthica*:** *On a testé 62 collections du mil pénicillaire sauvage (*Pennisetum violaceum*) à la réaction du mildiou, du charbon, et de l'ergot et on a testé 36 mils pénicillaires sauvages à la réaction du* Striga hermonthica. *ORSTOM a collecté les mils pénicillaires sauvages, nous avons testé, au Burkina Faso, Mali, Mauritania, Niger, et Sénégal. Deux entrées du Sénégal ont montré une réaction résistante au mildiou. Aucune entrée n'était résistante au charbon, mais quatre collections étaient résistantes à l'ergot. Deux mils sauvages étaient tolérants au* Striga hermonthica *mais tous les autres étaient sensibles.*

## Introduction

Since 1985 scientists of ORSTOM (Institut français de recherche scientifique pour le développement en coopération) have collected 212 accessions of wild millet (*Pennisetum violaceum*) in Burkina Faso, Mali, Sénégal, Niger, Nigeria, Mauritania, Algeria, Tunisia, and Chad (Tostain et al. 1986, Tostain 1986, Tostain et al. 1988, Tostain 1989). The objective of their work is to describe the morphological, agronomical and chemotaxonomical characters of the wild millet species in the Sahel. A selection of these wild millet collections from Burkina Faso, Mali, Niger, Mauritania, and Sénégal have been tested for their reaction to downy mildew (DM) (*Sclerospora graminincola* (Sacc.) Schroet.), smut (*Tolyposporium penicillariae* Bref.), ergot (*Claviceps fusiformis* Loveless) and *Striga hermonthica* (Del.) Benth. The objective of this study was to identify resistance to one of these three fungal pathogens and to *S. hermonthica*. Preliminary results are presented in this paper.

## Material and Methods

Sixty-two collections of *P. violaceum* and 19 millet cultivars (*Pennisetum glaucum* (L.) R. Br.) have been tested for smut, ergot and DM in pots in a 9x9 balanced lattice square with eight replications. Thirty-six collections of *P. violaceum* and 11 millet cultivars were evaluated for *S. hermonthica* reaction in a 7x7 lattice square with eight replications.

For all experiments, pots of 11 liters were filled with 2/3 river sand and 1/3 farmyard manure. Seeds were planted at a depth of 5 cm in the center of each pot and thinned to one plant 21 days after sowing (DAS).

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT Sahelian Center, Niamey, Niger, 4-7 Sep 1989.

2. Millet Pathologist, ICRISAT, Sahelian Center, B.P. 12404, Niamey, Niger.

3. Technicians, ICRISAT, Sahelian Center, B.P. 12404, Niamey, Niger.

For DM-inoculation oospore powder (10 g/pot) from diseased plants of the rainy season 1987 was added together with the seeds into the planting hole. Number of plants with DM-symptoms were recorded 29, 40, and 54 DAS and at 72 DAS; the DM-severity for each plant was also evaluated. Downy mildew severity was based on a 1 to 5 rating scale, where 1 = no DM-symptoms and 5 = symptoms on main stem and tillers so that there were no productive heads. Mean DM-incidence and severity for each observation and entry was calculated.

Entries were inoculated with smut by injecting 3 ml of sporidial suspension with an automatic syringe. An aqueous suspension of sporidia (ca. $10^6$ sporidia $ml^{-1}$) was obtained from 7-day growth culture of *T. penicillariae* incubated at 30° C on potato dextrose agar. After inoculation each panicle was covered with a parchment paper selfing bag. Plants were sprinkler-irrigated daily to maintain high humidity during the period from inoculation to symptom expression. Bags were opened 15-20 days after inoculation. Panicles were scored 25-30 day after inoculation using the standard smut severity scale (Thakur and King 1988a).

**Table 1. Number of plants, downy mildew incidence and severity of selected collections of wild millet and selected entries of pearl millet Sadoré, postrainy season 1988.**

| Collection no./ Test entry | Country | Location | Downy mildew incidence (%)[3] 29 DAS[1] | 40 DAS | 54 DAS | 72 DAS Total plants[2] | DM incidence (%) | DM severity[4] (%) |
|---|---|---|---|---|---|---|---|---|
| Wild millet species | | | | | | | | |
| S-86-84 | Mali | In Ata | 100.0 | 87.5 | 100.0 | 8 | 100.0 | 96.9 |
| S-86-94 | Mali | Eleoudj | 87.5 | 100.0 | 100.0 | 8 | 100.0 | 90.6 |
| S-86-110 | Mali | Tadekamat | 62.5 | 87.5 | 75.0 | 8 | 62.5 | 21.9 |
| S-85-1 | Burkina F. | Oursi | 50.0 | 62.5 | 50.0 | 8 | 75.0 | 31.3 |
| S-85-57 | Niger | Ileghitene | 62.5 | 87.5 | 87.5 | 8 | 100.0 | 50.0 |
| S-87-123 | Niger Aïr | Zilalet | 87.5 | 100.0 | 100.0 | 8 | 100.0 | 96.9 |
| S-87-124 | Niger Aïr | Afagag | 87.5 | 100.0 | 87.5 | 7 | 100.0 | 92.9 |
| S-87-125 | Niger Aïr | Zilalet | 100.0 | 100.0 | 100.0 | 8 | 100.0 | 100.0 |
| S-87-134 | Mauritanie | Gorgol | 12.5 | 25.0 | 50.0 | 7 | 42.9 | 10.7 |
| S-87-135 | Mauritanie | Laqceiba | 25.0 | 37.5 | 75.0 | 8 | 87.5 | 31.3 |
| S-87-139 | Mauritania | Kiffa | 62.5 | 75.0 | 87.5 | 8 | 87.5 | 37.5 |
| S-87-142 | Mauritania | Kankossa | 12.5 | 25.0 | 37.5 | 8 | 25.0 | 6.3 |
| S-87-143 | Mauritania | Karakoro | 37.5 | 37.5 | 37.5 | 6 | 16.7 | 4.2 |
| S-87-146 | Sénégal | Djabouguel | 0.0 | 12.5 | 25.0 | 8 | 0.0 | 0.0 |
| S-87-147 | Sénégal | N'Dyaye | 37.5 | 37.5 | 37.5 | 7 | 28.6 | 7.1 |
| S-87-150 | Sénégal | Thies | 12.5 | 12.5 | 0.0 | 7 | 14.3 | 3.6 |
| S-87-152 | Sénégal | Dakar | 0.0 | 0.0 | 25.0 | 8 | 0.0 | 0.0 |
| Mean[5] (62 entries) | | | 51.2 | 63.1 | 73.0 | 8 | 73.1 | 41.6 |
| Control | | | | | | | | |
| 700651 | (resistant breeding line) | | 0.0 | 0.0 | 12.5 | 8 | 0.0 | 0.0 |
| INMV 8230 | (resistant variety) | | 0.0 | 12.5 | 12.5 | 8 | 12.5 | 3.1 |
| HK Gaya | (local variety) | | 75.0 | 87.5 | 75.0 | 8 | 100.0 | 46.9 |
| CIVT | (improved local variety) | | 37.5 | 50.0 | 37.5 | 7 | 71.4 | 32.1 |
| NHB 3 | (susceptible control) | | 62.5 | 87.5 | 100.0 | 8 | 100.0 | 53.1 |
| 7042 | (susceptible control) | | 87.5 | 100.0 | 100.0 | 8 | 100.0 | 78.1 |
| Trial mean[5] (81 entries) | | | 49.1 | 60.8 | 69.3 | 8 | 70.5 | 39.9 |

1. DAS = days after sowing observations have been taken.
2. Number of plants/pots evaluated at date of observation.
3. Number of plants showing downy mildew symptoms in percentage.
4. Downy mildew (DM) severity based on 1 to 5 rating scale, where 1 = no DM symptoms, and 5 = symptoms on main stems and tillers so that there are no productive heads. Severity is calculated as infection index.
5. Based on mean of eight replications in a 9 x 9 balanced lattice square.

Inoculum for ergot was obtained as a conidial suspension by soaking and agitating infected panicles in water (originated from 1986 rainy-season and stored in the freezer). Panicles were covered with selfing bags at the boot-leaf stage and 3-4 days later the bags were removed and the panicles were spray-inoculated at the maximum fresh-stigma stage and bags were replaced immediately after inoculation. To maintain humidity sprinkler irrigation was used daily until bags were removed 10-15 days after inoculation. Panicles were scored 15-20 days after inoculation using the standard ergot severity scale (Thakur and King 1988b). For statistical analysis data were transformed using arc sine before analysis.

**Table 2. Reaction of selected collections of wild millet and five millet varieties (controls) in pots artificially inoculated with smut and ergot, ISC Sadoré, Niger, rainy season 1988.**

| Collection no./variety | Country | Location | Severity (%)[1] Smut[2] | | Ergot[3] | |
|---|---|---|---|---|---|---|
| **Wild millet species** | | | | | | |
| S-86-82 | Mali | Ganchira | 23.9 | (28.89) | 10.2 | (15.76) |
| S-86-93 | Mali | Telatak | 37.7 | (36.66) | 5.7 | (9.60) |
| S-86-94 | Mali | Eleoudj | 26.3 | (28.90) | 10.2 | (13.05) |
| S-86-102 | Mali | In Deliman | 20.6 | (24.23) | 6.6 | (12.80) |
| S-86-103 | Mali | In Tekenit | 42.8 | (39.42) | 8.2 | (14.61) |
| S-86-108 | Mali | Imenas | 19.3 | (24.65) | 11.5 | (18.75) |
| S-86-111 | Mali | Borari | 31.5 | (31.20) | 18.2 | (14.05) |
| S-87-172 | Mali | Adjindjer | 54.1 | (50.87) | 25.5 | (27.44) |
| S-87-176 | Mali | Assekarai | 42.2 | (39.78) | 22.0 | (24.29) |
| S-85-9 | Burkina Faso | Tin Akof | 33.3 | (34.90) | 15.0 | (18.89) |
| S-85-53 | Niger | Teguidda N | 10.1 | (16.49) | 4.5 | (9.39) |
| S-85-58 | Niger | Timoumenin | 22.5 | (26.60) | 0.1 | (2.64) |
| S-85-60 | Niger | In-Ouagar | 8.1 | (11.71) | 0.5 | (2.51) |
| S-85-65 | Niger | Tiguidit | 55.9 | (50.62) | 20.0 | (20.96) |
| S-87-120 | Niger Air | Aogadot | 9.8 | (31.63) | 4.2 | (8.86) |
| S-87-122 | Niger Air | In Acoulco | 45.0 | (40.20) | 4.1 | (8.07) |
| S-87-134 | Mauritania | Gorgol | 8.8 | (14.83) | 0.7 | (0.64) |
| S-87-135 | Mauritania | Laqceiba | 7.5 | (12.24) | 10.1 | (14.14) |
| S-87-137 | Mauritania | Guerou | 15.5 | (18.91) | 0.9 | (3.11) |
| S-87-142 | Mauritania | Kankossa | 9.9 | (14.47) | 1.8 | (1.99) |
| S-87-143 | Mauritania | Karakoro | 28.4 | (33.20) | 0.7 | (0.64) |
| Mean (62 wild millet species) | | | 25.8 | | 8.1 | |
| **Control** | | | | | | |
| BJ 104 (susceptible hybrid) | | | 59.4 | (50.12) | 42.8 | (39.30) |
| CIVT (local improved variety) | | | 26.5 | (30.20) | 20.0 | (26.82) |
| MBH 110 (susceptible hybrid) | | | 26.2 | (29.35) | 15.7 | (17.42) |
| 3/4 HK (local improved variety) | | | 51.7 | (50.12) | 21.5 | (27.10) |
| NHB 3 (susceptible hybrid) | | | 64.1 | (54.07) | 20.2 | (23.53) |
| SE | | | | (±6.50) | | (±4.83) |
| Trial mean (67 entries) | | | 27.1 | (29.67) | 9.8 | (14.12) |
| CV (%) | | | | (62 %) | | (96 %) |

1. Based on mean of eight replications of two bagged-inoculated panicles each in a 9 x 9 balanced lattice square. Entries with less than four replications are not included in the analysis. Severity based on an 0 to 100% rating scale, where 0 = no symptoms, and 100 = panicle completely covered with smut or ergot.
2. Panicles inoculated with a syringe with 3 ml sporidia suspension of $10^6$ sporidia $ml^{-1}$.
3. Panicles inoculated with a handsprayer of diluted honeydew containing micro- and macrospores.
4. Values in parentheses are arc sine transformations.

For *S. hermonthica* testing, the top 5 cm of each pot was filled with a 5 cm layer of river sand which was mixed with ca. 7,000 seeds of *S. hermonthica* originating from the Gaya area of Niger in the 1986 rainy season. Soil was kept humid by daily sprinkler irrigation and after seven days of irrigation the test entries have been planted. Number of emerged *S. hermonthica* plants were counted 49 DAS in weekly intervals until 139 DAS. Before analysis, a square root transformation was performed on the data.

## Results

Trial mean for DM-incidence of the 62 wild millet collections was 73.1% 72 DAS (Table 1). There were only two entries from Sénégal which did not show any DM-symptoms. However, the remaining wild millet collections were susceptible to DM and many of them had 100% DM-incidence.

None of the entries was resistant to smut and the lowest ratings were on a collection from Laqceiba (Mauritania) with 7.5%, from In-Ouagar (Niger) with 8.1%, and from Gorgol (Mauritania) with 8.8% smut severity (Table 2). Remaining entries showed a smut severity range from 10 to 55.9%. The susceptible control BJ 104 had 59.4% smut severity.

Four entries had a resistant reaction to ergot (Table 2). Wild millet collections were less susceptible to ergot than to smut and the highest reading was on a collection for Niger with 32.2% ergot severity. The susceptible control BJ 104 showed 42.8% severity.

**Table 3. Reaction of selected collections of wild millet pearl millet, and sorghum varieties in pots artificially infested with *Striga hermonthica*, ISC Sadoré, Niger, rainy season 1988.**

| Collection no./variety | | | Number of *Striga* plants per pot[1] | | | | |
|---|---|---|---|---|---|---|---|
| | | | 69 DAS | 85 DAS | 97 DAS | 111 DAS | 125 DAS |
| **Wild millet species** | | | | | | | |
| S-87-121 | Niger Aïr | Ouedigui | 4 (1.6) | 3 (1.6) | 3 (1.4) | 1 (1.0) | 2 (1.1) |
| S-87-122 | Niger Aïr | In Acoulcoul | 2 (1.5) | 3 (1.6) | 2 (1.5) | 2 (1.4) | 1 (1.2) |
| S-87-123 | Niger Aïr | Zilalet | 9 (2.1) | 7 (1.8) | 8 (2.0) | 8 (2.0) | 5 (1.8) |
| S-87-125 | Niger Aïr | Zilalet | 11 (2.8) | 9 (2.4) | 6 (2.0) | 5 (2.0) | 4 (2.0) |
| S-87-129 | Niger Aïr | Badeguicheri | 23 (4.5) | 31 (5.3) | 39 (6.1) | 36 (6.0) | 24 (5.0) |
| S-87-134 | Mauritania | Gorgol | 20 (4.3) | 26 (5.0) | 27 (5.0) | 26 (5.0) | 17 (4.0) |
| S-87-136 | Mauritania | Djouk | 41 (5.7) | 23 (4.6) | 31 (5.5) | 24 (5.0) | 15 (4.0) |
| S-87-141 | Mauritania | Kankossa | 17 (4.0) | 28 (4.9) | 30 (5.2) | 26 (5.0) | 20 (4.3) |
| S-87-143 | Mauritania | Karakoro | 22 (4.6) | 21 (4.5) | 24 (4.9) | 21 (4.5) | 16 (4.0) |
| S-87-152 | Sénégal | Dakar | 21 (4.2) | 25 (4.8) | 26 (4.9) | 23 (4.3) | 12 (3.1) |
| S-87-170 | Mali | Erre | 10 (3.0) | 21 (4.3) | 27 (5.1) | 26 (5.0) | 19 (4.2) |
| S-87-175 | Mali | In Tifinit | 10 (3.0) | 17 (4.0) | 27 (5.0) | 30 (5.0) | 22 (4.2) |
| S-87-176 | Mali | Assekarai | 7 (2.8) | 20 (4.5) | 31 (5.7) | 33 (6.0) | 25 (5.0) |
| Mean (36 entries) | | | 16.5 | 19.0 | 22.7 | 19.2 | 14.2 |
| **Control** | | | | | | | |
| Ex Bornu (local variety) | | | 12 (3.1) | 16 (3.7) | 19 (4.2) | 14 (3.4) | 6 (2.4) |
| Sadoré local (local variety) | | | 11 (3.0) | 10 (3.0) | 14 (3.6) | 12 (3.4) | 10 (3.0) |
| HK Gaya (local variety) | | | 8 (2.7) | 15 (3.7) | 17 (4.1) | 15 (4.0) | 14 (4.0) |
| CIVT (local improved variety) | | | 25 (4.5) | 17 (4.4) | 18 (3.4) | 12 (4.0) | 12 (3.0) |
| SE | | | (±0.6) | (±0.5) | (±0.5) | (±0.5) | (±0.5) |
| Trial mean (49 entries) | | | 14.4 (3.3) | 16.4 (3.7) | 19.4 (4.0) | 16.2 (3.6) | 12.1 (3.1) |
| CV(%) | | | (48) | (39) | (36) | (35) | (42) |

1. Based on mean of eight replications a in 7 x 7 balanced lattice square. Each pot inoculated with 7,000 *Striga* seeds in the top 5 cm layer.
2. DAS = days after sowing.
3. Square root transformation values ( (x+0.5)) are shown in parentheses.

The maximum number of *S. hermonthica* plants were recorded 97 DAS with an average of 23 plants per pot for the wild millets tested and 19 plants for the cultivated millets. Collections S-87-122 and S-87-121 (both from Niger Aïr) had the lowest *S. hermonthica* count 97 DAS with two and three plants per pot. However, most of the other entries had a high infestation rate of 20-38 *S. hermonthica* plants per pot (Table 3).

## Discussion

Most of the wild millet collections tested so far are susceptible to DM, smut, ergot, and *S. hermonthica*. Two collections only from Sénégal have been identified to be resistant to DM but all the other collections are highly susceptible to DM. This is one of the reasons for the high susceptibility to DM of *Shibras* which are spontaneous crosses between wild millet and cultivated millet. It is unlikely that there will be found any useful sources of resistance from wild millet accessions which can be used in breeding program. Moreover, good DM-resistance already exists in improved millet varieties in West Africa.

Four collections had ergot resistance and it would be resting to find out if these resistant reactions are repeatable and stable. Few breeding lines carrying ergot resistance identified at ICRISAT Center in India have a complicated genetically controlled resistance mechanism which is difficult to incorporate into agronomically acceptable varieties. It is possible that the genetical control of ergot resistance in these wild species is simpler and easier to transfer into improved varieties.

There were two collections which showed a tolerant reaction to *S. hermontica* while the other 34 collections were susceptible. It may be expected that wild millet species would be resistant to *S. hermonthica* because so far only in one case *S. hermonthica* has been reported on *P. violaceum* (S. Tostain, personal communication). However, one reason for not finding *S. hermonthica* on *P. violaceum* is that *S. hermonthica* seeds are, as yet, not found in the growing areas where wild millet is found. Therefore, wild millet has never been exposed to *S. hermonthica* in their natural habitat and has not had to adapt to this root parasite like cultivated millet. Therefore, it seems unlikely useful sources of resistance to *S. hermonthica* will be found in the wild millet species.

This year 68 wild millet will be tested from Algeria, Chad, Nigeria, and Sudan for their reaction to the three fungal pathogens and *S. hermonthica*.

## Acknowledgments

The authors wish to thank Serge Tostain and Louis Marchais (ORSTOM, Niamey) for supplying the seeds of the wild millet from their collections.

## References

**Tostain, S.** 1986. Catalogue of the wild millets (*Pennisetum violaceum*) collected through Mali in 1986. (In Fr.) ICRISAT-ORSTOM, Niamey, Niger.

**Tostain, S., Hamon, S., Bernus, E., and Marchais, L.** 1986. Catalogue of the wild millets (*Pennisetum violaceum*) collected through Burkina Faso and Niger in 1985. Institut français de recherche scientifique pour le déloppement en coopération (ORSTOM).

**Tostain, S., Watt, V., Toll, J., and Newby, J.** 1988. Catalogue of the wild millets (*Pennisetum violaceum*) collected in 1987. (In Fr.) IBPGR-ICRISAT-ORSTOM-WWF,/Niamey, Niger.

# Effect of Soil Temperature on Striga *asiatica* on Sorghum and *Striga hermonthica* on Pearl Millet[1]

M. A. Osman[2], J. Werder[3], and J. M. Peacock[4].

**Abstract**

Striga *seed requires a period of preconditioning before it germinates. The length of this period is mainly determined by temperature. Field experiments were conducted in 1988-89 at locations in India and Niger to investigate the effect of soil temperature on* Striga asiatica *and* S. hermonthica. *Soil temperature was varied by plastic covering or hay mulching which gave higher and lower temperatures, respectively, as compared to bare soil (control). Soil temperature under bare soil fluctuated between 36 and 50°C with few days of temperature reaching over 45°C. Under hay mulch, soil temperature rarely exceeded 40°C over the study period. Polythene covers, on the other hand, increased soil temperature by 10°C in 1988 and 5°C in 1989 over the control at all depths measured. The 1988 data showed* Striga asiatica *seeds buried at 2 cm for 34 days in bare soil or hay mulch retained relatively high germination and viability rates. Germination test of 1989 also showed that* Striga hermonthica *seeds buried at 5, 10, 15 and 20 in bare soil was not affected by temperatures recorded at these depths. In contrast, solarization drastically reduced both germination and viability of* Striga *seeds. The solarization effect, however, was restricted to the upper 10 cm as seeds buried below this depth maintained germination rates comparable to those recovered from bare soil or hay mulch. When sorghum was grown in all plots, more* Striga *plants emerged under solarized plots compared to control or hay. These plants were believed to come from lower depths where solarization effects were not detrimental to seeds. This was confirmed by the 1989 data which showed that* Striga *buried below 10 cm under plastic retained high germination rates.*

**Résumé**

**L'effet de la température du sol sur le *Striga asiatica* chez le sorgho et le *Striga hermonthica* chez le mil:** *Les graines de* Striga *ont besoin d'un pre-conditionnement avant de germer. La durée de cette période est déterminée principalement par la température. Des essais aux champs ont été menés en 1988-89 dans des localités en Inde et au Niger en vue d'étudier l'effet de la température du sol sur le* Striga asiatica *et le* Striga hermonthica. *La température du sol était variée à l'aide d'un sac en plastique ou un sol pailleux qui ont respectivement donné une haute et basse température par rapport à un sol dépouillé (contrôle). La température sur un sol dépouillé fluctuait entre 36° et 50°C et atteignait plus de 45°C pendant peu de jours. Sur un sol pailleux, la température avait à peine dépassé 40°C pendant la période d'étude. La couverture de polythène par contre, avait augmenté la température du sol de 10°C en 1988 et de 5°C en 1989 sur toutes les profondeurs mesurées au cours du contrôle. Les données de 1988 ont démontré que les graines de* Striga asiatica *enterrees à 2 cm pendant 34 jours sur un sol dépouillé ou un sol pailleux avait un taux relativement plus elevé de germination et de viabilité. Il a été déduit du test de germination conduit en 1989 que les graines de* Striga hermonthica *enterrées à 5, 10, 15, et 20 cm dans un sol dépouillé n'étaient pas affectées par les températures enregistrées dans ces profondeurs. Par contre, l'effet de l'ensoleillement était limité à un maximum de 10 cm, puisque les semences enterrées en dessous de cette profondeur maintiennent des taux de germination comparables à ceux recouvrés d'un sol dépouillé ou pailleux. Quand le sorgho a été cultivé sur toutes les parcelles, l'émergence des plantes de* Striga *était plus élevée sur des parcelles ensoleillées que sur un sol dépouillé ou pailleux. L'on a pensé que ces plantes ont émergé des profondeurs les plus basses ou l'effet de l'ensoleillement n'était pas nuisible aux semences. Cela a été confirmé par les données de 1989 qui ont démontré que la* Striga *enterré en dessous de 10 cm dans des plastiques retenait des taux de germination élevés.*

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Post-doctoral fellow, ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger.

3. Millet Pathologist, ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger.

4. Principal Sorghum Physiologist, ICRISAT Center, Patancheru, Andhra Pradesh 502 324, India.

## Introduction

In many developing countries of the semi-arid tropics where sorghum (*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum glaucum* (L.) R. Br.) are the main source of food, *Striga* is among the most serious causes of crop loss ( Doggett 1965, and 1984; Parker 1984; Vasudeva Rao et al., 1989). *Striga spp.* that are particularly harmful to sorghum and millet are *S. asiatica* (L.) Kuntze and *S. hermonthica* (Del.) Benth. While efforts to control these parasitic weeds by crop rotation, trap crops and soil fumigation have been successful, they have not been adopted by the resource-poor small farmers because of economic constraints (Bebawi 1981; and Ogborn 1972). Use of resistant cultivars has been recommended as a more appropriate alternative means of reducing *Striga* incidence. However, the selection for *Striga* resistant crops has been difficult and very slow due to lack of uniformity in *Striga* infestation in experimental plots and seasonal variation of *Striga* population (Vasudeva Rao et al. 1989).

*Striga* seeds undergo long periods of dormancy and will not germinate until exposed to a period of warm moist condition after which the seeds become responsive to stimulants produced by the host root system (Kust 1963; Musselman 1980). The length of this dormancy period (preconditioning) is determined mainly by soil temperature. Kust (1963) reported that *S. asiatica* seeds stored at 31, 24 and 4°C became responsive to a stimulant produced by corn (*Zea mays* L.) and had the highest germination rates after 6, 24, and 32 weeks, respectively. When these seeds were stored at 31°C and 100% relative humidity, both germination and viability were drastically reduced. Most infested soils often contain a large reservoir of *Striga* seeds which are distributed in the soil profile. Response of these seeds to prevailing climatic factors has not been studied under field conditions. The present study attempts to look at the effect of soil temperature on *Striga* seeds buried in the soil.

## Materials and Methods

Two field experiments were conducted on *S. asiatica* in ICRISAT, India, in 1988 and on *S. hermonthica* in ICRISAT Sahelian Center, Niger, in 1989. The experiments were conducted in *Striga*-sick fields. The details are given below.

### Preconditioning *Striga* seeds

*Striga* seeds, having 80-95% germinability, were artificially sown in *Striga*-sick fields and mixed into top 20-25 cm soil. Small samples of the same seeds were put in 5 x 3 cm nylon bags, tied with 20 cm long retrieval string wires, and buried at 2 cm soil depth in 1989 and at 5, 10, 15 and 20 cm in 1989 so these seeds would be preconditioned in their natural habitat. These nylon bags were resistant to degradation by soil microbes but allowed free passage of soil solutions to the seeds. Plots sizes used in 1988 were 4 x 1.2 m and 8 x 1.25 m in 1989.

Soil temperature was increased by polythene sheets (solarization) and decreased by hay giving high and medium temperature, respectively, compared to bare soil (control). In 1988, clear polythene and hay mulch were used whereas in 1989, black polythene sheets and no hay mulching were used. The polythene sheets were laid on pre-irrigated, well tilled bare soil, spread close to the ground and their edges firmly anchored in the soil to prevent heat loss and wind disturbance. Hay mulch consisted of a 5 cm thick layer of grass strapped to the surface of the soil using bamboo sticks and jute strings.

Soil temperatures were monitored in two replications using copper-constantine thermocouples buried at 2 and 10 (1988) and at 5, 10, 15 and 20 cm (1989). Soil temperatures measured at 2 h intervals were automatically recorded by a field micrologger.

Factorial experiments in a randomized complete block design were used in both years. In the 1988 trial, however, only four replications were used while in 1989 the trial consisted of ten replications to increase the degrees of freedom and thus validity of experiment.

### *Striga* seed germination and viability tests

Nylon bags containing *Striga* seeds were retrieved from the soil after [illegible] and 25 days in 1988 and 1989, respectively. Plots were immediately sown with sorghum (1988) or pearl millet (1989) to monitor emergence of *Striga asiatica* and *S. hermonthica*, respectively. Exhumed *Striga* seeds were tested for germinability in both years while viability test was conducted only in 1988.

Field preconditioned seeds were surface sterilized with a 1% NaOCl solution for five min, rinsed with distilled water until the chlorine odor disappeared and air dried for 4 - 5 h. About 50-100 air dried seeds were sprinkled on a small glass fiber filter paper discs (7 mm in diameter) using the procedure described by Vasudeva Rao (1985). These discs were replicated four times within each petri dish.

In 1988 trial, *Striga* seeds were germinated with root exudate that was obtained by growing a *Striga*-susceptible sorghum genotype (CSH-1) seedlings in prewashed and heat-sterilized quartz sand. Stimulant was extracted by using the "double pot technique" developed by Parker, Hitcock and Ramaiah (1977). In 1989 trial, however, 0.2 ppm of GR24 (a synthetic compound that promotes *Striga* germination) solution was used to induce *Striga* seed germination.

Thirty microliters of freshly extracted sorghum root exudate or the GR24 solution were applied on each disc. Discs were then placed in petri dishes and incubated in dark at 30°C for 24 h. At the end of the incubation period, the number of germinated *Striga* seeds per disc were recorded as a percentage of the total number of seeds on that disc. Radicle exertion (0.1-0.2 mm) was used as a criteria for *Striga* germination.

The procedure used for viability test was identical to that described for germination test with the exception that each disc was moistened with 25 ul of triphenyl tetrazolium chloride (TR) solution prepared as described by Kust (1963). Seeds were incubated in darkness as described for germination. Counts of viable seeds were made at the end of the incubation period. According to Kust (1963) viable seeds varied from light red to brick-red in color while non-viable seeds remained light brown. Because of the tiny size of *Striga* seeds, this procedure was not adequate to give reliable counts. Therefore, seeds were squeezed with forceps and, according to the color of the semi-liquid material that oozed out, seeds were scored viable if reddish-brown and non-viable if colorless.

In both germination and viability tests where counts were recorded as percentages, the data were arcsine transformed to obtain a valid analysis of variance.

### Tests for *Striga* emergence

Following the termination of temperature treatments, all plots were hand sown with susceptible sorghum (CSH1) or pearl millet (Sadore Local). These were used to induce *S. asiatica* and *S. hermonthica* emergence, respectively. The sorghum was planted in 4 rows 30 cm apart and 4 m long. Plots were thinned after seedling establishment leaving 10 cm between plants. *Striga* counts were made on the inner two rows. Pearl millet used in 1989, however, was grown on 80 x 80 cm hills. Thus, the plots size was 3 x 11 hills.

*S. hermonthica* has not emerged yet so data from the 1988 trial on *S. asiatica* are discussed in this paper. In 1988, *Striga* plants started to emerge about 35-40 days after sowing the host crop (sorghum). Counts were made weeks after the emergence of the first *Striga* plants and at weekly interval thereafter. Total number of *Striga* plants that emerged in each plot during the study period was counted to give an estimate of the parasite infestation.

## Results

### Soil temperature

Maximum soil temperatures recorded at different depths were reached daily at about 1500h. Maximum temperature at 1500h decreased with soil depth in most instances (Tables 1 & 2). Polythene covers always markedly increased soil temperatures at all depths as compared to bare soil, whereas hay mulch markedly decreased soil temperature (Table 1). On average, plastic sheeting increased soil temperature by 10°C over bare soil in 1988 while average increase was around 5°C in 1989 (Table 1 and 2). These results are in agreement with other studies (Horowitz et al. 1983) where black polythene (as used in our study in 1989) was observed to be less efficient than clear polythene in raising soil temperature. Under solarization treatments, soil temperatures exceeded 45°C most of the time in all depths measured in 1988. However, such high-temperature days which are regarded lethal to many soil organisms, like seeds, (Horowitz et al. 1983; Chauhan et al. 1988), were observed only at 5 cm depth of bare soil. Moreover, under hay mulch, soil temperature hardly reached 40°C (Table 1). Data from 1989 showed similar trend in soil temperature (Table 2). Under the polythene, soil temperature was never below 40°C at any depth. Such temperature extremes were fewer under bare soil and were never observed below 10 cm soil depth.

**Table 1. Maximum daily soil temperature recorded at 2 and 10 cm from surfaces of soils covered with polythene or hay and bare soil, ICRISAT Center, rainy season 1988.**

| Soil-ment | Soil depth (cm) | Soil temp. (°C) | | Number of days | |
|---|---|---|---|---|---|
| | | Range | Mean | >40°C | >45°C |
| Polythene | 2 | 62-55 | 58.9 | 34 | 34 |
| Bare soil | 2 | 53-36 | 47.2 | 33 | 25 |
| hay | 2 | 49-33 | 38.8 | 8 | 1 |
| Polythene | 10 | 53-43 | 49.6 | 34 | 32 |
| Bare soil | 10 | 41-34 | 38.1 | 0 | 0 |
| Hay | 10 | 39-29 | 32.6 | 0 | 0 |

### Effect of temperature on *Striga* seed germination and viability

The effects of soil temperature on *Striga* germination and viability for the 1988 trial are shown in Table 3. These results show that *Striga* germination and viability rates were not affected by the different soil temperatures experienced under bare soil or hay mulch. Under these treatments about 75% of the seeds germinated in the laboratory and 87% of them were viable. In contrast, *Striga* seeds exposed to solarization (polythene), with its associated effects such as high temperature (59 °C) and humidity , did not germinate and were non-viable after 34 days of pretreatment in the field. Because some studies (Vallance 1950) indicate that *Striga* seeds stored in hot humid conditions may under go a 'wet dormancy' state and such seeds respond to germination stimulants if dried, several viability tests were conducted on the same seeds (after allowing them to dry at room temperature for several months) recovered from the soil. These tests excluded the possibility of 'wet dormancy' being important within case since viability of *Striga* seeds remained the same.

**Table 2. Maximum daily soil temperature recorded at 5, 10, 15 and 20 cm from surfaces of soils covered with polythene and bare soil, ICRISAT Sahelian Center, rainy season 1989.**

| Soil treat-ment | Soil depth (cm) | Soil temp. (°C) | | Number of days | |
|---|---|---|---|---|---|
| | | Range | Mean | >40°C | >45°C |
| Polythene | 5 | 40-53 | 46.9 | 25 | 21 |
| Bare soil | 5 | 36-50 | 42.9 | 21 | 12 |
| Polythene | 10 | 39-49 | 44.2 | 24 | 12 |
| Bare soil | 10 | 35-42 | 38.6 | 6 | 0 |
| Polythene | 15 | 38-47 | 42.3 | 23 | 6 |
| Bare soil | 15 | 34-42 | 37.7 | 4 | 0 |
| Polythene | 20 | 37-42 | 40.1 | 14 | 0 |
| Bare soil | 20 | 33-40 | 36.6 | 1 | 0 |

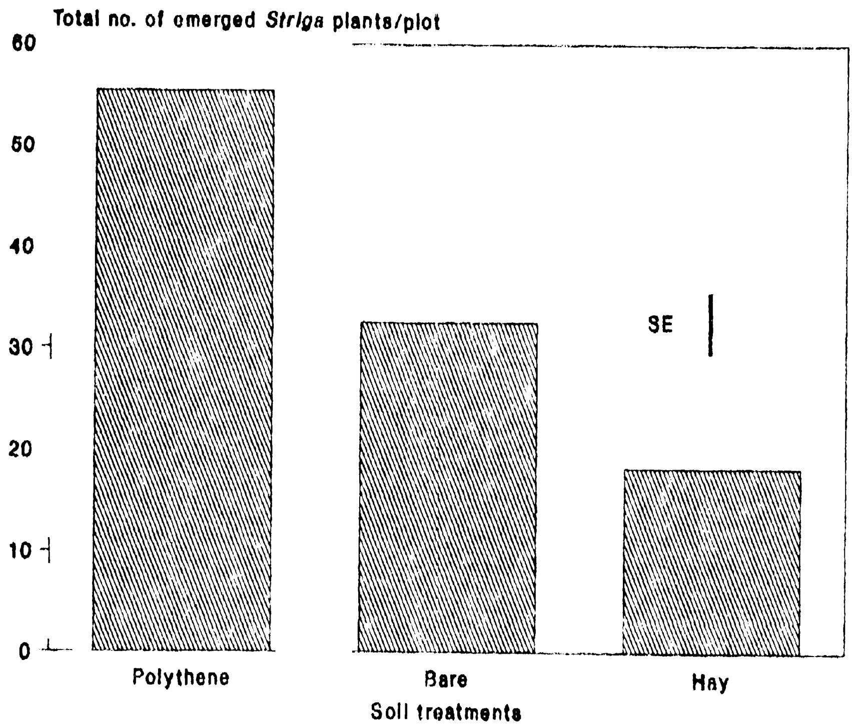



Figure 1. Total number of *Striga asiatica* plants ermerged in soils previously exposed to different temperatures as achieved by polythene, hay mulch, and bare soil treatments, ICRISAT Center, India, rainy season 1988.

The 1989 germination results are shown in Figure 2. Under the bare soil (control), *Striga* germination rate ranged from 65 to 70%, regardless of burial depth or soil temperature. These results essentially agree with those of 1988. The heating effect from solarization decreased with soil depth but significant reduction in seed germination was not apparent below 10 cm. Less than 3% of the *Striga* seeds buried at 5 cm germinated after 25 days when soil temperature exceeded 45°C (Fig. 2 and Table 2).

### *Striga* emergence

Soil temperature had also a significant ($P<0.01$) effect on *Striga* emergence. The results from 1988 trial show that about 55, 31, and 15 plants per plot emerged in the polythene, bare and hay mulch treatments, respectively (Fig. 1).

**Table 3. Germination and viability of *Striga asiatica* seeds in response to different soil temperatures, obtained under polythene, hay and bare soil treatments, ICRISAT Center, rainy season 1988.**

| Soil treatment | Germination[1] (%) | Viability (%) |
|---|---|---|
| Polythene | 0.0 (0.0)[2] | 0.0 (0.0) |
| Bare soil | 74.1 (60.1) | 87.8 (69.9) |
| hay | 73.5 (73.5) | 87.1 (69.0) |
| SE | ±1.54 | ±1.75 |
| CV (%) | 5.5 | 5.3 |

1. *Striga* seeds were buried at 2 cm soil depth for 34 days.
2. Arcsine transformed data are shown in parentheses.

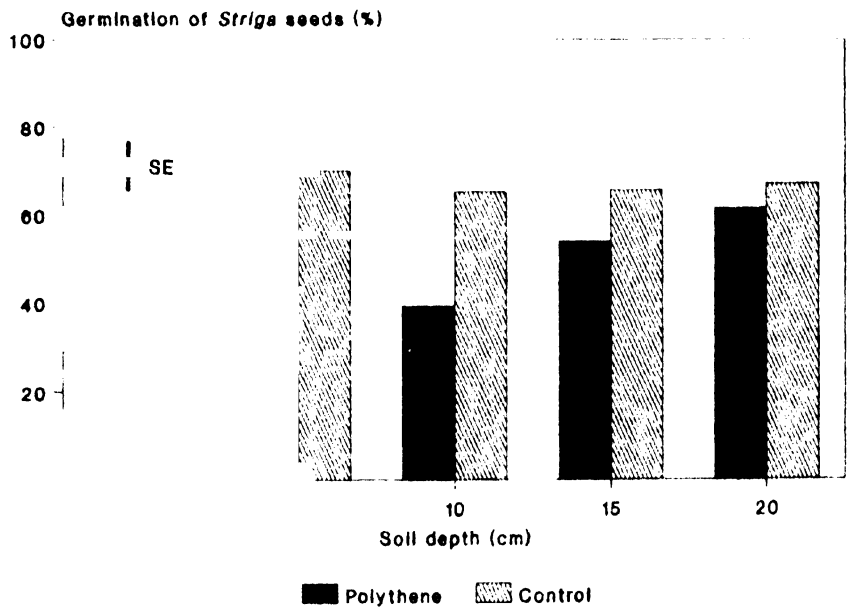



Figure 2. Germination of *Striga hermonthica* seeds in responsed to soil pre-treatment and burial depths, ICRISAT Sahelian Center, rainy season 1989.

## Discussion and conclusion

In general, *Striga* seeds buried up to 5 cm below the soil surface in the polythene treatment neither germinated nor were they viable. At this depth, mean maximum daily soil temperature often exceeded 50°C most of the time and the soil was always moist as a result of water vapor condensing on the polythene cover and precipitating on the soil surface. High soil moistures increase soil heat conductivity and seed sensitivity to high temperatures (Horowitz et al. 1983). Kust (1963) reported that prolonged storage of *Striga* seeds under hot humid conditions, similar to those observed under the polythene, reduced seed viability. Similar effects of solar heating (solarization) were observed for many soilborne pests (Jacobsohn et al. 1980; Katan 1981; Horowitz et al. 1983 and Chauhan et al 1988). It appears that under such a situation the time needed for germination induction is shortened probably due to a rapid activation of some respiratory enzymes or mobilization of reserve foods which may be exhausted in time, thus rendering the seed non-viable (Kust 1963; and Vallance 1951).

The 1988 data showed that more *Striga* plants emerged in the polythene treated plots compared to hay and bare soil pretreatments. Since the experiments were conducted in a *Striga*-sick field, which was the ploughed under, a large quantity of *Striga* seed reservoir was expected to exist and incorporated in the soil profile. Because soil solarization is usually limited to <10 cm depth , where temperatures reach lethal levels (Horowitz et al. 1983), most *Striga* seeds buried at deeper layers may escape the solarization effect. This hypothesis was tested in 1989 by burying the seeds at different depths. As indicated by the germination results, there is strong evidence that the observed *Striga* plants in these plots came from depths lower than 10 cm, where conditions were not detrimental to the seeds.

It appears, therefore, that *Striga* will germinate and may emerge from host root zone as long as (a) dormancy is broken and seeds are sufficiently preconditioned to become responsive to the host stimulant, (b) active host roots capable of producing enough exudate to induce germination are available, and (c) the growth and development of neither host nor parasite are interrupted during this period. In this context, therefore, *Striga* control practices involving treatments of top soil surfaces only, may not be effective.

Our study indicates that although soil temperature has large influences on *Striga* behavior, it is not the only one controlling its incidence. Other factors which may play a major role include soil moisture, distribution of seeds in soil profile, host root system etc. An understanding of the individual or combined effects of these factors on *Striga* life cycle is, therefore, required.

## Acknowledgment

The authors acknowledge and thank the International Development Research Centre (IDRC), Ottowa, Canada, who funded this research.

## References

**Bebawi**, F. F. 1981. Response of sorghum cultivars and *Striga* population to nitrogen fertilization. Plant and Soil 59:261-267.

**Chauhan**, Y.S., **Nene**, Y.L, **Johansen** C., **Haware**, M.P, **Saxena** N.P., **Sardar Singh**, **Sharma**, S.B., **Sahrawat**, K.1., **Burford**, K.R., **Rupela**, O.P., **Kumar Rao**, J.V.K.D, and **Sithanantham**, S. 1988. Effect of soil solarization on pigeonpea and chickpea. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Research Bulletin No. 11.

**Doggett**, H., 1965. Striga *hermonthica* on sorghum in East Africa. Journal of Agricultural Science 65:183-194.

**Doggett**, H. 1984. *Striga*-its biology and control: an overview. Pages 27-36 *in Striga* biology and control (Ayensu, E.S., Doggett, H., Keynes, R.H., Morton-Lefvre, J., Musselman, L.J., Parker, C., and Pickering, A., eds.) Paris: International Council of Scientific Unions Press.

Horowitz, M., Regev, Y., and Herzilinger, G. 1983. Solarization for weed control. Weed Science 31:170-179.

Jacobsohn, R., Greenberger, A., Katan, J., Levi, M., and Alon, H. 1980. Control of Egyptian broomrape (*Orobanche aegyptiaca*) and other weeds by means of solar heating of the soil by polythene mulching. Weed Science 28:312-316.

Katan, J. 1981. Solar heating (solarization) of soil for control of soilborne pests. Annual Review of Phytopathology 19:211-236.

Kust, C. 1963. Dormancy and viability of witchweed seeds as affected by temperature and relative humidity during storage. Weed Science 11:247-250.

…lman, L.J. 1980. The biology of *Striga*, *Orobanche* and other root parasitic weeds. Annual Review of Phytopathology 18:463-489.

Ogborn, J.E.A. 1972. Significance of seasonal pattern of emergence of *Striga hermonthica* Benth. Pages 562-571 *in* Sorghum in the Seventies (Rao, N.G.P., and House, L.R. eds.) New Delhi, India: Oxford and IBH Publ. Co.

Parker, C. 1984. The influence of *Striga* on sorghum under varying nitrogen fertilization. Pages 90-98 *in* Proceedings of 3rd International Symposium on Parasitic Weeds. Alleppo, Syria: International Center for Agricultural Research for Dry Areas (ICARDA).

Parker, C., Hitchcock, A.M., and Ramaiah, K.V. 1977. The germination of *Striga* species by crop root exudates. Techniques for selecting resistant crop cultivars. Pages 67-74 *in* Proceedings of Sixth Asian-Pacific Weed Science Society Conference Vol. I. Jakarta, Indonesia: Asian-Pacific Weed Science Society.

Vallance, K.B. 1950. Studies on the germination of the seeds of Striga *hermonthica* I. The influence of moisture-temperature, stimulant-dilution and after-ripening on germination. Annals of Botany 14:347-363.

Vallance, K.B. 1951. Studies on the germination of the seeds of Striga *hermonthica*. II. The effects of the stimulating solution on seed respiration. Journal of Experimental Botany 2:31-40.

Vasudeva Rao, M.J. 1985. Techniques for Screening for Sorghum Resistance to *Striga*. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Information Bulletin No. 20.

Vasudeva Rao, M.J., Chidley, V.L., and House L.R. 1989. Estimates of grain yield losses caused in sorghum (*Sorghum bicolor* L. Moench) by Striga *asiatica* (L.) Kuntze obtained using regression approach. Agricultural Ecosystems and Environment 25:139-149.

# AGRONOMIC FACTORS AFFECTING PRODUCTION

# Organic Recycling of Crop Residue and Fertilizer Use for Pearl Millet Production on the Sandy Soils of Niger[1]

Bationo[2], A., Christianson[3], B. C., and Mokwunye[4], A.U.

**Abstract**

*Traditionally, soil fertility in West Africa has been maintained through shifting cultivation and farmers abandoned the land to fallow as productivity declined. Use of mineral fertilizer can extend the soil productivity for a significant period but with the removal of crop residue yields will ultimately decline. Addition of crop residue can delay this soil degradation resulting in more stable cereal production. Although the effect of crop residue on millet was very pronounced, many farmers use the majority of their crop residue as fuel, animal feed or housing and fencing material, and little is left to return to the land. Use of fertilizers allows the farmer to increase the stover amounts at the farm level. This supplies him with enough crop residue to meet present needs and still leave sufficient straw to improve the productivity of his soil.*

*Traditionnellement, la fertilité du sol était maintenue à travers la divagation des cultures et les paysans mettaient les terres en jâchère au fur et à mesure que leur productivité se dégradait. L'utilisation de l'engrais minéral peut prolonger la productivité du sol pendant une période considérable, mais avec l'enlèvement des résidues de culture, le rendement sera certainement réduit. Une augmentation de residues de culture peut retarder cette dégradation du sol occasionnant ainsi une production de céréale beaucoup plus stable. Bien que l'effet des résidues de culture sur le mil était très remarquable, beaucoup de paysans utilisent leurs résidues de culture pour faire du feu, nourrir leurs animaux, faire des cases ou pour clôturer leur maison, laissant ainsi une quantité très négligeable au champ. L'utilisation de l'engrais permet aux paysans d'accroître la quantité du fourrage au champ et celà leurs fourni suffisamment de résidues de culture pour faire face non seuleument à leur besoin ponctuel, mais aussi assez de réserve de paille pour améliorer la productivité de leur sol.*

## Introduction

Climate in the major agricultural zone of Niger is characterized by low rainfall (400-600 mm) of great variability in total amount and distribution (Sivakumar 1986). In addition, high temperatures and sandy soils of low native fertility limit agricultural production capacity. In this region, pearl millet (*Pennisetum glaucum* (L.) R. Br.) is the most commonly grown crop making up 90% of the cropped area, though yields are typically very low (270kg $ha^{-1}$; IRAT 1974). Due to a rapidly expanding population in this region, food production must be increased in a sustainable manner to meet the projected nutritional requirements of the people (Pieri 1986). Though a significant increase in total production can be achieved through extension of current agricultural practices into marginal areas, the majority of the additional food must be the result of higher yields on existing farms. Techniques developed to achieve these goals must be adapted to the very limited resource base of the average farmer within the region if they are to have a significant impact on total food production. Within this constraint, fertilizers have a significant role to play (IRAT 1975).

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.
2. Soil Scientist, IFDC/ICRISAT. BP 12.404 Niamey, Niamey
3. Soil Scientist, IFDC Agronomic Division. PO Box 2040 Muscle Shoals, Alabama 35662
4. Soil Scientist and Agronomic Research Coordinator IFDC-Africa. BP 4483. Lomé, Togo.

Phosphorus (P) is frequently observed as being the nutrient most severely limiting yield in this region (Pichot et al. 1979) though those needs can be met by relatively low rates of fertilizer. In the presence of adequate P, a significant response to nitrogen (N) is found only in years of adequate rainfall (Pieri 1973; Christianson et al. 1989). Yield response to potassium is generally weak though its use may improve vigor of young plants (Pieri 1986).

Traditionally, soil fertility in West Africa has been maintained through shifting cultivation, and farmers abandoned land to fallow as productivity declined. Typically, it required at least seven years for land to be returned to original fertility levels (Charreau 1972). However, increasing population pressure has shorten the fallow period in many areas. Despite generally low nutrient levels in Sahelian soils, millet roots explore a large volume of soil (Chopart 1983) and are thus available to concentrate significant amounts of these nutrients in the plant tissue.

Total amount of N and P in the millet plant is apportioned approximately equal among the grain and stover fractions. However, the majority of the K (92%), calcium (Ca) (97%) magnesium (Mg) (90%) and sulphur (S) (75%) remain in the stover after harvest (Balasubramanian and Nnadi 1980) and represent a significant nutrient reserve for the subsequent crop, if the stover is returned to the soil. Conversely, removal of this dry matter can result in rapid degradation of the soil and significant yield depression (Pichot et al. 1981). Use of mineral fertilizer can extend soil productivity for a significant period even if residues are removed, though yields will ultimately be expected to decline as micronutrient levels become depleted. Return of crop residue can delay this soil degradation resulting in more stable cereal production.

Studies of millet production have shown a significant correlation between stover removal and declining grain yields due to nutrient loss (Diaye 1978). However, straw decomposition is very rapid in this region and, in the absence of mineral fertilizer, incorporation of millet compost was shown to decrease soil organic carbon levels by stimulating native organic matter mineralization (Feller and Ganry 1982). In addition, straw tends to be relatively deficient in N and therefore its incorporation into the soil can significantly depress millet yields due to immobilization of soil N (Ganry et al. 1973; Traoré 1974).

Traditionally, very little stover has been used in maintenance of soil fertility in the Sahel. The problem is not one of stover quality but rather availability (Pieri 1985). In the millet-producing zones, the amount of millet straw available for recycling can be very limited (Allan et al. 1983). Trees are generally not plentiful and straw is used as fuel and building material as well as a source of animal feed. Though some of the nutrients may be returned to the soil as manure and thus remain in the fields when the stover is consumed as feed (Quilfen and Milleville 1983), animals tend to be kept near the village. As a result, soil fertility tends to decline as distance from the village increases (Balasubramanian and Nnadi 1980). Also, straw used as fuel is burned in the village and any ash that is put back into the soil is generally placed in those fields closest to the village.

The objective of this experiment was to assess the effects of fertilizer use and crop residue management on the production of millet in Niger.

## Materials and Methods

### Site description

A long-term field study was initiated in 1983 40 km SE of Niamey, Niger, at Sadoré, the site of the Sahelian Center of the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Soils of the experimental site were derived from eolian sand deposits and the 0-15 cm soil layer had 940 g $kg^{-1}$ clay with a CEC of 0.9-1.0 cmol(+) $kg^{-1}$ and organic matter (OM) of 0.2%. By the USDA classification system, this was a sandy Psammentic Paleustalf: sandy siliceous isohyperthermic (West et al. 1984). Long term average rainfall in Niamey is 560 mm and the average temperatures 29°C (Sivakumar 1986).

## Experimental design

The trial was a randomized complete block design containing four treatments with four replicates. Treatments consisted of 1) control (no fertilizer or crop residue); 2) fertilizer only (30 kg $P_2O_5$ $ha^{-1}$ as single superphosphate, 30 kg N $ha^{-1}$ as urea, and 30 kg $K_2O$ $ha^{-1}$ as KCl); 3) crop residue (CR) only (no fertilizer); and 4) crop residue plus fertilizer (CRF--combination of treatments 2 and 3).

Fertilizers were surface applied and incorporated by tractor-drawn disks (1983-84) or by hand rake (1985-86). In the first year of the trial, crop residue was applied to the CR and CRF plots at 4 tons $ha^{-1}$ as chopped (15 cm length) pearl millet two weeks before planting. In subsequent years, the straw produced on each CR or CRF plot was returned to that plot and no attempt was made to equalize the total amount of straw applied to each of the plots within a treatment. After grain harvest, stover was left standing until early May when it was cut down and left on the soil surface. In order to simulate the local farmers' practice of residue removal, standing stover was cut down in November and removed from the fertilizer only and control plots. No attempt was made to remove any root material.

Individual plots were 10 x 10 m separated by a 1 mm alley and were planted to pearl millet (cv. CIVT) at 1 x 1 m (10,000 pockets $ha^{-1}$) spacing with 20-30 seed per pocket. At harvest, an area of 64 $m^2$ was sampled for grain yield and 10 $m^2$ was harvested for an estimate of straw production. Yield data are based on samples dried at 60°C.

Soil were sampled in September 1986 (0-15 cm) and analyzed for Bray P1 (Bray and Kurtz 1945), organic carbon (Nelson and Somers 1982), exchangeable bases (Rhoades 1982) and pH in 1N KCl (McLean 1982). Plant samples (grain and stover) harvested in 1985 were analyzed for total N (Buresh et al. 1982) and total P and cations by ascorbic acid method (Murphy and Riley 1962) and atomic absorption, respectively after digestion as described by Blanchard et al. (1965).

Table 1. Monthly rainfall for study period at experimental site as compared to long-term averages.

| | Normal† | Sadoré (mm) | | | |
|---|---|---|---|---|---|
| | (mm) | 1983 | 1984 | 1985 | 1986 |
| May | 35 | 18 | 44 | 0 | |
| June | 75 | 157 | 42 | 75 | |
| July | 141 | 133 | 91 | 136 | |
| August | 191 | 92 | 57 | 257 | |
| September | 89 | 195 | 26 | 91 | |
| October | 16 | 4 | 0 | 1 | |
| Total | 547 | 599 | 260 | 560 | |

† Based on 74 years of data from Niamey, 45 km to northwest of Sadoré (Sivakumar 1986).

## Results and Discussion

### Yield

Rainfall varied greatly over the study period in amount received and distribution (Table 1). Diminished rainfall in August 1983 limited yield response and a severe drought in 1984 reduced yields dramatically. Data from 1984 will be discussed separately. In 1985 and 1986 rainfall was well distributed.

**Table 2. Effect of crop residue and fertilizer use on pearl millet grain and stover yield.**

| | Grain yield (kg $ha^{-1}$) | | | | Stover yield (kg $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 | 1983 | 1984 | 1986 | 1986 |
| 1. Control | 280 | 215 | 160 | 75 | | 900 | 1,100 | 1,030 |
| 2. Crop residue (CR) (no fertilizer) | 400 (43[1]) | 370 (380) | 770 (900) | 745 | | 1,175 | 2,950 (170) | 2,880 (180) |
| 3. Fertilizer (no CR) | 1,040 (270) | 460 | 1,030 (545) | 815 (1,000) | | 1,175 | 3,540 (220) | 3,420 (230) |
| 4. Crop residue plus fertilizer | 1,210 (330) | 390 | 1,940 (1,110) | 1,660 2,150 | | 1,300 | 6,650 (505) | 5,690 (450) |
| LSD(0.05) | | | | | | | | |

[1] Numbers in brackets are percentage yield increase over controls.

In all years a significant yield response was found to both crop residue addition and fertilizer use (Table 2). Over the duration of the study, grain yields in the control plots declined steadily despite yield increases in 1985 and 1986 over 1983 levels in all other treatments. This indicates that the potential for sustained millet production in these soils is very limited in the absence of amendments such as fertilizer or residue.

The selection of the rather low fertilizer rates for this study was similar to the national recommendations and, based on data from fertilizer trials conducted currently with this study (data not shown). They were not sufficient to achieve maximum yields. Response to fertilizer use was pronounced in 1983 resulting in a 270% yield increase (Table 2). Yield in the treatment were quite constant over the four years. Thus, as the control yields diminished, the relative effectiveness of fertilizer use became greater resulting in a tenfold yield increase over controls by 1986.

Though reports exist of initial yield suppression due to N immobilization after addition of CR, no negative effects of crop residue addition were found. Thus, in 1983 CR improved yields 40% though the yield benefit was significantly weaker than that of fertilizer use (Table 2). However, as the study continued, the effect of CR vis-à-vis that of fertilizer became progressively more pronounced such that by 1986 the two treatments gave equivalent yield responses.

Highest yields were consistently found in the CRF treatments in which the effects of the individual treatments were approximately additive. Thus, as yields of the control plots declined, the relative response of the CRF treatment rose from 330% in 1983 to 2150% in 1986 (Table 2).

Trends in stover production were similar to those found with grain yield though less pronounced (Table 2). Use of either CR or fertilizer increased stover production an average of only 190% each in 1985 while the CRF treatment increased production by 500%. Similar trends were found in 1986.

Table 3. Effect of crop residue use on the nutrient concentration and uptake in millet grain and stover (1985)[1].

| | Nitrogen | | Phosphorus | | Potassium | | Calcium | | Magnesium | | Manganese | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C[2] | U | C | U | C | U | C | U | C | U | C | U |
| | (µg g⁻¹) | (kg ha⁻¹) | (µg g⁻¹) | (kg ha⁻¹) | (µg g⁻¹) | (kg ha⁻¹) | (µg g⁻¹) | (kg ha⁻¹) | (µg g⁻¹) | (kg ha⁻¹) | (µg g⁻¹) | (kg ha⁻¹) |
| 1. Control | 19.5 a | 3.1 c | 2.5 a | 0.42 c | 35.6 c | 5.9 c | 89.4 a | 0.014 c | 1,090 a | 0.18 c | 84 b | 0.014 c |
| 2. CR | 19.9 a | 15.1 b | 2.5 a | 1.97 b | 52.4 b | 42.0 b | 86.5 b | 0.067 b | 1,020 b | 0.79 b | 110 a | 0.097 b |
| 3. Fertilizer | 20.8 a | 21.3 b | 2.4 a | 2.64 b | 61.5 a | 64.5 b | 86.5 b | 0.089 b | 1.040 ab | 1.09 b | 86 b | 0.091 b |
| 4. CR + fertil | 20.0 a | 39.5 a | 2.6 a | 5.06 a | 66.8 a | 130.0 a | 86.8 b | 0.168 a | 1,080 ab | 2.09 a | 91 ab | 0.177 a |
| LSD | 1.3 | 5.4 | 0.3 | 0.93 | 5.4 | 23.0 | 2.1 | 0.029 | 70 | 0.36 | 24 | 0.054 |
| **Stover** | | | | | | | | | | | | |
| 1. Control | 6.0 a | 6.1 b | 0.51 a | 0.50 c | 13.9 a | 15.7 c | 2.190 a | 2.49 b | 4,380 a | 4.70 b | 107 a | 0.111 c |
| 2. CR | 6.5 a | 17.6 b | 0.43 a | 1.20 bc | 16.0 a | 48.9 bc | 1.950 a | 5.29 b | 4,060 a | 12.20 b | 156 a | 0.410 b |
| 3. Fertilizer | 5.7 a | 19.5 b | 0.42 a | 1.42 b | 19.1 a | 65.6 ab | 1.820 a | 6.42 b | 3,380 a | 12.10 b | 118 a | 0.392 b |
| 4. CR + fertilizer | 6.3 a | 41.1 a | 0.34 a | 2.27 a | 15.4 a | 97.9 a | 1.750 a | 11.48 a | 3,810 a | 25.50 a | 132 a | 0.881 a |
| LSD | 2.8 | 15.4 | 0.26 | 0.79 | 9.0 | 35.3 | 1.050 | 4.80 | 1,530 | 7.70 | 68 | 0.270 |

1. A different letter in each column indicates numbers ar significantly different at P<0.01 using Duncan,s multiple Range test.

2. C = Concentration in tissue; U = total uptake of nutrient in grain or stover.

## Analysis of crop residue and grain

Tissue analysis was conducted in order to determine the rates of nutrient export in the grain and stover fraction of each treatment and the amount of nutrient returned to the soil with CR (Table 3). Concentrations of Ca, Mg, Mn, N, P, and K in the stover and grain generally did not differ greatly among treatments, the exception being K in grain. However, because yield differences between treatments were large, significant difference in the total amount of each nutrient in both the grain and stover were found for each treatment.

Uptake of the Ca and Mg was much higher in the stover than the grain, whereas the uptake of the other nutrients was lower (N, P, and K) or equivalent (Mn) with that fraction. Thus, when CR was returned to the soil, large amounts of nutrients were returned to the plots and the only export that occurred was in the grain fraction. Conversely, in the fertilizer only and control treatments, nutrients in both the grain and stover fraction were exported. This resulted in large differences between the treatment in terms of total nutrient removal. Calcium removal in the CR treatment was only 0.07 kg while the fertilizer and control plots lost 6.51 and 2.5 kg $ha^{-1}$, respectively. Similar, though less pronounced difference were noted for Mg and to a lesser extent Mn. Since the CRF treatment received the nutrient from CR, export of nutrients in this treatment was lower (Ca, Mg, and Mn) or equivalent to (N, P, K) that of the fertilizer treatment, even though yields were consistently higher with fertilizer only (Table 4).

**Table 4. Total nutrient export (CR and CRF treatments) or grain plus stover in grain (control and fertilized treatments), 1995.**

| | Nutrient export (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Ca | Mg | N | P | K | Mn |
| Control | 2.50 | 4.80 | 9.1 | 0.92 | 21.6 | 0.12 |
| CR | 0.07 | 0.79 | 15.1 | 1.97 | 42.0 | 0.10 |
| Fertilizer | 6.51 | 13.19 | 40.8 | 4.06 | 130.1 | 0.48 |
| CR + fertilizer | 0.17 | 2.09 | 39.5 | 5.06 | 130 | 0.18 |
| LSD(0.05) | | | | | | |

## Soil analysis

Application of single superphosphate over four years resulted in an increase in extractable P level (Bray-1 P) in the fertilized and CRF treatments of 7.1 and 8.1 ug P $g^{-1}$ soil, respectively, though no significant difference was found for the control and the CR plots (2.6 and 2.9 ug P $g^{-1}$ soil) (Table 5). Previous studies in this region have shown a strong response to P and indicate that soils with a Bray-1 P of below 3.0 are very responsive to phosphorus (Bationo et al. 1989). In addition, a strong response to N has been found in the presence of adequate P. Thus, the response to fertilizer use in this trial was probably due to the presence of the P and N applied to these plots. In comparison with the control plots, fertilizer use had no significant effect on soil pH, Al saturation, or soil OM levels (Table 5).

However, the soils of the plots which had received CR had significantly high pH's and percent base saturation with a lower aluminum saturation than the control and fertilizer only treatments. This was probably due to the large amounts of calcium and magnesium returned with the residue to the CR and CRF plots and the chelation of Al and Fe by the OM fraction (Manu et al. 1988). Higher pH and reduction in Al saturation would have improved the soil environment for root growth and thus improved yields. However, these changes in soil chemistry were found only in the surface 20cm and no significant differences between treatments were found at lower depths in later years (Geiger et al. 1988). The CRF soils exhibited the best characteristics of both the fertilized (high Bray-1 P) and CR (high pH, lower Al saturation) treatments and, as a result, showed the best yields.

Table 5. Effect of crop residue and fertilizer use on soil characteristics after four cropping

| | pH (KCl) | Bray-1 P (ug $g^{-1}$ soil) | Organic matter (%) | Cation exchange capacity (%) | Ca + Mg saturation (meq 100 $g^{-1}$ soil) | Aluminum (meq 100 g-1 soil) | Aluminum saturation (%) |
|---|---|---|---|---|---|---|---|
| Control | 4.11 | 2.60 | 0.24 | 1.05 | 43 | 0.49 | 48 |
| Crop residue only (no fertilizer) | 4.37 | 2.97 | 0.29 | 1.02 | 68 | 0.21 | 20 |
| Fertilizer only (no crop residue) | 4.11 | 7.10 | 0.26 | 1.01 | 44 | 0.44 | 43 |
| Crop residue plus fertilizer | 4.42 | 8.14 | 0.34 | 1.16 | 72 | 0.18 | 16 |
| LSD(0.05) | | | | | | | |

No significant change was noted in CEC or OM content among the treatments after four years of crop production. This is in part due to the rapid degradation of OM that can occur during the rainy season in this climate. In addition, the measured levels of OM were at the lower limit of the analytical technique for bulk soil samples. Due to soil variability, a slight change in OM status could therefore not be detected (Table 5).

## Conclusion

Reasons for the positive effects of crop residue on millet yield is not clear. Though subtle changes in pH and Al saturation did not occur in the CR and CRF plots, these difference do not appear to have been sufficiently large to improve yield so greatly. Although CR is reported to increase water infiltration rates and reduce run-off losses in other environments, problems of run-off were not pronounced in these very sandy soils. In a similar study conducted at Sadoré in 1985, addition of CR did not significantly alter total water use efficiency at the end of the season (ICRISAT 1986).

However, stover standing over the seven month dry season did trap significant amounts of winds blown dust which may have provided some nutrient to the crop. This may have been responsive for the slight improvement of the surface soil characteristics that was associated with CR use (Geiger et al. 1988).

An additional factor may have been the toxic nature of some decomposing residue. It has been shown that the population of parasitic nematodes can be reduced by the incorporation of wheat straw and other organic amendments (Gaur and Prasad 1970). Experiment with Carbofuran at Sadoré have shown a beneficial effect on millet yield greater than would be expected by destruction of the stem borers (*Coniesta* (*Acigona*) *ignefusalis*) for which it was applied (ICRISAT 1988). This suggests that a soil organism susceptible to this chemical is limiting yield. It may be that the use of CR has a natural inhibitory effect on plant pathogens in the soils which causes root disease.

Although the effect of CR on yield was pronounced, many farmers now use the majority of their CR as fuel, animal feed, or housing and fencing material, and little is left to return to the land. However, present rates of fertilizer use in the country are very low (average less than 1.0 kg nutrient $ha^{-1}$, McIntire 1986). If the farmer can be provided with a source of fertilizer for even one or two years, the increase in stover yield that can be expected will supply him with enough CR to meet present needs and still leave sufficient straw to improve the productivity of his soil. If this CR is returned to the land along with fertilizer the farmer will be able to increase food production in a sustainable manner. The data suggests that without fertilizer or CR, yield will decline rapidly to the point that the farmer must abandon the field to a long fallow. An additional benefit to the CR is that the increased amounts of stover standing in the fields over the hot dry season reduce wind erosion effects on the soil and limit process that degrade the land.

## References


**Allard, J.L., Berthaud, Y., Drevon, J.J., Seze, O., and Ganry, F.** 1983. Resources en résidues de récolte et potentialités pour le biogaz au Sénégal. Agronomie Tropicale, Paris 38:213-222.

**Blanchard, R.W., Rehm, G., and Galdwell, A. C.** 1965. Sulfur in plant material by digestion with nitric and perchloric acids. Soil Science Society of America, Proceedings 29:71-72.

**Balasubramanian, V., and Nnadi, L.A.** 1980. Crop residue management and soil productivity in savanna areas of Nigeria. Pages 106-120 *in* Organic Recycling in Africa. Food and Agriculture Organization, Rome, Italy: FAO.

**Bationo, A., Baethgen, W.E., Christianson, C.B., and Mokwunye, A.U.** 1989. Comparison of five soil testing methods to establish phosphorus sufficiency levels and to determine fertilizer needs for millet production in Niger. [Submitted Journal of Soil Science Society of America]

**Bray, R.H., and Kurtz, L.T.** 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Science 59:39-45.

**Buresh, R.J., Austin, R.E., and Craswell, E.T.** 1982. Analytical methods of $^{15}N$ research. Fertilizers Research 3:37-42.

**Charreau, C.** 1972. Problèmes posés par l'utilisation agricole des sols tropicaux par des cultures annuelles. Agronomie Tropicale, Paris 27:905-929.

**Chopart** 1983. Etudes du système racinaire du mil (*Pennisetum typhoides*) dans un sol sableux du Sénégal. Agronomie Tropicale, Paris 38:37-46.

**Christianson, C.B., Bationo, A., Henao, J., and Vlek, P.L.G.** 1989. The efficiency of N fertilizers applied to pearl millet in Niger. [Accepted in Plant Soil]

**Feller, C., and Ganry, F.** 1982. Décomposition et humification des résidus végétaux dans un agro-système tropical III-Effet du compostage et de l'enfouillissement de divers résidus de récolte sur la répartition de la matière dans différent compartiments d'un sol sableux. Agronomie Tropicale, Paris 37:262-269.

**Ganry, F., Guiraud, G., and Dommergues** 1978. Effects of straw incorporation on the yield and nitrogen balance in the sandy soil pearl millet cropping system of Senegal. Plant Soil 50: 467-662.

**Gaur, A.C., and Prasad, S.K.** 1970. Effect of organic matter and inorganic fertilizer on soil and plant nematodes. Indian Journal of Entomology 32:186-188.

**Geiger, S.C., Manu, A., and Bationo, A.** 1988. Changes in the chemistry of a sandy Nigerien soil following long term residue and fertilizer additions. Agronomy Abstracts - 1988, p.55.

**Institut de Recherches Agronomiques Tropicales** (IRAT). 1974. Rapport Annuel 1972 de l'IRAT. Agronomie Tropicale, Paris 29:464-467.

**Institut de Recherches Agronomiques Tropicales** (IRAT). 1975. Etudes de lysimétrie et acidification des sols. *In* Les recherches en agronomie à l'IRAT de 1969 à 1974. Agronomie Tropicale 30:148-153.

**International Crop Research Institute for the Semi-Arid Tropics** (ICRISAT). 1986. ICRISAT Annual Report 1985. Patancheru, A.P. 502324, India:ICRISAT.

**International Crop Research Institute for the Semi-Arid Tropics** (ICRISAT). 1988. ICRISAT Annual Report 1987. Patancheru, A.P. 502324, India:ICRISAT.

**Manu, A., Geiger, S.C., and Bationo, A.** 1988. The interactive effect of P fertilizers and millet residue on P dynamics of a sandy Nigerian soil. Agronomy Abstracts, 1988, p.241.

**McIntire, J.** 1986. Constraints to fertilizer use in Sub-Saharan Africa. Pages 33-68 *in* Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan Africa. (Mokwunye, A.U., and

Vlek, P.L.G., eds.), Netherlands:Martinus Nijhoff.

McLean, E.O. 1982. Soil pH and lime requirement. Pages 199-224 *in* Methods of Soil Analysis. Part 2. (Page, A.L., Miller, R.H., and Keeney, D.R., eds.). Madison, WI: American Society of Agronomy.

Murphy, J. and Riley, J.P. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytical Chemistry 27:31-36.

Nelson, D.W., and Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. Pages 539-578 *in* Methods of Soil Analysis. Part 2 (Page, A.L., Miller, R.H., and Keeney, D.R., eds.), Madison, WI: American Society of Agronomy.

Pichot, J., Sedego, M.P., Poulain, J.F., and Arrivets, J. 1981. Evolution de la fertilité d'un sol ferrugineux tropical sous l'influence de fumures minérales et organiques. Agronomie Tropicale, Paris 36:122-133.

Pichot, J., Truong, B., and Beunard, P. 1979. L'action des phosphates naturels d'Afrique de l'Ouest sur l'absorption du phosphore par l'agrostis et sur le phosphore isotiquement diluable (valeur L.) dans cinq sols tropicaux. Pages 463-477 *in* Isotopes and Radiation in Research on Soil Plant Relationships, Colombo, Sri Lanka, December 11-15, 1978, Vienna: IITEA.

Pieri, C. 1973. La fumures des céréales de cultures sèches en République du Mali--Premier essai de synthèse. Agronomie Tropicale, Paris 28:751-766.

Pieri, C. 1985. Bilan minéraux des systèmes de cultures pluviales en zones arides et semi-arides. Agronomie Tropicale, Paris 40:1-20.

Pieri, C. 1986. Fertilisation des cultures vivrières et fertilité des sols en agricultures paysanne subsaharienne. Agronomie Tropicale, Paris 41:1-20

Rhoades, J.D. 1982. Cations exchange capacity. Pages 149-158 *in* Methods of Soil Analysis. Part 2 (Page, A.L., Miller, R.H., and Keeney, D.R., eds), Madison, WI: American Society of Agronomy,

Quilfen, J.P., and Milleville, P. 1983. Residus de cultures et fumure animale: un aspect des relations agriculture-élevage dans le Nord de la Haute-Volta. Agronomie Tropicale, Paris 38:206-212.

Sivakumar, M.V.K. 1986. Agroclimatology Progress Report. 1. Climate of Niamey, ICRISAT Sahelian Centre, Niamey, Niger: ICRISAT.

Traoré, M.F. 1974. Etude de la fumure minérale azoté intensive des céréales et du rôle spécifique de la matière organique dans la fertilité des sols au Mali. Agronomie Tropicale, Paris 24, 1-20.

West, L.T., Wilding, L.P., Landeck, J.K., and Calhoum, F.G. 1984. Soil survey of the ICRISAT Shelian Center, Soil Crop Science Dept./Tropsoils, College Station. Texas: Texas A & M.

# Effect of Sulphur on the Efficiency of Nitrogenous and Phosphatic Fertilizers in Millet[1]

Edward O. Uyovbisere[2]

**Abstract**

*A study was carried out to evaluate the effects of sulphur on the efficiency of N and P fertilizers in millet production at Samaru, Nigeria (Lat. 11°11'N and Long. 7°38'E) in the northern Guinea savanna. Treatments consisted of four levels each of N and P and three levels of S carried out in three separate trials.*

*Phosphorus was observed to be the most limiting nutrient for millet. Nitrogen was not considered crucial as yields were depressed by N-application. A rational combination of 20 kg N, 10-20 kg P2O5, adequate S and K was considered optimum for millet in this study. S was observed to improve the efficiencies of N and P fertilizers though not to a significant extent with N; S should be considered a fourth major nutrient in fertilizer formulations.*

**Résumé**

**L'effet du soufre sur l'efficacité de l'engrais azoté et phosphaté chez le mil:** *Une étude a été menée pour évaluer les effets du soufre sur l'efficatité de l'engrais N et P dans la production du mil à Samaru, Nigéria (Lattitude 11°11'N et Longitude 7°38'E) dans la savanne Nord-guinéenne. Les traitements étaient composés de quatre niveaux chacun de N et P et trois niveaux de S mis au point dans trois essais différents.*

*Il a été observé que le phosphore est la substance nutritive la plus restrictive pour le mil. L'azote par contre n'a pas été estimé décisif car une réduction sensible dans les rendements a été enregistrée due à l'application de N. Une combinaison rationnelle de 20 kg de N, 10-20 kg P2O5, et d'une quantité adéquate de S et de K a été estimée optimum pour le mil dans cette étude. Il a été observé que S améliore l'efficacité de l'engrais N et P, mais pas à tel point que N et S puissent être considérés comme une quatrième substance nutritive importante dans la formulation des engrais.*

## Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is an important staple food crop in the semi-arid, as well as the sub-humid savannas of West Africa. The widespread cultivation of the crop results from its early harvest and value as a hunger-breaker (Johnston 1958).

Millet thrives in poor soils which could be marginal for other crops (Singh et al. 1983, Egharevba 1979). Because of limited research on the crop and its low economic returns compared to other cash crops, convincing farmers to fertilizer it has been difficult (Egharevba 1979). Therefore, yields remain low under traditional systems. Average national millet yields in Nigeria are 750 kg grain $ha^{-1}$ (Egharevba 1979). With improved management practices, yields of up to 2-4 t $ha^{-1}$ have been obtained in research centers (Egharevba 1979, Nwasike et al. 1982), implying the existence of potential for improvement in yield.

Favorable responses of millet to fertilization have been recorded in varied agro-climatic environments (Egharevba 1979, Catherinet et al. 1963). Significant response to 50 kg nitrogen (N) and 30-60 kg phosphate ($P_2O_5$) $ha^{-1}$ are reported (Egharevba 1979, Balasubramanian et al. 1978). Current fertilizer recommendation for sole crop millet in Nigeria is 60 kg N, 30 kg $P_2O_5$ and 30 kg potash ($K_2O$) $ha^{-1}$ (Singh et al. 1983). Urea, calcium ammonium nitrate (CAN), single superphosphate (SSP), muriate of potash (MOP), as well as the compound formulation (eg. 15:15:15) dominate the Nigeria fertilizer market as sources of the major nutrients.

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT Sahelian Center, Sadoré, 4-7 Sep 1989.

2. Research Fellow, Soil Science Department, Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, Nigeria.

Incidental additions of sulphur (S) has continued to be an important source of S for crop production (SSP contains 12% S, Jordan and Ensiminger 1958). If the present trend towards the use of higher analysis fertilizer with little or no S-content is to continue, deficiency may start to be manifested in S-deficient tropical soils (Enwezor 1976, Goldsworthy and Heathcote 1963, Greenwood 1951, Jodan and Ensiminger 1958).

The efficiency of N- and phosphorus (P)- fertilizers were observed to improve with the application of adequate S (Coulter 1970). Reports on the relation of S to soil fertility show yield increases of between 16-400% of various crops when S was added to fertilizer packages that lack S (Coleman 1966, Fox et al. 1976, Vogt 1964). Invariably, the efficiency of N- and P-fertilizers can be improved by proper management practices including proper balance of nutrients in fertilizer packages. The present study focuses on the effects of S on the response of millet to N- and P-fertilizers in a northern Guinea savanna.

## Materials and Methods

### Site

The trials were conducted at the Institute for Agricultural Research Farm, Samaru, Nigeria (Lat. 11°11'N, Long. 7°38'E) in the sub-humid savanna ecological zone. Total rainfall in 1988 was 1156 mm spread essentially over 7 months, May to Oct. The soil was formed on Loess material overlying undiffientiated basement complex and was coarse textured and classified as Alfisol in the USDA system (Harpstead 1973). Chemical analysis of the preplanting top-soil show the following: clay - 10%, pH ($H_2O$) - 6.1, organic matter - 1.03%, Bray $P_1$ - 11.4 ppm, soluble $SO_4$ - 4.75 ppm, extractable $NO_3$ - 4.80 ppm, extractable K - 0.14 meq/100 gm, CEC - 1.86 meq/100 gm.

### Experimental Design

Multinutrient trials on millet were conducted in the 1988 cropping season. Four rates of N, four rates of P and three rates of S were tested in three separate trials. These were (a) a $2^3$ factorial employing two levels of N, P and S ($N_1$, $N_3$, $P_1$, $P_3$, $S_1$, $S_2$), (b) a non-factorial experiment designed to compare the means of one combination of N and P ($N_2P_2$) at the various levels of S (So, $S_1$, $S_2$), (c) a non-factorial experiment to compare the means of the single nutrients (No $P_2$ and $N_2P_o$) at 2 levels of S ($S_1$ and $S_2$).

Experimental design was a randomized complete block design for all trials with three replications. All trials were influenced by the same set of edaphic and climatic conditions. *Gero* type millet, cultivar Ex-Borno, was planted on the flat at 25 x 75 $cm^2$ spacing, giving an estimated plant population of 53 000 plants to the hectare. Plot size was 4.5 $m^2$ comprising six rows.

Fertilizers were applied at the following rates:

Phosphorus : $P_o$ = 0, $P_1$ = 10, $P_2$ = 20, $P_3$ = 30 kg $P_2O_5$ $ha^{-1}$

Nitrogen : $N_o$ = 0, $N_1$ = 20, $N_2$ = 40, $N_3$ = 60 kg N $ha^{-1}$

Sulphur : $S_o$ = 0, $S_1$ = 7.5, $S_2$ = 15 kg S $ha^{-1}$

Blanket application of K was made at 30 kg $K_2O$ $ha^{-1}$. An absolute control with no fertilizer applied was included as a check. Urea, triple superphosphate

(TSP), gypsum and MOP were used as sources of N, P, S, and K, respectively. All fertilizers were banded at one week after planting (WAP) except N which was split at 1 WAP and 5 WAP. The crop was planted on June 24 and harvested Sep 14-28 1988, giving an average maturing period of about 90 days. Variables estimated were grain yield, stover yield, head length and grain weight per head. Yields were estimated from the four middle rows of each plot.

## Results and Discussion

Statistical analysis of yield parameters showed that response to treatment effects were mostly non-significant for grain yield, head length and grain weight per panicle. Response to treatments was more evident in stover yield estimates (with lower coefficient of variation), as compared with grain yield, where bird damage by *Quelea* sp.to mature grains was evident.

### Critical nutrients

Extent of deficiency in the soil of each of the nutrients under consideration was evaluated from the results of the non-factorial trials. Yield levels (stover and grain) improved with the application of all nutrients but effect were non-significant with N and S-applications alone (Table 1). Response to P-application was highly significant over control. Phosphorus appears to be the most critical nutrient in this soil. When applied in the right combination with S, yield was greatly improved by 96% over control (Fig 1). Response due to application of S with N and P gave a 16% yield increase, while N seemed to be marginally responsive. In these sandy soils, P appears more crucial for a low N demanding crop like millet. Importance of P in sandy semi-arid agriculture and for low nutrient demanding crop like millet has been reported (Jones and Wild 1975). Sulphur seems to stimulate better grain development (Table 1).

Table 1. Response of millet to N and P combinations as influenced by sulphur levels.

| Treatment | Stover yield (kg $ha^{-1}$) | Grain yield (kg $ha^{-1}$) |
|---|---|---|
| Control | 1760 | 444 |
| $N_o$ $P_2$ $S_1$ | 2710 | 721 |
| $N_o$ $P_2$ $S_2$ | 3400 | 1010 |
| $N_2$ $P_o$ $S_1$ | 2150 | 510 |
| $N_2$ $P_o$ $S_2$ | 2570 | 404 |
| $N_2$ $P_2$ $S_o$ | 2280 | 546 |
| $N_2$ $P_2$ $S_1$ | 2510 | 559 |
| $N_2$ $P_2$ $S_2$ | 2650 | 914 |
| SE | ±713[1] | ±173 |

1. Significant at $P<0.05$.

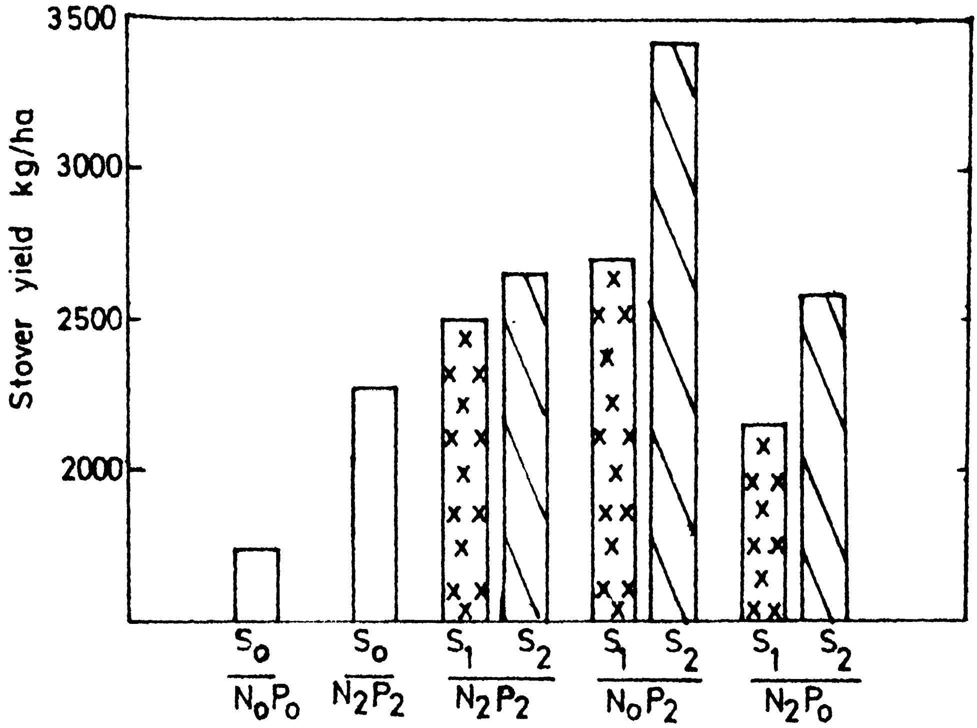



Figure 1. Response of millet stover to NPS interaction.

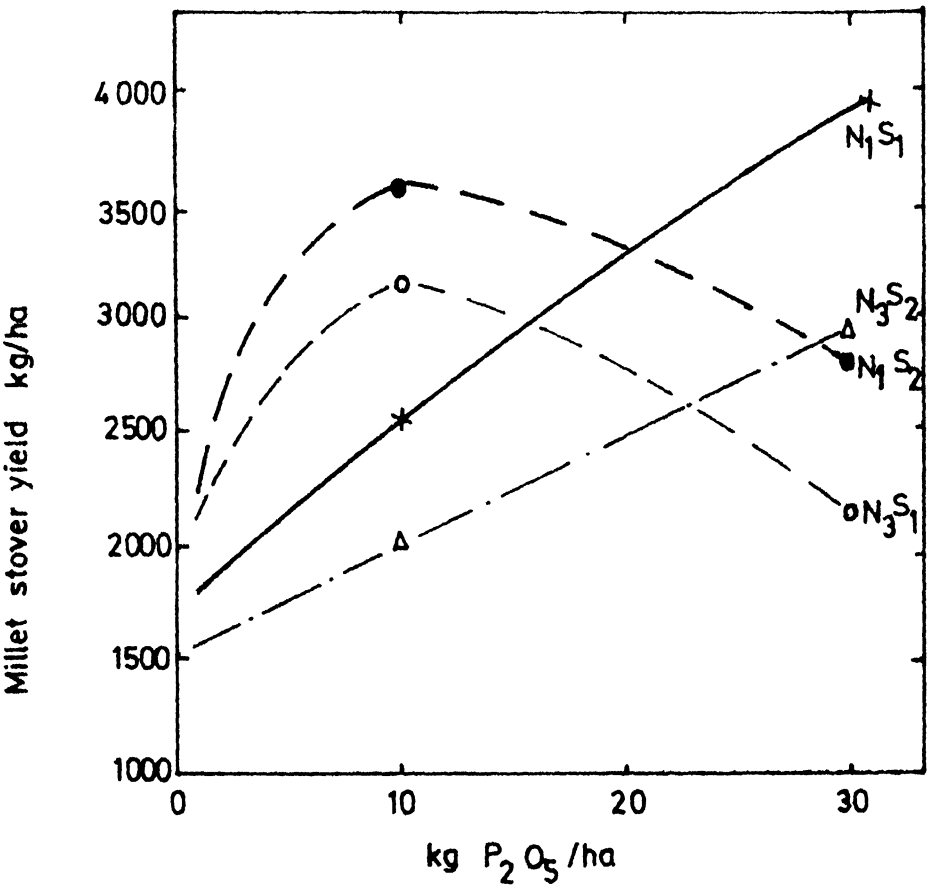



Figure 2. Response of millet grain to NPS interaction.

**Table 2. Mean response of millet to various levels of N, P and S fertilization.**

| Treatment | Stover yield (kg $ha^{-1}$) | Grain yield (kg $ha^{-1}$) |
|---|---|---|
| Control | 1730 | 444 |
| Phosphorus | | |
| $P_0$ | 2360 | 457 |
| $P_1$ | 2830 | 579 |
| $P_2$ | 3060 | 864 |
| $P_3$ | 2960 | 765 |
| Nitrogen | | |
| $N_0$ | 3060 | 868 |
| $N_1$ | 3210 | 669 |
| $N_2$ | 2360 | 650 |
| $N_3$ | 2580 | 674 |
| Sulphur | | |
| $S_0$ | 2280 | 546 |
| $S_1$ | 2720 | 638 |
| $S_2$ | 2650 | 770 |
| SE | ±476[1] | ±137 |

1. Significant at $P<0.05$.

**Mean response to fertilization**

Mean response of millet to N, P and S fertilization are presented in Table 2. Response was consistent in both stover and grain and were all superior to the control. This indicates that even for the low nutrient demanding millet crop, it is necessary to fertilize the savanna soils for any yields to be obtained.

Response to the various nutrient elements was not marked. Significant response to P went up to 20 kg $P_2O_5$ $ha^{-1}$ though the mean at 10 kg $P_2O_5$ $ha^{-1}$ was not different statistically. The need for N-application was not suggested as yields were depressed by N application. With S, it may not be beneficial to apply it in excess of 7.5 kg S $ha^{-1}$. It is evident from the results that this soil requires P for adequate millet growth.

N x P x S interaction

Assuming minimal fertilization for the millet crop, the $2^3$ factorial trial was designed to determine the most promising combination of N, P and S for the crop. The NxPxS interaction was significant ($P<0.05$) for stover but not for grain yield (Fig. 2 and 3). The responses were both linear and quadratic in character for both parameters depending on the treatment combinations. The linear relationship may not be an economically viable option since reasonable yields can be expected only at the higher rates of inputs. At the economic range of application of N and P fertilizer, 20 kg N, 10 kg $P_2O_5$ and adequate supply of S and $K_2O$ would seem a rational fertilizer balance for millet.

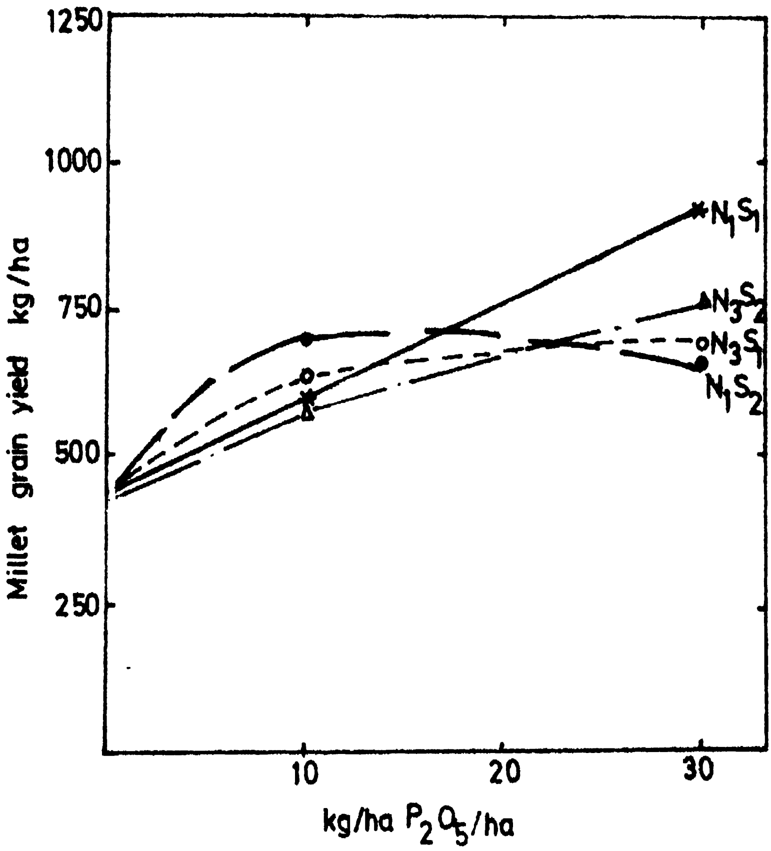



Figure 3. Effects of sulphur application on the response of millet to fertilization (stover).

However, for soils with severe deficiencies of specific nutrients, as was observed with P in this study, there is a need to satisfy that requirement. As shown in Table 1, and illustrated in Figs 1, 2 and 3, it is apparent that a rational balance of S in fertilizer packages improved the efficiencies of P- and N- fertilizers. Sulphur is required for several vital functions in plants, including the synthesis of vital amino acids for protein formation, and also for chlorophyll formation (Coleman 1966). It is also required at about the same extent as P in plants (Beeson 1941, Coleman 1966). With the current trend to higher analysis fertilizers, a proposal for S as a fourth major nutrient in fertilizer formulations is long over-due. Investigations are still in the preliminary stages. More trials will be conducted to substantiate these results in the 1989 season.

## Conclusion

To improve food crop production in the Nigerian savanna, improved soil fertility is needed. In coarse textured soils characteristic of the savanna, P could be the most limiting nutrient for low N-demanding crops like millet. Effectiveness of N and P fertilizers in the savanna soils can be improved by a rational S balance in fertilizer formulations. It should therefore be considered an indispensable nutrient in fertilizers. Should incidental sources of this nutrient be discontinued due to changes in national fertilizer policy, adequate provision should be made for this nutrient. National programs should consider S a fourth major nutrient in fertilizer formulations. A rational balance of 20 kg N, 10-20 kg $P_2O_5$ and adequate S and $K_2O$ was considered optimum for millet in this study.

## References

**Balasubramanian, V., Nnadi, L.A., and Mokwunye, A.U.** 1978. Fertilizing sole crop maize for high yields. Samaru Miscellaneous Paper Series No. 76.

**Beeson, K.C.** 1941. *In* Jordan and Ensminger, 1958. Agronomy Journal. Listed.

**Catherinet, M.D., Dumond, S., and Mayaki, A.A.** 1963. Millet and sorghum in Niger agriculture. A cultivation requirements, soil and climate, limiting factors. Agronomie Tropicale 18:108-113.

**Coleman, R.** 1966. The importance of sulphur as a plant nutrient in world crop production. Soil Science 101:230-239.

**Coulter, J.K.** 1970. Soils of Central Africa. A review of investigations on their fertility and management. Harpendon Herts, United Kingdom, Rothamsted Experimental Station.

**Egharevba, P.N.** 1979. Agronomic practices for improved sorghum and millet production, Samaru Miscellaneous Paper Series No. 90.

**Enwezor, W.O.** 1976. Sulphur deficiencies in soils of south-eastern Nigeria. Geoderma 15:401-411.

**Fox, R.L., Olson, R.A., and Thoades, H.F.** 1964. Evaluating the sulphur status of soils by plant and soil tests. Soil Science Society of America Proceedings. 28:243-246.

**Goldsworthy, P.R., and Heathcote, R.G.** 1963. Fertilizer trials with groundnut in northern Nigeria. Empire Journal of Experimental Agriculture. 31:351-366.

**Greenwood, M.** 1951. Fertilizer trials with groundnut in northern Nigeria. Empire Journal of Experimental Agriculture. 19:225-241.

**Harpstead, M.I.** 1973. The classification of some Nigerian soils. Soil Science. 116:437-433.

**Jones, M.J., and Wild, A.** 1975. Soils of the West African savanna. Comm. Bur. Soil Tech. No. 35. Harpenden, U.K.

**Johnston, B.F.** 1958. The staple food economies of West Tropical Africa. Stanford University Press.

**Jordan, H.V., and Ensiminger, L.E.** 1958. The role of sulphur in soil fertility. Advances in Agronomy 10:407-434.

**Nwasike, C., Baker, E.F.I., and Egharevba, P.N.** 1982. The potentials for improving millet (*Pennisetum typhoides*) in farming systems of the semi-arid areas of Nigeria. Agriculture and Environment. 7:15-21.

**Singh, L., Egharevba, P.N., Ogunlela, V.B., and Balasubramanian, V.** 1983. Proposed new fertilizer recommendation for sole crop millet. Professional and Academic Board of IAR (Memo).

**Vogt, J.B.M.** 1966. Responses to sulphur fertilization in N. Rhodesia. Agrichimika 10:105-113.

# Effect of Some Selected Agronomic Practices on the Grain Yield of *Gero* Millet[1]

D.A. Labe and C.E. Odion[2]


### Abstract

*A field investigation was conducted at the Institute for Agricultural Research, Zaria, during the rainy seasons of 1985-1987 to assess the combined effect of four agronomic factor on the grain yield of Gero millet. The four factors were variety, plant density, time of weed control and time of fertilizer application. Each factor was subdivided into improved and unimproved practices. Four management practices representing each factor were constituted into possible production management package.*

*The time of weed control consistently affected the grain yield. Any management package that had late weeding reduced grain yield. Plant density and time of fertilizer application showed no pronounced effects. Varietal effects were also notable. Unimproved management packages gave low grain yield; the improved packages increased grain yield.*



### Résumé

**L'effet de certaines pratiques agronomiques sélecitonnées sur le rendement en grains du mil gero**: *Une enquête sur le terrain a été menée à l'Institut de Recherche Agricole de Zaria, Nigéria, au cours des saisons pluvieuses 1985-1987 en vue d'évaluer l'effet combiné de quatre facteurs agronomiques sur le rendement en grain du mil gero. Les quatre facteurs étaient la variété, la densité des plantes, la période de désherbage et de l'application de l'engrais. Chaque facteur a été subdivisé en pratiques améliorées et non-améliorées. Quatre pratiques de gestion représentant chaque facteur ont été constituées en une gestion conditionnée possible de la production.*

*La période de désherbage a régulièrement affecté le rendement en grain. Toute gestion conditionnée ayant subi un désherbage tardif a régulièrement réduit le rendement en grain. La densité de plantes et la période d'application de l'engrais n'ont pas eu d'effets sur le rendement en grain, par contre l'effet variétal n'a été remarquable. La gestion conditionnée comprenant les pratiques non-améliorées ont donné un faible rendement en grain; cependant les pratiques améliorées ont augmenté les rendements en grain.*


## Introduction

*Gero*, a photoperiod-insensitive, early-maturing pearl millet (*Pennisetum glaucum* (L.) R. Br.), accounts for more than 90% of the total millet produced in Nigeria (Khader and Oyinloye 1977). It accounts for 87-98% of cereals consumption in the Sahel and some parts of the Sudan savannas (Agboola 1979). With the grain protein content of about 13% (Okoh et al. 1985), *gero* millet constitutes a major source of protein in the diets of a large number of people in Nigeria (Okoh and Eka 1978). Despite its dietary importance, its production is stagnated in the face of rising human population. The stagnation in production is attributed to the inherent use of the traditional cultural practices which are often sub-optimal. Consequently yields on farmers' fields are low with a resultant national average of 750 kg $ha^{-1}$ (Egharevba 1979) while yields above 2000 kg $ha^{-1}$ under improved field cultural practices are not uncommon (Egharevba 1978, 1981; Choudhary et al. 1979; Khader et al. 1979, Singh et al. 1983). Field management factors that influence crop yield are numerous but sub-optimum plant density, untimely weed control, incorrect fertilization practices and the use of local unimproved varieties are the most important.

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Department of Agronomy, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Millet is extensively grown on soils low in fertility; however, best grain yields are realized on fertile soils. Grain yields attained at optimum nutrient level in Nigeria exceed yield from non-fertilized crops by 54-79% (Egharevba 1978, Singh et al. 1983). Similar yield increases of up to 74% were achieved through fertilization in India (Mariakulandai and Morachan 1966) and as high as 152% in Zimbabwe (Ferraris 1973). However, the optimum rate of fertilization is dependent on the appropriate time of its application to get the best yield is another. Farmers generally apply their fertilizers at or after sorghum (*Sorghum bicolor* (L.) Moench) is relay intersown at about four weeks after the millet has been sown. This practice results yield loss of up to 20% (Egharevba 1978).

With regard to weed control, little attention is shown to weed competition in traditional agriculture. Farmers usually sow millet when the first rain is received at the beginning of the season. Since the first rains are usually inadequate to sufficiently wet the soil for proper tillage, the crop is sown on non-tilled land where weeds germinate simultaneously with the crop. The farmers' practice is to allow the weeds to grow and weeding is done often at a time when sorghum is to be sown in relay with millet. This allows the weeds to compete effectively with millet seedlings. When weeding is done in this manner, the crop yield is inevitably lower than weed-free crop. Consequently, grain yield losses of 45% (Choudhary et al. 1979) and as high as 70% (Choudhary and Lagoke 1981) and 90% (Egharevba 1978) have been reported. Farmers generally do not have a true appreciation of the magnitude of the damage caused by weeds.

The study reported here was undertaken to assess the grain yield losses in *gero* millet as affected by a combined effect of variety, plant density, and timing of weed control and fertilizer application.

## Material and Methods

Trials were conducted on the research farm of the Institute for Agricultural Research, Samaru, Nigeria during the 1985-87 wet seasons. The crop was sown on 4 June 1985, 30 June 1986, and 15 June 1987, in each season after the land was ploughed, harrowed and ridged at 75 cm apart. Wide variation in the date of sowing was dictated by the time of establishment of the rains.

The crop was managed at two levels each of variety, plant density, time of the fertilizer application and the time of weed control. The two levels of factors represented the improved and unimproved crop management levels. Ex Borno, the standard variety, at the recommended plant density, 53 000 plants $ha^{-1}$, on 75 cm ridges ($P_1$), fertilizer application at planting as early application ($F_1$) and hoe-weeding at two weeks after sowing (WAS) as early weed control ($W_1$), constituted the improved levels. The unimproved levels comprised Ex Bomo, a local unimproved variety, the sub-optimum plant density 27 000 plants $ha^{-1}$ ($P_2$), and the farmers' intra-row spacing (50 cm), fertilizer application ($F_2$) and weeding at four WAS ($W_2$), representing the farmers' delayed operations.

Sowing was done at the intra-row spacings of 25 and 50 cm to achieve 53 000 and 27 000 plants $ha^{-1}$, respectively. The recommended fertilizer rate of 60 kg N and 30 kg each of $P_2O_5$ and $K_2O$ per hectare (Singh et al. 1983) as a mixture of NPK (15-15-15) and calcium ammonium nitrate was applied at sowing and 4 WAS as early and late fertilizer application, respectively. Early fertilizer application was as a basal dressing through band placement while the delayed fertilizer application was by side-dressing. Each year, the crop was weeded once. Weeding was by manual hoeing at two and four WAS for early and delayed weeding, respectively.

Treatments were arranged in a randomized complete block design and replicated three times. Each plot was 4.00 x 3.75 $m^2$ and had a net plot of 4.00

x 2.25 m². Effect of the field management factors were assessed on the number of flowering tillers, otherwise referred to as the productive tillers per plant, percentage of the plants survived to maturity, the number of harvestable heads and grain yield.

## Results

Percentage of the *gero* millet plants that survived to maturity was not significantly affected by the varying combination of the selected factors (variety, plant density, time of weeding and fertilizer application) (Table 1). Although the rate of plant survival was not peculiar to any treatment, it was interesting to note that the plants of the two varieties had the highest rate of survival when they were raised at the sub-optimum plant density and maintained by delayed fertilizer application and early hoe-weeding ($P_2F_2W_1$).

**Table 1. Effect of some agronomic practices on the percentage of the plants that survived to maturity.**

| | Plants that survived to maturity (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | | 1986 | | 1987 | |
| Treatment | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo |
| P1F1W1[1] | 95 ab[2] | 95 ab | 97 a | 93 a | 97 a | 95 ab |
| P1F1W2 | 93 ab | 85 b | 94 a | 92 a | 99 a | 99 a |
| P1F2W1 | 97 a | 97 a | 97 a | 97 a | 97 a | 96 a |
| P1F2W2 | 91 ab | 87 b | 95 a | 94 a | 98 a | 99 ab |
| P2F1W1 | 98 a | 100 a | 81 b | 97 a | 97 a | 97 a |
| P2F1W2 | 92 ab | 93 ab | 93 a | 92 a | 97 a | 97 a |
| P2F2W1 | 100 a | 100 a | 99 a | 97 a | 91 b | 100 a |
| P2F2W2 | 95 a | 99 a | 96 a | 95 a | 99 a | 97 a |

[1] P1 = 53 000 plants $ha^{-1}$  F1 = fertilizer applied at 0 WAS
P2 = 27 000 plants $ha^{-1}$  F2 = fertilizer applied at four WAS

W1 = weeding at two WAS
W2 = weeding at four WAS.

All level 1 had unproved variety, Ex Borno, and all level 2 had unimproved local variety Ex Bomo.

[2] Value in a year followed by a common letter are not significant different at $P<0.05$ using the Duncan's multiple range test.

Number of tillers per plant that produced heads varied from 1.0-4.9 (Table 2). Lowest productive tiller number occurred in the unimproved variety (Ex Bomo) at the poorest management of sub-optimum plant density delayed fertilizer application and delayed weed control ($P_2F_2W_2$). Highest number of productive tillers was observed in the improved variety (Ex Borno) when it was established at the sub-optimum plant density and treated with the delayed fertilizer dressing and early weed control ($P_2F_2W_1$). Generally, the number of the productive tillers per plant was higher in the early than the delayed weed control treatments irrespective of the variety involved. Between the varieties, the improved (Ex Borno) variety has a higher number of productive tillers than the unimproved (Ex Bomo) variety. There was also a notable year effect with the number of the productive tillers being highest in 1987.

Treatment effects of the production factors on the number of harvestable heads (Table 3) and the grain yield (Table 4) followed a similar pattern as described for the number of the productive tillers per plant. Highest grain yields of the improved variety were attained consistently at the treatment that had the delayed fertilizer application as an unimproved factor ($P_1F_2W_1$) contrary to the expectation that the highest grain yields would be attained at a treatment that had all the four improved factors ($P_1F_1W_1$). Lowest grain yields of the improved variety were not consistent at a particular treatment nor were they at the poorest management ($P_2F_2W_2$). For treatments that had delayed weed control, with few exceptions, grain yield was decreased irrespective of the variety. Although other factors were also implicated in reduced grain yield, the delayed weed control had the deleterious effect on grain yield. The improved variety generally gave higher grain yields than the unimproved variety in 1985 and 1986, while the reverse occurred in 1987.

**Table 2. Effect of some agronomic practices on the number of productive tillers per plant.**

| | Number of productive tillers per plant | | | | | |
|---|---|---|---|---|---|---|
| Treatment[1] | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo |
| P1F1W1 | 2.7 bc | 1.9 bc | 3.3 a | 2.9 ab | 3.8 abc | 2.3 c |
| P1F1W2 | 1.5 c | 1.2 d | 1.9 ab | 1.7 b | 2.9 c | 3.3 bc |
| P1F2W1 | 3.1 ab | 2.2 bcd | 2.4 ab | 2.1 ab | 3.9 abc | 3.4 bc |
| P1F2W2 | 1.7 bc | 1.2 d | 2.9 ab | 2.0 ab | 3.0 c | 2.9 c |
| P2F1W1 | 4.2 a | 1.9 bc | 3.0 ab | 2.5 ab | 3.0 c | 2.9 c |
| P2F1W2 | 1.6 c | 1.1 d | 2.5 ab | 2.2 ab | 4.5 ab | 3.8 abc |
| P2F2W1 | 3.1 ab | 2.1 bc | 3.4 a | 2.6 ab | 4.9 a | 4.2 ab |
| P2F2W2 | 2.0 b | 1.0 d | 3.1 ab | 2.0 ab | 3.2 b | 4.3 ab |

1. For explanation of observations and letters see Table 1.

**Table 3. Effect of some agronomic practices on the number of harvestable heads of *gero* millet.**

| | Number of harvestable heads | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | | 1986 | | 1987 | |
| Treatment[1] | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo |
| P1F1W1 | 95 ab | 51 df | 125 ab | 89 c | 133 ab | 90 cb |
| P1F1W2 | 78 bcd | 38 f | 88 c | 80 c | 148 a | 109 abc |
| P1F2W1 | 118 a | 53 def | 126 ab | 89 c | 115 abc | 97 bc |
| P1F2W2 | 77 bc | 45 f | 131 a | 93 b | 128 abc | 97 bc |
| P2F1W1 | 87 bc | 46 f | 90 c | 69 c | 116 abc | 99 bc |
| P2F1W2 | 51 d | 28 f | 94 bc | 62 c | 104 bc | 103 bc |
| P2F2W1 | 95 ab | 51 df | 93 bc | 79 c | 106 bc | 91 c |
| P2F2W2 | 54 def | 38 f | 29 bc | 67 c | 108 abc | 93 bc |

1. For explanation of observations and letters see Table 1.

## Discussion

Number of plants that survived to maturity was not affected by the field management practices. This meant that the rate of plant survival was proportional to the number of plants that were established per plot regardless of the plant density. It should be noted, however, that since the plants at the optimum plant density were twice as many as the plants at the sub-optimum plant density, for similar percentage rates of the plant survival at both plant densities, more plants were affected at the optimum than the sub-optimum plant density.

Number of tillers per plant that produced heads were low in the unimproved variety as compared to the improved variety and when the weeds were allowed to compete with the crop up to 4 WAS before control. Depressed tiller development might have originated from the adverse effects of the weed competition. Since the productive tillers are an important factor in the grain yield of *gero* millet (Yusufu 1985), the adverse effects of the weed infestation on tiller productivity accounted for the low grain yields for the delayed weed control and the unimproved variety.

Consistently highest grain yields were obtained when the improved variety was established and managed at optimum plant density, early weed control and delayed fertilizer application. This finding indicates the following: where the soil has sufficient mineral nutrients to effectively sustain normal growth and development at the initial stage of the crop growth delaying the application of fertilizer would not adversely affect the crop provided the other field management practices are not limiting. However, in soils that are deficient in the mineral nutrients, delaying the application of fertilizer would not give the same results since early growth as well as development of the plants, would suffered adverse effects of the nutrient deficiency. Furthermore, delaying the time of weed control reduced the grain yield. This confirmed the importance of timely weeding in the attainment of the optimum grain yield of millet, as shown by other studies (Egharevba 1978, Choudhary et al. 1979, Choudhary and Lagoke 1981).

Grain yield trends indicated the importance of each factor of production. Higher plant density and early time of fertilizer application had beneficial effects but the time of weed control and the variety had the over-riding effects. A combination of poor management practices resulted poorer yields and would suggest that farmers who use predominantly unimproved management practices for the production of this crop are unlikely to attain optimum grain yields.

**Table 4. Effect of some agronomic practices on the grain yield of *gero* millet.**

| | Grain yield (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | | 1986 | | 1987 | |
| Treatment[1] | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo | Ex Borno | Ex Bomo |
| P1F1W1 | 1281 ab | 1017 bcd | 748 ab | 689 ab | 2909 ab | 3106 a |
| P1F1W2 | 843 cde | 659 de | 537 b | 693 ab | 2819 ab | 3073 a |
| P1F2W1 | 1586 ab | 705 de | 1067 a | 582 ab | 2949 ab | 2734 ab |
| P1F2W2 | 691 de | 573 e | 741 ab | 648 ab | 2339 bc | 2685 ab |
| P2F1W1 | 1160 abc | 809 cde | 433 b | 481 b | 1822 c | 2595 ab |
| P2F1W2 | 544 e | 560 e | 782 ab | 448 b | 2529 abc | 2596 ab |
| P2F2W1 | 1257 ab | 633 de | 667 ab | 304 b | 2502 abc | 2822 ab |
| P2F2W2 | 629 de | 523 e | 615 ab | 348 b | 2658 ab | 2966 ab |

1. For explanation of observations and letters see Table 1.

## References


Agboola, S.A. 1979. Atlas of Nigeria. Oxford University Press, Oxford Great Britain, pp 81-85.

Choudhary, A.H., and Lagoke, S.T. 1981. Weed control in pearl millet in the savanna zone of Nigeria. Tropical Pest Management 27:465-471.

Choudhary, A.H., Lagoke, S.T., and Tanko, Y.M. 1979. Evaluation of herbicides for weed control in millet (*Pennisetum typhoides* (L.)) in the nigerian savanna. A paper presented at the 9th Annual Conference of the Weed Science Society of Nigeria, University of Ife, Ile-Ife, Nigeria, 3-4 Dec 1988.

Egharevba, P.N. 1978. A review of millet work at the Institute for Agricultural Research, Samaru. Samaru Miscellaneous Paper 77. Ahmadu Bello University, Zaria, Nigeria. 17 pp.

Egharevba, P.N. 1979. Agronomic practices for improved sorghum and millet production - two papers. Samaru Miscellaneous Paper 90. Ahmadu Bello University, Zaria, Nigeria. 21 pp.

Egharevba, P.N. 1981. Contribution of assimilate from different leaf zones to developing millet grain. Samaru Journal of Agriculture 1:27-36.

Ferraris, R. 1973. Pearl millet *Pennisetum typhoides* (L.). Commonwealth Bureau of Pasture and Field Crops Review series No. 1. Commonwealth Agricultural Bureaux, Bucks, UK, 1-49 pp.

Khader, F.H., Odion, C.E., Kaigama, B.K., and Oyinloye, A.K. 1979. Nitrogen fertilization and plant density for pearl millet production in northern Nigeria. Alexandra Journal of Agricultural Research 27:135-140.

Khader, F.H., and Oyinloye, A.K. 1977. Improvement of Nigerian millet and formation of two composites. Samaru Agricultural Newsletter, Nigeria 19:50-53.

Mariakulandai, A., and Morachan, Y.B. 1966. Results of manurial trials in Madras State on millet. Part 1 - cholam and cumbu. Madras Agricultural Journal 53:163-170.

Okoh, P.N., and Eka, O.U. 1978. Effect of traditional methods of preparation on the nutrient status of Fura-Nono: a fermented milk - cereal based food of the Hausas and the Fulanis in northern Nigeria. Savanna 7:67-70.

Okoh, P.N., Nwasike, C.C., and Ikediobi, C.O. 1985. Studies on seed protein of pearl millets 1. Amino acid composition of protein fractions of early and late maturing varieties. Journal of Agriculture and Food Chemistry 33:55-57.

Singh, L., Egharevba, P.N., Ogunlela, V.B., and Balasubramanian, V. 1983. New fertilizer recommendation for sole crop millet. Institute for Agricultural Research, Ahmadu Bello University, PMB 1044, Zaria, Nigeria, 15 pp.

Yusufu, I.K. 1985. Effect of plant population, sowing date and variety on tiller survival and yield of pearl millet *Pennisetum typhoides* (L.). M.Sc Thesis, Ahmadu Bello University, Zaria, Nigeria.

# Competitive Ability of Cowpea Genotypes in Crop Mixtures with Millet[1]

K.A. Elemo[2]

**Abstract**

*Performance of cowpea in crop mixtures with millet may be affected by genotype differences in competitive ability. This paper presents a field experiment aimed at assessing the competitive ability of cowpea genotypes in mixture with gero millet with a view to identifying those cultivars that are most adaptable to mixed cropping. Ten genotypes of cowpea were tested in sole and mixed crop with millet using a randomized complete block design. Sole millet was included as check.*

*Cultivation of cowpea in mixture with millet generally reduced cowpea grain yield irrespective of genotypes. Millet grain yield was, however, not affected by cowpea. For grain yield, the cowpea genotype x cropping systems interaction was significant. Ability of a cowpea genotype to be high yielding in sole crop did not necessarily mean that it would yield high in mixture. Genotypes Kano 1696 and Sampea 7 appeared most adaptable to mixed cropping with millet. In both 1986 and 1987, days to 50% bloom and 100-grain weight consistently correlated positively with cowpea grain yield in mixture but not in sole crop. These plant characters could be used in selecting genotypes that could compete better in mixture with millet.*

**Résumé**

**La capacité compétitive des génotypes du niébé en association avec le mil:** *Les génotypes peuvent être influents sur la performance du niébé associé au mil dans le système de cultures associées. Ce document présente une essai conduit au champ qui a pour objectif d'évaluer la capacité compétitive des génotypes du niébé en association avec le mil Géro en vue d'identifier des cultivars plus adaptés à la cultures associées. Dix génotypes du niébé cultivé isolément et puis associé au mil ont été testés en utilisant un dispositif complet randomisé en bloc. Le mil cultivé isolément a été incluse comme témoin.*

*La culture du niébé en association avec le mil a généralement réduit le rendement en grain du niébé quelqu'en soient les génotypes utilisés. Le rendement en grain du mil n'a cependant pas été affecté par l'association avec le niébé. Par contre, l'association du niébé x l'interaction des systèmes culturaux était significative pour le rendement en grain. La capacité du niébé d'avoir un rendement élevé quand il est cultivé isolément n'implique pas nécessairement qu'il aurait un rendement plus élevé que quand il est associé. Les Génotypes Kano 1696 et Sampea 7 ont paru être plus adaptables à la culture associée au le mil. En 1986 et 1987, le nombre de jours à 50 et 100% à la floraison, a régulièrement démontré une correlation positive entre le poids de grains et le rendement en grain du niébé en culture associé plutôt que quand il est cultivé isolément. Ces genres de plantes pourraient être utilisées pour la sélection des génotypes pouvant avoir une plus grande capacité compétitive en association avec le mil.*

## Introduction

The early maturing *gero* millet (*Pennisetum glaucum* (L.) R. Br.) is a principal staple food crop in the northern Guinea savanna of Nigeria. In the traditional farming system, *gero* millet is the first crop to be sown with the onset of rains. This is a strategy used to quickly produce grains to replenish the depleted reserves from the previous season's harvest caused by the period of six months of dry season. As millet is a photoperiod-insensitive crop maturing between 70-100 days (Nwasike et al. 1982), the harvesting coincides with the peak of the monomodal rainfall pattern in August. The rains terminate in September/October (Kowal and Knabe 1972) and cowpea (*Vigna unguiculata* (L.) Walp.) is grown as a complementary crop in mixture or relay with millet.

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Cropping Systems Agronomist, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Average grain yield of cowpea is low (150-200 kg $ha^{-1}$) in the traditional farming system. This has been attributed to the cultivation of photoperiod-sensitive indigenous genotypes without chemical pest control (IAR 1985). Nevertheless, recent advances in cowpea research have raised grain yield to between 1 500 and 2 000 kg $ha^{-1}$ in sole crop with chemical pest control (Hayes and Raheja 1977). Breeding efforts on cowpea in research institutes in the past have laid more emphasis on early to medium maturing (60-100 days) genotypes (Fisher et al. 1987). The consequence is the availability of a vast array of new genotypes belonging to these maturing groupings. The determination of their competitive ability in mixture with millet is desirable, if they are to find a place in the traditional farming systems.

This study was aimed at assessing the competitive ability of cowpea genotypes in mixture with *gero* millet with a view to identifying those genotypes that are most adaptable to mixed cropping.

## Material and Methods

### Cropping environment

This experiment was conducted during the rainy seasons of 1986 and 1987 at the research farm of the Institute for Agricultural Research (IAR), Samaru (11°11'N, 7°38'E and 675 m above mean sea level). This location is in the northern Guinea savanna of Nigeria. The soil is deep and imperfectly drained with the topsoil of fine sandy loam. Clay content increases from about 13% at the surface to about 40% at 20-40 cm depth. In 1986, the soil tested pH 4.5 (in 1:1 soil-water suspension), 0.06% N, 0.70% organic carbon, C.E.C. of 12.8 meq/100 g, K of 0.13 meq/100 g, Ca of 4.10 meq/100 g, Mg of 0.47 meq/100 g and available P of 11.81 pp. In 1987, the chemical analysis of the soil showed pH of 5.9, 0.04% N, 0.50% organic carbon, C.E.C. of 13.2 meq/100 g, K of 0.11 meq/100 g, Ca of 1.06 meq/100 g, Mg of 0.33 meq/100 g and available P 14.00 ppm. The site in 1986 was previously planted to groundnut during the preceding growing season, while cowpea was the previous crop on the 1987 site.

### Experimental treatments and design

The factorial experiment comprised of ten levels of cowpea genotypes and two levels of cropping system (sole and mixed crop with millet) in a randomized complete block design with three replicates. A sole millet (variety Ex Borno) treatment was also included. One of the cowpea genotypes, IT 82E-60, was early maturing (60-65 days) while one genotype, Kano 1696, (an improved local selection) was late maturing (more than 100 days). The remaining eight genotypes were of medium maturity (70-75 days).

### Cultural conditions

In sole crop, cowpea was sown on 75 cm spaced ridges. Two seeds were planted at intervals of 20 cm along ridge at about 1.5 cm depth without thinning. Sole millet was also established on 75 cm spaced ridges but at 25 cm spacing along ridge. About 6-7 seeds were sown per hole and later thinned to one plant per stand about a week after emergence.

The replacement series technique was used for the crop mixture. A ridge of millet was alternated with one of cowpea. The between and within ridge spacings were maintained for each component as in sole crops thus giving a 50:50 ratio. In both cropping systems, each plot was made up to six ridges (4.5 m wide and 7.0 m long) with the inner four ridges and the entire length of the plot constituting the harvest area. Millet was sown on 18 June in 1986 and 17 June in

1987 while cowpea was sown on 21 July in both years.

Fertilizer was applied to each component crop separately. Millet received the rate of 60 kg N $ha^{-1}$, 30 kg $P_2O_5$ $ha^{-1}$ and 30 kg $K_2O$ $ha^{-1}$ as calcium ammonium nitrate, single superphosphate and muriate of potash, respectively. Cowpea received the same P and K sources at the rate of 40 kg $P_2O_5$ $ha^{-1}$ and 40 kg $K_2O$ $ha^{-1}$, respectively. No nitrogen fertilizer was applied at planting.

The trial was hoe-weeded thrice (two weeks after emergence of millet, three days before sowing cowpea and two weeks after sowing cowpea). Insect pests were managed by spraying a tank mixture of cypermethrin and dimethoate at the rate of 50 g a.i. $ha^{-1}$ and 500 g a.i. $ha^{-1}$ respectively. Four sprays were applied to cowpea from first flowering at fortnightly interval. No fungicide was applied to cowpea.

## Results

### Cowpea grain yield and yield attributes

In both years, mixed cropping with *gero* millet severely lowered cowpea yields (Table 1). Cowpea genotypes differ in their yielding ability and this was again depended on the cropping pattern. In each year, the interaction effect of cropping system x genotypes was significant (Table 2).

**Table 1. Grain yield, shelling percentage, canopy height, days to 50% bloom and hundred grain weight of cowpea genotypes as influenced by mixed cropping with *gero* millet at Samaru, Nigeria.**

| | Grain yield (kg $ha^{-1}$) | | Shelling (%) | | Canopy height (cm) | | 50% to bloom (days) | | 100 grain weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 |
| **Cropping system** | | | | | | | | | | |
| Crop mixture | 235 | 172 | 64 | 66 | 43 | 33 | 54 | 51 | 11.2 | 15.9 |
| Sole crop | 599 | 918 | 67 | 70 | 45 | 44 | 53 | 50 | 11.5 | 15.1 |
| SE | ±31.3 | ±33.7 | ±1.1 | ±0.8 | ±0.9 | ±1.0 | ±0.2 | ±0.3 | ±0.22 | ±0.35 |
| **Cowpea genotype**[1] | | | | | | | | | | |
| TVX 4659-02E | 488 ab | 476 cde | 61 b | 67 bcd | 50 ab | 39 abc | 50 d | 48 de | 10.8 cd | 13.0 d |
| TVX 3236-01G | 328 bc | 557 bcd | 67 ab | 74 a | 42 cd | 33 c | 52 cd | 50 bcd | 9.6 d | 9.8 e |
| 339-1-2 | 526 ab | 277 e | 66 ab | 70 abc | 52 a | 40 abc | 52 cd | 47 e | 11.9 bc | 13.9 cd |
| IT 81D-1137 | 488 ab | 339 de | 68 ab | 71 abc | 48 abc | 42 ab | 51 d | 48 cde | 10.1 d | 19.6 b |
| Kano 1696 | 504 ab | 837 a | 73 a | 73 ab | 25 e | 28 d | 76 a | 77 a | 15.9 a | 22.2 a |
| Sampea 7 | 502 ab | 677 abc | 62 b | 68 abcd | 46 abc | 46 a | 52 cd | 46 e | 12.5 b | 15.7 c |
| IT 81D-988 | 316 bc | 728 ab | 63 b | 61 e | 38 d | 40 abc | 52 cd | 51 b | 10.8 cd | 20.4 ab |
| IT 82E-60 | 188 c | 256 e | 66 ab | 67 bcd | 43 bcd | 38 bc | 38 bc | 43 e | 10.5 cd | 18.7 c |
| Ife-Brown | 215 c | 480 cde | 65 b | 66 cde | 44 bcd | 44 ab | 53 bc | 47 e | 11.0 bcd | 12.5 d |
| TVX 1948-012F | 617 a | 829 a | 65 b | 64 de | 48 ab | 42 ab | 54 ab | 50 bc | 10.1 d | 12.2 d |
| SE | ±70.0 | ±75.4 | ±2.4 | ±1.7 | ±1.9 | ±2.3 | ±0.5 | ±0.6 | ±0.49 | ±0.78 |
| **Interaction** | | | | | | | | | | |
| Cropping system x cowpea genotype | * | ** | ns | ns | ns | ns | ns | ns | ns | ns |

1. For cowpea genotypes, means followed by same letter in a column are not significantly different at P<0.05 using Duncan's multiple range test.

* Significant at P<0.05, ** significant at P<0.01, ns = not significant.

**Table 2. Interaction effect of cowpea genotype and cropping system on grain yield of cowpea in mixture with *gero* millet in 1986 and 1987 at Samaru, Nigeria.**

| Cowpea genotype | 1986 Cropping system[1] Mixture with millet ($kg\ ha^{-1}$) | 1986 Cropping system[1] Sole crop ($kg\ ha^{-1}$) | 1987 Cropping system[1] Mixture with millet ($kg\ ha^{-1}$) | 1987 Cropping system[1] Sole crop ($kg\ ha^{-1}$) |
|---|---|---|---|---|
| TVX 4659-02E | 349 bcd | 628 ab | 107 gh | 845 cd |
| TVX 3236-01G | 131 d | 526 abc | 67 h | 1047 bc |
| 339-1-2 | 260 cd | 791 a | 99 h | 455 efg |
| IT 81D-1137 | 170 d | 807 a | 79 h | 598 de |
| Kano 1696 | 435 bcd | 574 abc | 596 de | 1076 bc |
| Sampea 7 | 161 d | 844 a | 284 efgh | 1069 bc |
| IT 81D-988 | 185 d | 447 bcd | 175 fgh | 1281 ab |
| IT 82E-60 | 119 d | 258 cd | 44 h | 468 ef |
| Ife-Brown | 143 d | 285 cd | 118 fgh | 843 cd |
| TVX 1948-012F | 400 bcd | 833 a | 153 fgh | 1506 a |
| SE | ±70.0 | | ±105.7 | |

1. In column and row for a year, means followed by, same letter are not significantly different at P<0.05 using Duncan's multiple range test.

In 1986, cowpea genotypes TVX 4659-02E, Kano 1696, IT 81D-988, IT 82E-60 and Ife-Brown produced mixture yields that were statistically comparable to their respective sole crop yields while at the same time each of the other genotypes produced significantly ($P<0.05$) higher sole crop yields (Table 2). On the other hand, mixture yield of genotypes TVX 4659-02E, Kano 1696 and TVX 1948-012F were as good as those produced by sole crops of TVX 3236-01G, IT 81D-988, IT 82E-60 and Ife-Brown. Nevertheless, cowpea grain yields were statistically similar in mixed crop but significantly different ($P<0.05$) in the sole cropping system.

In 1987, every cowpea genotype gave significantly ($P<0.01$) higher grain yield in sole crop than in mixture (Table 1). However, Kano 1696 produced a mixture yield that was comparable to the sole crop yield of TVX 4669-02E, IT 81D-1137, IT 82E-60 and Ife-Brown (Table 2). Similarly, Sampea 7, IT 81D-988, Ife-Brown and TVX 1948-012F gave mixture yields that were comparable to the sole crop yields of genotypes 339-1-2 and IT 82E-60. Nevertheless, the grain yields of Kano 1696 in sole crop was exceeded only by that of TVX 1948-012F, while those of TVX 3236-01G, Sampea 7 and IT 81D-988 were statistically similar to those of Kano 1696.

In both years, the interaction effect of cropping system x cowpea genotype on shelling percentage, canopy height, days to 50% bloom and hundred-grain weight was not significant (Table 1). However, the main effects of genotype and cropping system were generally significant. Attainment of 50% bloom appeared delayed in crop mixture, but shelling percentage, canopy height and hundred-grain weight were generally higher in sole crop. Except for its significantly shorter canopy, Kano 1696 generally gave higher shelling percentage, hundred-grain weight and days to 50% bloom than IT 82E-60 and Ife-Brown.

The correlations among yields of genotypes in sole and mixed crop were not significant ($r = 0.28$ in 1986, $r = 0.30$ in 1987). In both years, the hundred grain weight was highly significantly ($P<0.01$) associated with days to 50% bloom irrespective of cropping system ($r = 0.48$ for mixed crop and $r = 0.567$ for sole crop in 1987). Similarly, the canopy height was highly significantly ($P<0.01$) correlated to the days to 50% bloom consistently ($r = -0.704$ for mixed crop and $r = -0.612$ for sole crop in 1986, $r = -0.525$ for mixed crop and $r = -0.713$ for sole crop in 1987). In both years, days to 50% bloom and hundred-grain weight were consistently correlated with grain yield in crop mixture but not in sole crop (r = 0.49 for days to 50% bloom and r = 0.397 for hundred-grain weight in 1986 and r = 0.682 for days to 50% bloom and r = 0.426 for hundred-grain weight in 1987).

## Millet grain yield and plant attributes

Table 3 presents the data on grain yield and plant attributes for *gero* millet for the two years of study. Performance of millet was statistically similar irrespective of cropping system and cowpea genotype. Consequently, no correlation analysis was performed.

**Table 3. Grain yield, plant height, panicle length, and thousand-grain weight of *gero* millet in crop mixture with cowpea genotype and sole crop at Samaru, Nigeria.**

| | Grain yield ($kg\ ha^{-1}$) | | Plant height (cm) | | Panicle length (cm) | | 1,000 grain weight (g) | |
|---|---|---|---|---|---|---|---|---|
| Treatment | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 | 1986 | 1987 |
| TVX 4659-02E | 594 | 1370 | 212 | 243 | 41 | 39 | 12.1 | 9.7 |
| TVX 3236-01G | 1005 | 1640 | 211 | 243 | 38 | 41 | 8.2 | 9.9 |
| 339-1-2 | 827 | 1370 | 207 | 228 | 37 | 40 | 10.7 | 10.4 |
| IT 81D-1137 | 682 | 1660 | 225 | 238 | 39 | 38 | 9.6 | 10.8 |
| Kano 1696 | 826 | 1390 | 236 | 226 | 42 | 42 | 10.9 | 9.7 |
| Sampea 7 | 814 | 950 | 225 | 228 | 42 | 38 | 9.5 | 9.3 |
| IT 81D-988 | 666 | 860 | 221 | 231 | 37 | 39 | 8.5 | 9.9 |
| IT 82E-60 | 742 | 1580 | 215 | 238 | 38 | 40 | 9.9 | 11.6 |
| Ife-Brown | 853 | 1160 | 228 | 239 | 39 | 40 | 8.7 | 10.5 |
| TVX 1948-012F | 1222 | 1380 | 225 | 224 | 39 | 40 | 10.0 | 11.1 |
| Sole crop millet | 999 | 1850 | 224 | 241 | 39 | 39 | 11.0 | 9.9 |
| SE ± | ns | ns | ns | ns | ns | ns | ns | ns |

NS = Not significant.

## Discussion

The results indicate that cowpea genotypes differ in their response to cropping system. Varieties Kano 1696 and Sampea 7 generally appeared as best competitive in crop mixture with millet. Fisher et al. (1987) reported that late photoperiod-sensitive cowpea variety Kano 1696 yielded higher than TVX 1948-01F in mixed crop but was greatly inferior in sole crop. Davies and Garcia (1983) observed that the most competitive bean (*Phaseolus vulgaris*) varieties yielded most in intercrop but were not necessary the highest yielding in monoculture.

No relationship was observed between the yield of cowpea genotypes and those of millet, notwithstanding the fact that millet adversely reduced cowpea yield in mixture. In the mixed cropping system, millet is the dominant crop. It is taller and offers keen competition to cowpea in mixture. This explains why millet yield and plant attributes in mixture were not affected by cowpea. The earlier the cowpea is intersown into millet, the more it suffers from competition, as it then comes before millet (Egharevba and Fisher 1982). Sowing the cowpea late in the system could however result in low yield as to little time is left before the cessation of rains. Elemo (1989) found in a later study that increasing N dressing beyond 30 kg N $ha^{-1}$ decreased cowpea yield. In the present paper the recommended N dressing used on millet was 60 kg N $ha^{-1}$. This partly resulted into lower cowpea yields. It has been established that fertilizer N application in excess of 25 kg N $ha^{-1}$ reduces cowpea grain yield because N fixation of cowpea is inhibited. Nevertheless, grain yields of genotypes Kano 1696 and Sampea 7 appeared less reduced in mixture (Eaglesham et al. 1983; Ofori and Stern 1986).

The results show days to 50% bloom and hundred-grain weight were consistently correlated with cowpea grain yield in mixture but not in sole crop. This suggests that suitability of cowpea genotypes for mixed cropping with millet could be based on these two plant attributes. It could be concluded that the later the maturity of the cowpea and larger the seed size, the more adaptability it is in mixture with millet. It is evident in this study that cowpea genotypic suitability for crop mixture with millet could not be based on the sole performance.

## References


Davies, J.H.C., and Garcia, S. 1983. Competitive ability and growth habit of indeterminate beans and maize for intercropping. Field Crops Research 6:59-75.

Eaglesham, A.R.T., Hassouna, S., and Seegers, R. 1983. Fertilizer N effects on N2 fixation by cowpea and soyabean. Agronomy Journal. 75:61-66.

Egharevba, P.N., and Fisher, N.M. 1982. Farming systems research in northern Nigeria. Seminar paper delivered at Kansas State University, U.S.A. 23 pp.

Elemo, K.A. 1989. Millet/cowpea relay cropping as influenced by cultivar and nitrogen fertilization. Paper presented at the OAU/STRC/SAFGRAD Maize/Cowpea Joint Network at Lome, Togo, 20-24 Mar, 1989.

Fisher, N.M., Raheja, A.K., and Elemo, K.A. 1987. Insect pest control for cowpea in crop mixtures. Experimental Agriculture 23.9-20.

Hayes. H.M., and Raheja, A.K. 1977. Economics of sole cowpea production at the farmers' level using improved practices. Experimental Agriculture 13:149-154.

IAR. 1985. Sole crop cowpea production package for the savanna. Legumes and oil seeds research programme. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, 13 pp.

Kowal, J.M., and Knabe, D. 1972. An agroclimatology atlas of the northern states of Nigeria. Ahmadu Bello University, Zaria, Nigeria, 111 pp.

Nwasike, C.C., Baker, E.F.I., and Egharevba, P.N. 1982. The potential for improving millet (*Pennisetum typhoides* (Burm) Stapf and Hubb) in farming systems of the semi-arid areas of Nigeria. Agriculture and Environment 7:15-21.

Ofori, F., and Stern, W.R. 1986. Maize/cowpea intercrop system: effect of nitrogen fertilizer on productivity and efficiency. Field Crop Research 14:247-261.

# Screening Pearl Millet (*Pennisetum glaucum* (L.) R.Br.) for Postflowering Drought Response in West Africa.[1]

P.Bieler[2] and L.K.Fussell[3]

**Abstract**

*A field trial was carried out at ICRISAT Sahelian Center, Sadoré, Niger to evaluate a technique for screening pearl millet genotypes for response to postflowering drought. Yield and its attributes were analyzed and compared using an estimation of a drought response - DRI. Absolute values of all yield attributes were markedly reduced by the stress treatment. Correlation analysis indicated strong relationships of the DRI to yield attributes in the stress treatment, but not in the irrigated control.*

*Parameters of observed yield - phenotype relationships such as time to flowering and harvest index were identified as strong constitutive traits, i.e. equally well related to yield in stress whether measured in the control or stress treatment, but are measures of drought escape. Weaker constitutive traits such as panicle mass, grain yield per panicle, grains $m^{-2}$, and threshing percentage had markedly improved associations with stress yield under stress conditions, suggesting improved progress could be made in selecting for drought tolerance under drought conditions. Facultative traits were grain mass, panicles $m^{-2}$ and per panicle, i.e. such traits are associated with yield in the stress only when assessed in the stress.*

**Résumé**

**Criblage du petit mil (*Pennisetum glaucum* (L.) R. Br.) pour la réaction à la sécheresse d'après floraison en Afrique de l'Ouest:** *Un essai au champ a été conduit au Centre Sahélien de l'ICRISAT, Sadoré, Niger, afin d'évaluer une technique de criblage des génotypes du petit mil pour la réaction à la sécheresse d'après floraison. Le rendement et ses attributs ont été analysés et comparés à l'aide d'une estimation de la réaction à la sécheresse - DRI. Les valeurs absolues de tous les attributs du rendement ont été remarquablement réduites par le traitement de stress. L'analyse de corrélation a indiqué desfortes relations du DRI avec les attributs du rendement dans le traitement de stress, mais pas dans le contrôle irrigué.*

*Les paramètres de rapports phénotype - rendement observés tels que le temps à la floraison et l'indice de récolte ont été identifiés comme de caractéristiques constitutifs puissants, c'est-à-dire, en rapport équitable avec le rendement sous stress, qu'ils soient mesurés sous traitement stressé ou de contrôle. Cependant ils ne sont que des mesures de défense contre la sécheresse. Des caractéristiques constitutifs plus faibles tels que la masse paniculaire, rendement en grain par panicule, grains $m^{-2}$, et le pourcentage de battage, ont remarquablement amélioré les associations avec le rendement stressé sous des conditions stressées, laissant à croire ainsi que l'on pourrait arriver à une nette amélioration en faisant la sélection pour la tolérance à la sécheresse sous des conditions de sécheresse. Les caractéristiques facultatifs constaté étaient la masse en grains, panicules $m^{-2}$ et par panicule, c'est-à-dire, de tels caractéristiques sont associés avec le rendement sous stress s'ils sont seulement evalués sous stress.*

## Introduction

The Sahelian climate is characterized by high inter- and intra-seasonal variation of amount and duration of rainfall (Sivakumar 1986). Such rainfall variability leads to instability in the traditional means of crop production and the need for cropping systems and crop cultivars capable of coping with this variation. Frequent drought which results from this rainfall variability is one of the major abiotic factor reducing yields in the Sahelian zone, and as a consequence is a major constraint to pearl millet (*Pennisetum glaucum*

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT, Sahelian Center, Sadoré, Niger, 4-7 Sep 1989

2. Ph.D student, ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger.

3. Millet Agronomist, ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger.

(L.) R.Br.) production, the principal cereal in the zone. Furthermore, probability analysis suggests that drought stress is more likely to occur in this zone at the beginning or end of the rainy season than mid-season (Sivakumar 1986).

The extent of grain yield loss by drought is dependent on the stage of crop growth at which the drought occurs. Drought research in pearl millet has shown that prior to panicle initiation water stress did not affect the grain yield of the main shoot but increased tiller grain yield, resulting in a higher total grain yield (Mahalakshmi and Bidinger 1985b). Water stress during panicle development affected the growth of the main shoot reducing its grain yield, but this loss was compensated for by the better growth of the tillers (Mahalakshmi and Bidinger 1985a&b, Mahalakshmi and Bidinger 1986). Drought stress from the time of flowering and during grain-filling of pearl millet reduced grain yields of both main shoot and tillers, making this the most sensitive stage (Mahalakshmi and Bidinger 1985b; Bidinger et al. 1987a; Bidinger et al. 1988). Drought affecting the crop from the time of flowering resulted in a grain yield loss of 50%, reducing all yield components. Each day-advance in the onset of stress from flowering was shown to decreased the relative yield by 0.9%, mainly due to a reduction in grain number (Bidinger et al. 1988).

Since drought tolerance is a phenotypic expression in the stress environment, specific traits have to be identified to screen for postflowering drought. This necessitates the availability of a viable screening technique. By withholding irrigation from the time of flowering, Bidinger, Mahalakshmi, and Rao (1987a) were able to show varietal differences in grain yield of pearl millet. However, such differences are a result of the effects of yield potential, time to flowering and drought response. These researchers developed an analytical technique to remove the effects of yield potential and flowering from stress yield, calculating a drought response index (DRI) from the residual, for each genotype (Bidinger et. al. 1987b). The research described herein was undertaken to test in West Africa the postflowering drought screening method and analysis developed by Bidinger et al. (1987b), using materials largely of West African origin.

## Material and Methods

### Experimental design and treatments

A field trial was conducted at the ICRISAT Sahelian Center, Sadoré (13°N, 2°E) in Niger during the dry-season (February-May) in 1989. This period is characterized as rain-free, with high mean air temperatures, and large vapor pressure deficits which result in high potential evaporation rates (Fig.1).

The experimental designs were a modified split-plot, with main plots (irrigation treatments) replicated thrice and sub-plots (genotypes) twice within each main plot. Irrigation treatments consisted of a fully irrigated control and a postflowering stress where irrigation was terminated when 50% of the pearl millet genotypes reached 50% flowering. The postflowering stress was used to observe the effect of the water stress imposed during the grain filling period, simulating an early ending of the rains. The control (well-irrigated) treatment was used to measure non-stress crop characteristics of the potential yield and its components for comparative purposes with the stress treatment. Both treatments received regular sprinkler irrigation on a 4- to 7-day cycle (38mm per irrigation). Subplots were four rows (3.0m) by 4.8m, of which two rows by 2.0m(3.0m$^2$) were harvested at maturity. The remaining plants were used in a grain growth study, not reported here. A total of 45 genotypes were included in the experiments. However, only 41 entries were included in the final analysis , as certain genotypes were dropped because of high disease incidence, late planting and extremes in flowering date. The range in flowering date of the 41 included in the analysis was limited to 10 days (Table 1). The genetic material grown in the experiment were advanced breeding lines, released varieties and local landraces of Sahelian origins: Senegal, Mali, Burkina Faso, Niger and Nigeria.

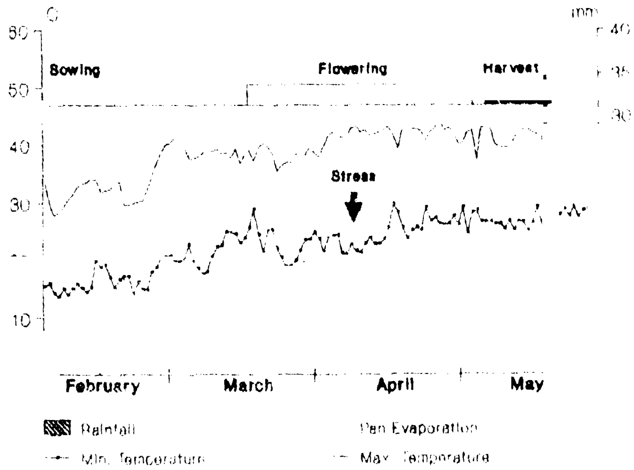



Figure 1. Daily maximum and minimum temperatures, total pan evaporation and rainfall during the crop's development (indicated by the upper horizontal line). Terminal Drought Screen, ISC dry season 1989.

## Crop management

The experiment was sown on a sandy loam soil (Alfisol, Labucheri series, after West et al. 1984) containing a sand fraction of more than 90% and more than 3m in depth. Seeds were sown by machine on ridges 0.75m apart and thinned to three plants per hill, 0.4m apart at 11-13 days after sowing (DAS). The resultant high plant population (100 000 plants $ha^{-1}$) hastened and enhanced drought stress after termination of irrigation. Before planting, farmyard manure and fertilizer were broadcast and incorporated with a tractor-drawn tyned cultivator, at the rate of 10 tonnes of manure $ha^{-1}$ and fertilizer at the rate of 45 kg $ha^{-1}$ of N, $P_2O_5$, and $K_2O$. A side dressing of 26 kg N $ha^{-1}$ was incorporated 18 DAS using a donkey-drawn tyned cultivator. Carbofuran was applied at the rate of 4 kg a.i. $ha^{-1}$ at the time of sowing. Apart from birdscaring, no other disease or pest control were required after planting. Weeds were controlled by mechanical cultivation and hand weeding once on the ridges.

## Observations and data analysis

Time to flowering was determined when stigmas had emerged on 50% of all inflorescences. All inflorescences of the yield plot were tagged at this stage to determine the flowering distribution of individual genotypes. At harvest, number of plants and panicles, grain yield, above-ground crop biomass and 100-grain mass (from triplicate samples of 100 grains taken at random from the bulk plot harvest) were recorded. Number of grains per panicle and per unit area, as well as, threshing percentage were derived from the data. All samples were oven dried at 70°C for 24h before weighing.

The method developed at the ICRISAT Center in Hyderabad, India (Bidinger et al. 1987a,b) was used to classify the genotypes according to a Drought Response Index (DRI). It is based on the assumption that the grain yield of a genotype under stress conditions ($Y_{si}$) is a function of potential yield under irrigated conditions ($Y_{pi}$), time to flowering ($FL_i$) and a drought response ($DR_i$):

$$Y_{si} = a + bY_{pi} + cFL_i + DR_i + E,$$

where E is random error with zero mean and variance $\delta$.

The parameters a,b and c can be estimated by minimizing the residuals ($DR_i$ + E) and the yield under stress estimated:

$$\hat{Y}_{si} = a + bY_{pi} + cFL_i$$

A test of significance of the drought response can be calculated as:

$$Z = |Y_{si} - \hat{Y}_{si}|/\delta$$

where $\delta$ is the standard error of $\hat{Y}_{si} = a + bY_{pi} + cFL_i$. The DRI is then calculated after considering a threshold value of Z (in this case, 1.3) and a new estimation of $\delta$, $\delta'$.

The drought response index (DRI) is based on DR and is defined as follows:

(i) if $|Y_{si} - \hat{Y}_{si}| \leq \delta'$, then $DRI_i = 0$

(ii) if $|Y_{si} - \hat{Y}_{si}| \geq \delta'$, then $DRI_i = (Y_{si} - \hat{Y}_{si})/\delta'$

$DR_i$ is, thereby, expressed as a multiple of $\delta'$ and may have a positive or negative value. The DRI calculated for all genotypes were correlated to yield components to identify traits related to drought response.

## Results and Discussion

### Effects of stress treatment on yield and phenology

Time to flowering ranged from 61 to 76 days, with little effect of stress treatment on the range (Table 1). Stress was imposed 66 DAS (Fig.2) which approximates closely to the mean 50% flowering of all genotypes in both treatments.

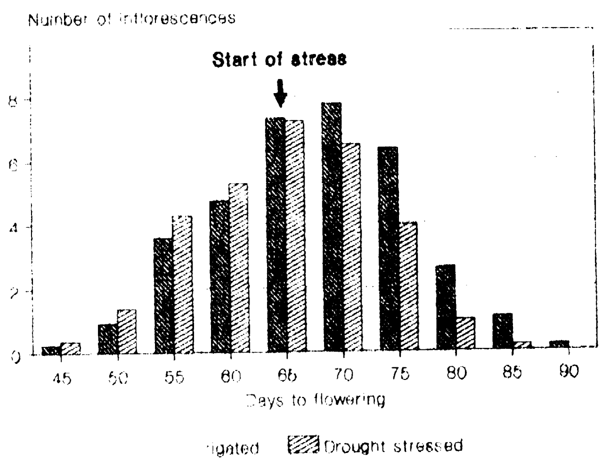



Figure 2. Flowering distribution of the trial's mean (all genotypes). Terminal Drought Screen, ISC dry season 1989.

Table 1. Treatment means, ranges and results of the analyses of variance in time to flowering, grain yield and yield attributes in the irrigated control and stress treatments. Postflowering Drought Screen, ISC dry season 1989.

| Variable | Irrigated control | | | | Post-flowering stress | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Range | F ratio | CV% | Mean | Range | F ratio | CV% |
| Time to flowering (d) | 67 | 61-76 | 12.1** | 3.6 | 66 | 57-74 | 12.8** | 3.6 |
| Biomass (g m-$^2$) | 873 | 674-1110 | 3.2* | 15.7 | 592 | 422-736 | 3.4* | 19.4 |
| stover (g m-$^2$) | 497 | 339-730 | 4.6** | 20.4 | 371 | 236-517 | 5.6** | 23.2 |
| panicle (g m-$^2$) | 378 | 316-460 | 2.4 | 14.5 | 221 | 151-286 | 2.7* | 23.9 |
| Grain yield (g m-$^2$) | 268 | 202-344 | 2.8* | 16.6 | 133 | 62-191 | 3.5* | 29.1 |
| yield panicle$^{-1}$ (g m-$^2$) | 23.7 | 14-30 | 4.5** | 15.5 | 13.2 | 6-18 | 4.3** | 22.1 |
| 100 grain mass (g) | 0.78 | 0.68-0.90 | 4.6** | 7.3 | 0.59 | 0.50-0.73 | 2.7 | 13.4 |
| Panicles m-$^2$ | 11.4 | 9-15 | 4.6** | 13.1 | 9.9 | 8-13 | 2.3* | 17.5 |
| Grains panicle$^{-1}$ | 3080 | 1660-3830 | 4.3** | 17.2 | 2240 | 999-3000 | 4.6** | 19.9 |
| $10^{-3}$ x gains m-$^2$ | 34.7 | 24.2-44.6 | 3.1* | 18.3 | 22.3 | 11.2-32.3 | 4.0* | 25.8 |
| Harvest index (%) | 31.3 | 20-41 | 6.3** | 13.0 | 22.7 | 12-34 | 5.5** | 24.4 |
| Threshing % | 71.0 | 64-76 | 2.6* | 6.6 | 58.7 | 37-69 | 6.2** | 9.7 |

* P <0.05, ** P <0.01

Considering firstly the mean effect of the irrigation treatments, postflowering drought stress reduced grain yield by 50% across all genotypes, mainly due to a reductions in number of panicles m$^2$ (13%) and grains per panicle (24%) (Table 1). A mean reduction in grain mass of 28% in the stress treatment compared to the irrigated control was largely a result of reduced length of the grain filling period (details of the grain growth study are not reported here). As a consequence of inferior grain number per panicle and lighter grains per panicle, threshing percentage fell from 70.6% in the irrigated control to 58.7% in the stress treatment. The biomass production was 32% lower in the stress treatment, compared to the irrigated control. Furthermore, harvest index was reduced from 31.1% in the well irrigated treatment to 22.7% in the stress treatment.

On average, the mean coefficient of variation across attributes increased from 14.2% in the irrigated treatment to 19.7% in the stress treatment (Table 1). With this slight increase, the significance of genotype differences, as judged by the F ratio from the analyses of variance, was as great in the stress treatment as in the irrigated control for all variables analyzed. The ability to distinguish statistical differences among varieties was therefore not necessarily poorer in the stress treatment than it was in the irrigated control treatment, which is an objection often raised against conducting trials in drought-stressed conditions.

The range in grain yield among varieties in the stress treatment was very broad (620 - 1910 kg ha$^{-1}$)(Table 1), indicating that there were considerable differences among the varieties tested in their ability to produce a yield under this type of drought stress. This broad range also presented an excellent opportunity to evaluate the factors which are related to such yield differences.

## DRI and its association with yield attributes

Drought response indices were calculated for the postflowering stress treatment using linear terms for both yield potential and time to flowering. The indices provide an estimate of drought response independent of time to flowering and yield potential, as indicated by the non-significant correlation of DRI to yield potential (grain yield in the control) and time to flowering

(Table 2). However, DRI was significantly related to grain yield in the stress and, therefore, does provide, in this trial, an indication of a genotypes performance under postflowering drought stress. Individual cultivar DRI values varied from less than -2.5 and more than +2.0. Out of 41 genotypes included in the analysis, 10 showed a positive value or tolerant drought response and 10 genotypes had a negative DRI or susceptible drought response. The remaining genotypes had a DRI=0, indicating their grain yield in the stress treatment could be adequately estimated using their yield potential and time to flowering.

Drought response indices were tested for their association with yield attributes to determine whether certain structures were useful selection predictors of stress response. Correlation analysis indicated that DRI was associated most directly ($P<0.001$) with grain yield, yield per panicle and panicle mass in the stress, and to a slightly lesser extent ($P<0.01$ or $P<0.05$) with high threshing %, grain mass, grains per panicle and per unit area (Table 2). Bidinger et al. (1987b) found similar associations when screening pearl millet genotypes largely from the Indian sub-continent.

**Table 2. Correlations of drought response index (DRI) with yield related variables in the control and stress treatments. Postflowering Drought Screen, ISC dry season 1989.**

| | Correlation coefficient | |
|---|---|---|
| Variable | Control | Stress |
| Time to flowering | 0.06 | 0.07 |
| Biomass | 0.13 | 0.50*** |
| Stover | 0.16 | 0.27 |
| Panicle | -0.03 | 0.54*** |
| Grain yield | -0.11 | 0.51*** |
| Yield panicle$^{-1}$ | -0.21 | 0.58*** |
| 100 grain mass | 0.06 | 0.41** |
| Panicles m$^{-2}$ | -0.30 | 0.12 |
| Grains panicle$^{-1}$ | 0.18 | 0.43** |
| Grains m$^{-2}$ | -0.02 | 0.42** |
| Harvest index | -0.16 | 0.18 |
| Threshing % | 0.01 | 0.34* |
| Stress/control yield | - | 0.65*** |

* P <0.05, ** P <0.01, *** P <0.001

**Table 3. Correlations of yield under stress to yield related variables in control and stress. Postflowering Drought Screen, ISC dry season 1989.**

| | Correlation coefficient | |
|---|---|---|
| Variable | Control | Stress |
| Time to flowering | 0.75*** | -0.66*** |
| Biomass | 0.09 | 0.15 |
| Stover | -0.30 | -0.28 |
| Panicle | 0.45** | 0.97*** |
| Yield panicle$^{-1}$ | 0.31* | 0.91*** |
| 100 grain mass | -0.02 | 0.51*** |
| Panicles m$^{-2}$ | 0.19 | 0.58*** |
| Grains panicle$^{-1}$ | 0.29 | 0.77*** |
| Grains m$^{-2}$ | 0.58*** | 0.92*** |
| Harvest index | 0.61*** | 0.61*** |
| Threshing % | 0.71*** | 0.85*** |

* P <0.05, ** P <0.01, *** P <0.001

In the irrigated control treatment no relationships of DRI to any of the yield attributes occurred (Table 2). This shows the necessity to have a drought environment to screen for postflowering drought resistance.

The relationships between DRI and yield attributes can be more clearly seen if means of the four most tolerant genotypes (i.e. largest positive DRI values) and the four most susceptible genotypes (i.e. largest negative DRI values) are compared (Table 4). There is very little difference between the mean of the susceptible and tolerant groups, and between these means and the trial mean for any of the attributes measured in the control treatment. This suggest that there is no inherent bias in the construction of the two groups of genotypes. Under stress, however, there are clear reductions in absolute values of the yield related characters which correspond with the low DRI values.

**Table 4. Various yield and plant characters of the four most susceptible and the four most tolerant genotypes to postflowering drought stress under control (C) and stress conditions (S). Postflowering Drought Screen, ISC dry season 1989.**

| | | Grain yield ($kg\ m^{-2}$) | | Flowering (days) | | 100 grain mass (g) | | Grains $m^{-2}$ ($x10^{-3}$) | |
|---|---|---|---|---|---|---|---|---|---|
| Genotype group | DRI | C | S | C | S | C | S | C | S |
| Susceptible | -2.24 | 274.8 | 103.7 | 66.3 | 64.1 | 0.80 | 0.56 | 34.6 | 18.2 |
| Tolerant | 1.58 | 278.2 | 169.8 | 67.1 | 65.2 | 0.82 | 0.64 | 34.0 | 26.1 |
| Trial mean | | 268.5 | 133 | 67 | 66 | 0.78 | 0.59 | 34.7 | 22.3 |
| CV % | | 16.6 | 29.1 | 3.61 | 3.6 | 7.3 | 13.4 | 18.3 | 25.8 |

| | Panicles $m^{-2}$ | | Grains $panicle^{-1}$ | | Threshing % | | Harvest index | | Biomass ($kg\ m^{-2}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | S | C | S | C | S | C | S | C | S |
| Susceptible | 12.7 | 9.9 | 2780 | 1840 | 77.2 | 55.6 | 33.6 | 21.6 | 0.84 | 0.50 |
| Tolerant | 11.0 | 10.3 | 3100 | 2550 | 71.8 | 63.9 | 31.5 | 26.1 | 0.89 | 0.65 |
| Trial mean | 11.4 | 9.9 | 3080 | 2240 | 71.0 | 58.7 | 31.3 | 22.7 | 0.87 | 0.59 |
| CV % | 13.1 | 17.5 | 17.2 | 19.9 | 6.6 | 9.7 | 13.0 | 24.4 | 15.7 | 19.4 |

**Table 5. Correlations of time to flowering (drought escape) and drought response index to yield related variables in the stress treatment. Postflowering Drought Screen. ISC dry season 1989.**

| | Correlation coefficient | |
|---|---|---|
| Variable | DRI | Flowering |
| Biomass | 0.50*** | 0.39* |
| Stover | 0.27 | 0.65*** |
| Panicle | 0.54*** | -0.59*** |
| Grain yield | 0.51*** | -0.66*** |
| Yield $panicle^{-1}$ | 0.58*** | -0.52*** |
| 100 grain mass | 0.41** | -0.46** |
| Panicles $m^{-2}$ | 0.12 | -0.58*** |
| Grains $panicle^{-1}$ | 0.43** | -0.36* |
| Grains $m^{-2}$ | 0.42** | -0.57*** |
| Harvest index | 0.18 | -0.83*** |
| Threshing % | 0.34* | -0.70*** |

* P <0.05, ** P <0.01, *** P<0.001

## Selection of drought tolerant traits

For the purpose of pearl millet improvement in general and for drought tolerance screening in particular, specific traits have to be identified. Traits associated with grain yield differed between treatments, indicating different phenotype response to the stressed and control environments. Facultative traits, that is, traits which are associated with yield in the stress only when assessed in the stress, were panicles $m^{-2}$, grains per panicle and grain mass (Table 3). Therefore, selection for these traits to improve adaptation to stress will require their selection in stress conditions.

Parameters of observed yield - phenotype relationship such as time to flowering and harvest index were identified as strong constitutive traits, i.e. equally well related to yield in stress whether measured in the control or stress treatments (Table 3). However, both are measure of drought escape, as harvest index is highly related to flowering (Table 5). Weaker constitutive traits were panicle mass, grain yield per panicle, grains $m^{-2}$, and threshing percentage. However, their relationship to stress yield markedly improved under stress conditions, suggesting more progress could be made in improving drought tolerance when such traits are selected under drought conditions.

Correlations of yield related traits in the stress treatment to the time of flowering (escape) and to the DRI (tolerance) were made to investigate which effect a particular trait represents (Table 5). Harvest index, stem biomass and panicles $m^{-2}$ were correlated to the time of flowering. These traits reflect drought escape. Although this study seeks to identify tolerance to drought, drought avoidance through photoperiod control of floral initiation and, thus, adjustment of cycle length is a valid breeding strategy for dealing with the likelihood of end-of-season drought.

Panicle biomass, grain yield per panicle, threshing %, grain mass, grains $m^{-2}$ are related to both time to flowering and DRI. Of these traits, grain yield per panicle is equally related to drought escape and tolerance, and is the most promising trait to be used for selection for drought tolerance. Genotypes with a panicle yield higher than the trials' mean show either an indifferent reaction to drought or have a positive response (Fig.3). This information can be used in interpretation of results from multilocational trials where postflowering drought has occurred. Selecting entries for their response to the drought purely on a final grain yield in such trials would possibly result in a selection of a high proportion of drought escapers (early flowering). By selecting entries on the basis of grain yield per panicle, a large proportion of genotypes which have a tolerant response to the drought could be identified.

Figure 3. Correlation of DRI to grain yield per panicle. Terminal Drought Screen, ISC dry season 1989.

In conclusion, this study has shown that the postflowering drought technique and analysis, as developed by Bidinger et. al. (1987b), was successful in differentiating genotypes for drought response. Similar yield - phenotype relationships observed in this study were reported by the methods' author, although the background of the genetic material, soil type and irrigation method were different.

## References


Bidinger, F.R., Mahalakshmi, V., and Rao, G.D.P. 1987a. Assessment of drought resistance in pearl millet. I Factors affecting yields under stress. Australian Journal of Agricultural Research 38: 37-48.

Bidinger, F.R., Mahalakshmi, V., and Rao, G.D.P. 1987b. Assessment of drought resistance in pearl millet. II Estimation of genotype response to stress. Australian Journal of Agricultural Research: 49-59.

Mahalakshmi, V., and Bidinger, F.R. 1985a. Flowering response of pearl millet to water stress during panicle development. Annual of Applied Biology 106: 571-578.

Mahalakshmi, V., and Bidinger, F.R. 1985b. Water stress and time of floral initiation in pearl millet. Journal of Agricultural Science, Cambridge 105: 437-445.

Mahalakshmi, V., and Bidinger, F.R. 1986. Water deficit during panicle development in pearl millet: yield compensations by tillers. Journal of agricultural Science, Cambridge 106: 113-119.

Mahalakshmi, V., Bidinger, F.R., and Rao, G.D.P. 1988. Timing and intensity of water deficits during flowering and grain-filling in pearl millet. Agronomy Journal 80: 130-135.

Sivakumar, M.V.K. 1986. Soil climatic zonation for West African semi-arid tropics - implications of millet improvement. Paper presented at the Regional Millet Workshop, Sept. 1986, Niger.

West, L.T., Wilding, L.P., Landeck, J.K., and Calhoun, F.C. 1984. Soil survey of the ICRISAT Sahelian Center, Niger, West Africa. Soil and Crop Science Department/Tropsoils, Texas A&M University System College Station, Texas, U.S.A., pp. 30-47.

# CROP IMPROVEMENT FACTORS AFFECTING PRODUCTION

# Etude de quelques Paramètres Génétiques des Cultivars de Mil (*Pennisetum glaucum* (L.) R. Br.) de Côte d'Ivoire et Stratégies de Sélection[1]

**M.B. Beninga[2]**

**Abstract**

**Studies of some genetic parameters of pearl millet of Côte d'Ivoire (*Pennisetum glaucum* (L.) R. Br.) and breeding strategies**: *Twenty-two S1 progenies from the first generation of selfed traditional millet varieties collected from Côte d'Ivoire were assessed at the 'Institut des Savannes' (IDESSA), in a trial during the 1983 rainy season. Analysis of the data collected from 11 vegetative and agronomic characters was used to calculate a correlation matrix, to estimate and splitting-up of the variances, to estimate their heritability in the wider sense and their expected genetic development.*

*Grain production was negatively correlated with the date of ear emergence of the principal tiller and positively correlated with the majority of the other characters (length and width of flag leaf, plant height, number of productive tillers, length and weight of the principal stem, grain weight of the principal stem). It is therefore interesting to calculate a selection index that integrates these variables.*

*The analysis of variance showed significant differences between the S1 progenies. Genetic variances of most of the characters were higher than the residual variances and have higher heritability. These can be rapidly improved through mass breeding (date of ear emergence, description of the flag leaf and the principal stem). Apart from the rapidity of the method, it results in an indirect yield improvement. However, the heritability and the genetic development of this method are limited. It is therefore necessary to use recurrent breeding in order to improve regularly the millet growth potential by increasing the frequency of favorable genes, while maintaining those genetic combinations that are interesting and genetically variability.*

*Vingt deux familles S1 issues de la première génération d'auto-fécondation de variétés traditionnelles de mil prospectées en Côte d'Ivoire ont été évaluées à l'Institut des Savanes (IDESSA), dans un essai pendant l'hivernage 1983. L'analyse des données recueillies pour 11 caractères végétatifs et agronomiques a permis d'établir une matrice des corrélations, l'estimation et la décomposition de leurs variances, leur héritabilité au sens large et le progrès génétique attendu.*

*La production de grains par plante est en corrélation négative avec la date d'épiaison de la talle principale et en corrélation positive avec la plupart des autres caractères (longueur et largeur de la feuille paniculaire, hauteur de la plante, nombre de talles productives, longueur et poids de la chandelle principale, poids de grains de la chandelle principale). Il est donc intéressant de calculer un index de sélection qui intègre ces variables.*

*Les analyses de variance indiquent des différences significatives entre les familles S1. La plupart des caractères ont des variances génétiques supérieures aux variances résiduelles et des héritabilités élevées. Ceux-ci peuvent être améliorés rapidement par sélection massale (date d'épiaison, description de la feuille paniculaire et de la chandelle principale). Outre la rapidité de la méthode, elle entraîne une amélioration indirecte du rendement. Toutefois, l'héritabilité et le progrès génétique de ce dernier sont limités. Il est nécessaire de recourir à la sélection récurrente pour améliorer régulièrement le potentiel de production du mil en augmentant la fréquence des gènes favorables, tout en maintenant les combinaisons géniques intéressantes et la variabilité génétique.*

## Introduction

Le mil (*Pennisetum glaucum* (L.) R. Br.) est cultivé traditionnellement en Côte d'Ivoire dans la partie septentrionale du pays comprise entre le 9e et le 11e parallèle. La production annuelle est de 40 000 t environ. Les variétés locales de taille très élevée (de 2 à 4 m), avec des chandelles moyennes (17 à 40 cm de

1. Papier présenté à l'Atelier Régional sur l'Amélioration du Mil, ICRISAT Centre Sahélien, Sadoré, Niger, 4-7 Sep 1989.

2. Sélectionneur Mil, IDESSA, B.P. 121 Ferkessédougou, Côte d'Ivoire.

long), peu larges (20 à 36 mm) et à grains gris-bleuté à gris jaune. Leur cycle végétatif est long (125-145 jours), elles sont sensibles à la photopériode et peu productives.

L'amélioration de cette espèce végétale nécessite une meilleure connaissance de l'organisation du génotype et des structures génétiques du matériel de départ. Dans la pratique, on recherche des informations précises sur les points suivants :

- o Existe-il une variabilité génétique suffisante pour permettre l'amélioration des caractères d'intérêt agronomique ?

- o Quels sont la nature et le degré de liaison entre les caractères principaux ?

- o L'héritabilité des caractères agronomiques les plus importants est-elle susceptible d'autoriser des progrès rapides ?

De telles informations existent pour diverses céréales tropicales comme le riz (*Oryza sativa* L.) (Sarthe et coll. 1969, Kaul et Bhan 1974), le maïs (*Zea mays* L.) (Stuber et coll. 1969) et le sorgho (*Sorghum bicolor* (L.) Moench) (Liang et coll. 1969, Eckebil et coll. 1977) mais rarement pour le mil (Gupta et Dhillon 1974, Pokhriyal et coll. 1967).

Un programme d'amélioration du mil a été initié en Côte d'Ivoire en 1979 par l'IDESSA et l'ORSTOM. Après une prospection des mils cultivés dans le nord du pays (Attey et Leblanc 1979), la diversité morphophysiologique des 72 cultivars collectés a été étudiée en essai à Ferkessédougou (Brac de la Perrière 1982). De même leur variabilité enzymatique a été établie (Leblanc et Pernes 1983). Ces études préliminaires sur la diversité des mils ivoiriens nous ont appris que :

- o la variabilité intra-cultivars est très importante par rapport à la variabilité de l'ensemble,

- o à l'exception de quelques isolats originaires de la région occidentale, il existe d'Est en Ouest un gradient continu de formes très lié aux courbes de précipitation qui s'échelonnent de 1 000 mm de pluie par an, à la frontière ghanéenne, à 1 500 mm à la frontière guinéenne (Fig 1),

- o les analyses électrophorétiques ont permis d'estimer les fréquences alléliques de chaque cultivar des trois marqueurs enzymatiques étudiés :

  Alcool deshydrogénase (ADH),
  Phosphoglucomurase (PGN),
  Phospho-gucoisomérase (PGI);

- o ces auteurs ont confirmé le cline Est-Ouest remarquable par une liaison positive pour l'ADH ( r = 0,67) et une liaison négative pour la PGM (r = -0,85) avec la position géographique des cultivars; et

- o la conservation du polymorphisme des mils de Côte d'Ivoire devrait être assurée grâce à plusieurs populations réservoirs regroupant dans des zones écologiques différentes du cline les variétés traditionnelles de la région.

L'objectif de cette étude est d'apporter une contribution à la connaissance des paramètres génétiques du mil. Sur un échantillon de 22 populations de la Côte d'Ivoire, on a calculé les corrélations, les résultats permettant de proposer des stratégies de sélection pour cette céréale.

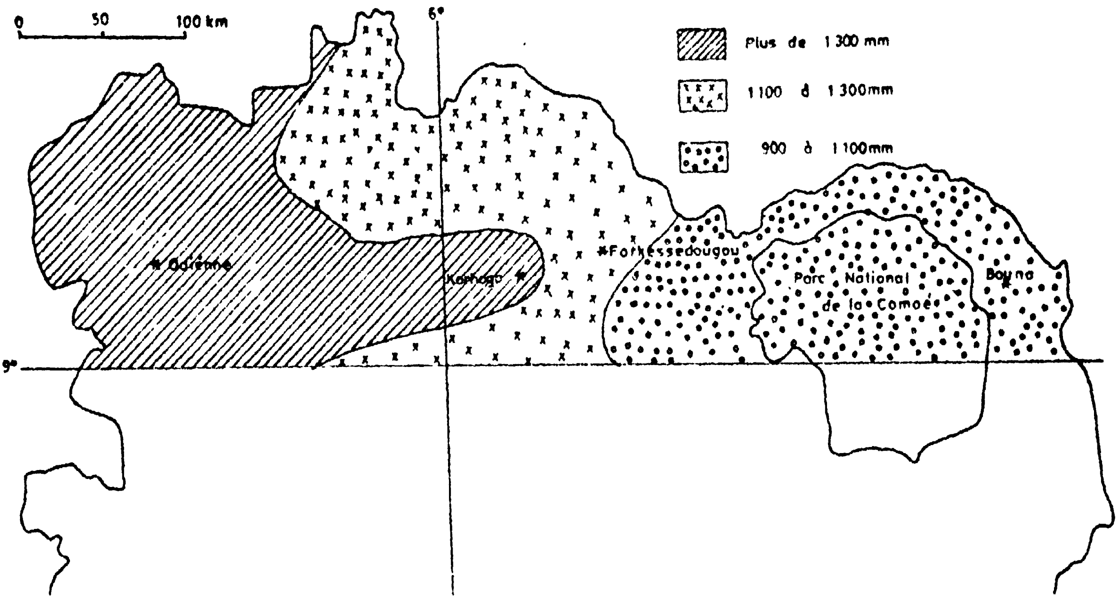



Figure 1. Limites approximatives des zones climatiques dans l'aire de culture du mil pénicillaire en Côte d'Ivoire.

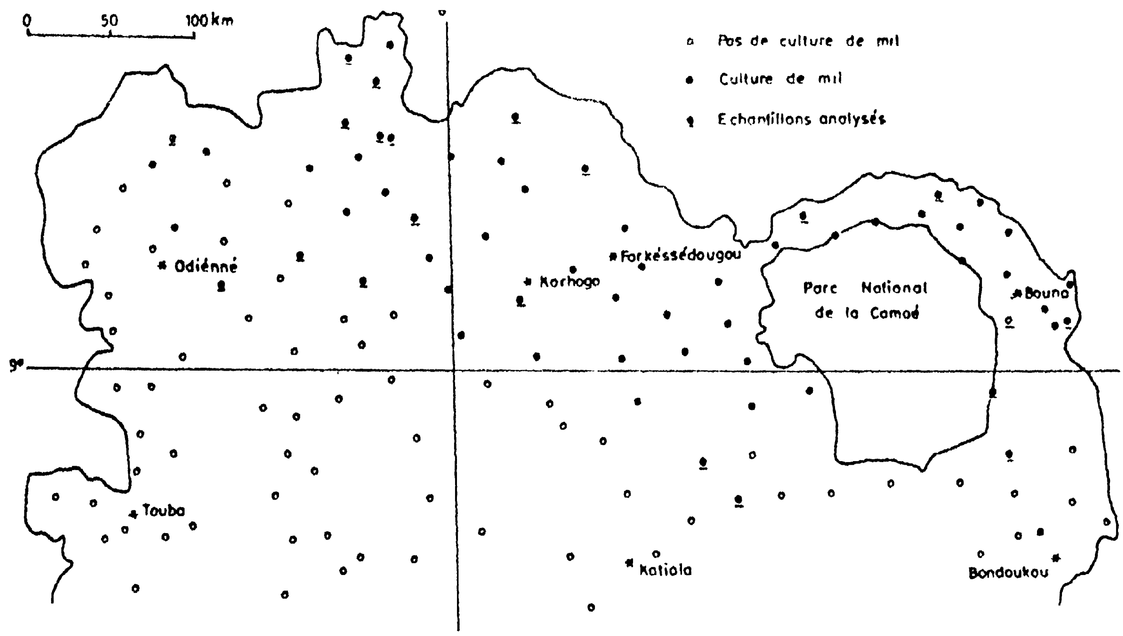



Figure 2. Localisation des cultivars traditionnels de mil collectés en avril [illegible] au nord de la Côte d'Ivoire.

## Matériels et Méthodes

### Le matériel végétal et conditions de culture

Vingt deux familles de mil issues de la première génération d'autofécondation ($S_1$) des variétés traditionnelles collectées (Attey et Leblanc 1979) ont été utilisées. Chaque famille est formée d'un bulk de 20 plantes $S_0$ autofécondées. Le matériel végétal est représentatif de l'aire de culture du mil en Côte d'Ivoire (Fig 2).

les descendances $S_1$ ont été mises en culture pendant l'hivernage 1983 à la station IDESSA de Ferkessédougou (9°36'N, 5°11'W, 330 m Côte d'Ivoire). Cette station est située dans une zone à saison des pluies unique allant d'avril à octobre avec une moyenne de 1 300 mm.

La préparation du sol était le labour, le pulvérisage et l'hersage. Le hersage est précédé d'un apport d'engrais complexe (15N - 27P - 27K). Le mil était semé sur billons, en poquets de 10 à 15 grains le 1er Août. La fumure minérale étant incorporée dans les billons et les écartements entre plantes sont de 1 mètre en tous sens. La pluviométrie totale de l'année 1983 a été de 881,4 mm ; cependant du semis à la récolte (mi-décembre) nous avons enregistré 459,3 mm de pluies.

Le démariage était à 3 semaines et à un pied/poquet, associé au premier sarclage (manuel) et les sarclages suivants à la demande.

### Dispositif Expérimental et Caractères Observés

L'essai a été conduit selon un dispositif en blocs randomisés à quatre répétitions, la parcelle élémentaire est un billon de 30 m long.

Le matériel végétal a été décrit plante par plante grâce à l'observation de onze caractères suivants :

o le cycle

1. date d'épiaison de la talle principale en nombre de jours (ETP);

o le développement végétatif

2. longueur de la feuille paniculaire appelée drapeau (LOD);
3. largeur du drapeau (LAD);
4. la hauteur de la plante à maturité (HAM);

o les composantes du rendement

5. le nombre de talles productives (NTP);
6. longueur de la chandelle (LOC);
7. largeur de la chandelle (LAC);
8. le poids de la chandelle principale entière (PCP);
9. le poids de grains de la chandelle principale (PGCP);
10. le poids de 100 grains (P 100 G);
11. le poids total de grains par plante (PTGP).

### Analyses statistiques

Les différentes analyses statistiques portent sur 40 plantes par famille $S_1$ (10 plantes ont été choisies au hasard par répétition).

La variance génotypique est estimée par la méthode employée par Kaul et coll (1974) :

$$V_G = \frac{\text{carré moyen "famille" - carré moyen de l'erreur}}{\text{nombre de répétitions}}$$

et la variance phénotypique $V_P$ est égale à la somme de la variance génotypique et de la variance de l'erreur.

$$V_P = V_g + V_e$$

Les coefficients de variation génétique sont obtenus en divisant la racine carrée de la variance génotypique par la moyenne de la population et exprimée en pourcentage.

$$C = \frac{V_g}{X_8}$$

Le progrès génétique est calculé selon la méthode de Allard (1960).

$$G_s = (k)\ (\delta_p)\ (H)$$

où : k = 2,06 pour une intensité de sélection de 5%

$\delta_p$ = écart-type phénotypique

H = héritabilité au sens large caractérisée par :

$V_g$

Résultats

L'analyse des réponses des 22 populations pour deux variables (ETP et PTGP) fait apparaître des différences de comportement selon leur position initiale dans le cline (Fig 3 et 4). Les populations provenant de l'Est sont tardives et peu productives tandis que celles issues des régions occidentales sont précoces et productives. Les mils de la région Ferkessédougou-Korhogo, du fait probable de brassages entre les deux formes extrêmes, présentent des caractéristiques intermédiaires. Dans son étude sur l'organisation de la variabilité globale des mils de Côte d'Ivoire, Brac de la Perrière (1982) a abouti aux mêmes conclusions.

L'étude des corrélations simples (effets inter-familles) entre les 11 variables utilisées permet de mesurer leur degré d'association à l'intérieur des 22 familles (Tableau 1). Elle porte sur la totalité des individus observés, soit 880 plantes. La date d'épiaison de la talle principale est corrélée négativement avec tous les caractères de développement végétatif et certaines caractéristiques de production (PCP, PGCP et PTGP). Il y a un développement végétatif et un rendement en grains d'autant plus faibles que la plante est tardive. Le poids total de grains par plante est corrélé positivement avec la hauteur de la plante à maturité (HAM), la taille du drapeau (LOD, LAD) et la plupart des composantes du rendement: nombre de talles productives (NTP), longueur de la chandelle (LOC), le poids de grains de la chandelle principale (PGCP); elles mêmes corrélées entre elles. Le poids de 100 grains et le nombre de talles productives sont corrélés négativement tout comme le sont la largeur de la chandelle et la hauteur de la plante à maturité.

L'analyse de variance caractère par caractère (Tableau 2) révèle

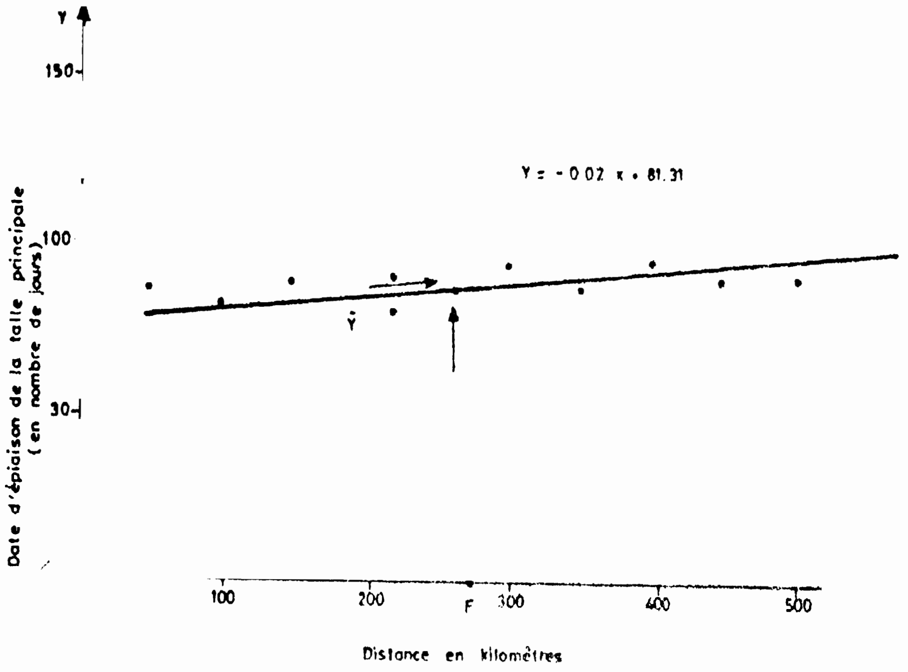



Figure 3. Régression de la date d'épiaison de la talle principale selon la distance de prélèvement des échantillons (en kilomètre). L'origine des abscisses (0) présente la ville d'Odiénné et F présente la ville Férkéssédougou.

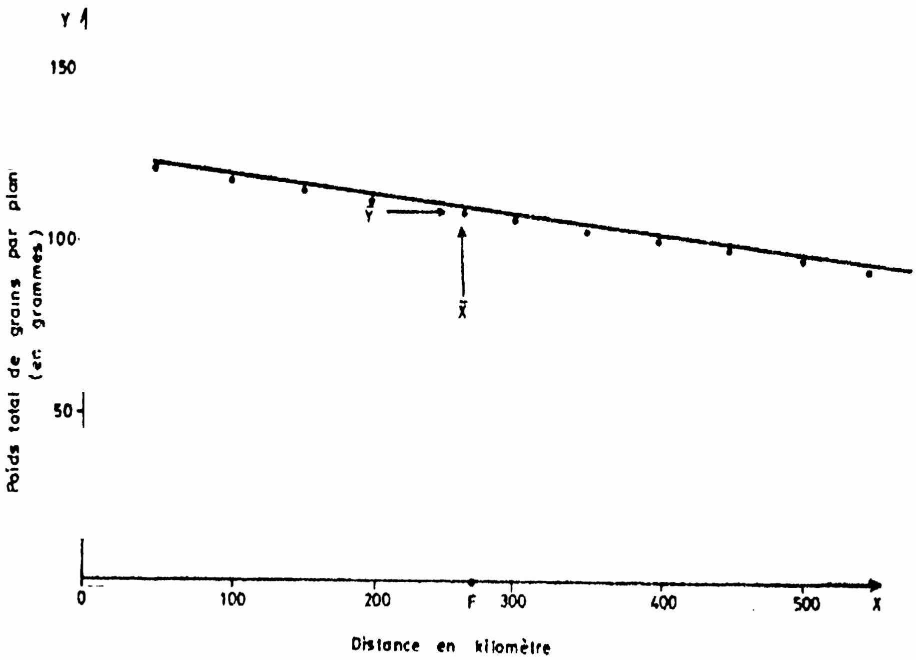



Figure 4. Régression du poids de grains par plante selon la distance de prélèvement des échantillons (en kilomètre). L'origine des abscisses (0) présente la ville d'Odiénné et F présente la ville Férkéssédougou.

Tablelau 1. Coefficients de corrélation entre les différents caractères.

| | ETP[1] | LOD | LAD | HAM | NTP | LOC | LAC | PCP | PGCP | P100G |
|---|---|---|---|---|---|---|---|---|---|---|
| LOD | -0.88** | | | | | | | | | |
| LAD | -0.87** | 0.93** | | | | | | | | |
| HAM | -0.59** | 0.54** | 0.49* | | | | | | | |
| NTP | -0.73** | 0.68** | 0.73** | 0.42ns | | | | | | |
| LOC | -0.80** | 0.72** | 0.72** | 0.73** | 0.63** | | | | | |
| LAC | -0.17ns | 0.08ns | 0.15ns | -0.60** | -0.10ns | -0.35ns | | | | |
| PCP | -0.61** | 0.69** | 0.73** | 0.53* | 0.43* | 0.57** | 0.22ns | | | |
| PGCP | -0.51* | 0.58** | 0.62** | 0.41ns | 0.34ns | 0.49* | 0.30ns | 0.95** | | |
| P100G | 0.38ns | -0.33ns | -0.28ns | -0.25ns | -0.62** | -0.39ns | 0.30ns | -0.03ns | 0.13ns | |
| PTGP | -0.69** | 0.64** | 0.68** | 0.60** | 0.63** | 0.63** | -0.01ns | 0.80** | 0.78** | -0.11ns |

[1] Se reporter au tableau 2 pour les caractères.
* = significatif P<0.05
** = significatif P<0.01
ns = non significatif

Tableau 2. Valeurs de F données par les analyses de variance univariable.

| Caractères | Bloc | Famille |
|---|---|---|
| Date d'épiaison de la talle principale (ETP) | 3.1* | 20.4** |
| Longueur du drapeau (LOD) | 0.3ns | 5.3** |
| Largeur du drapeau (LAD) | 6.3** | 12.8** |
| Hauteur de la plante à maturité (HAM) | 15.1** | 5.4** |
| Nombre de talle productives (NTP) | 1.7ns | 3.8** |
| Longueur de la chandelle (LOC) | 3.0* | 19.0** |
| Largeur de la chandelle (LAC) | 5.0** | 11.0** |
| Poids de la chandelle principale (PCP) | 1.0ns | 6.8** |
| Poids de grains par chandelle principale (PGCP) | 4.6** | 3.8** |
| Poids de 100 grains (P100G) | 5.8** | 3.1** |
| Poids total de grains par plante (PTGP) | 6.0** | 2.3** |

* = significatif P<0.05
** = significatif P<0.01
ns = non significatif

Tableau 3. Estimation des variances phénotypique, génotypique et de l'erreur des différents caractères et leurs coeffcients de variation.

| | Variance phénotypique | riance otypique | Variance de l'erreur | Coefficient de variation génotypique (%) | Coefficient de variation phénotypique (%) | Valeurs moyennes des caractères |
|---|---|---|---|---|---|---|
| Date d'épiaison de la talle principale (jours) | 29.8 | 24.7 | 5.1 | 16 | 6 | 86.8 |
| Longueur du drapeau (cm) | 83.4 | 43.4 | 40.0 | 17 | 24 | 38.2 |
| Largeur du drapeau (cm) | 0.2 | 0.2 | 0.10 | 11 | 13 | 3.5 |
| Hauteur de la plante à maturité (cm) | 745 | 407 | 368 | 8 | 10 | 265 |
| Nombre de talle productives | 6.2 | 1.8 | 4.4 | 14 | 28 | 9.8 |
| Longueur de la chandelle (cm) | 20.6 | 16.9 | 3.8 | 16 | 18 | 25.0 |
| Largeur de la chandelle (cm) | 0.10 | 0.0 | 0.0 | 8 | 10 | 2.5 |
| Poids de la chandelle principale (g) | 40.10 | 23.7 | 16.4 | 20 | 26 | 24.6 |
| Poids de grains par chandelle principale (g) | 13.8 | 5.6 | 8.2 | 18 | 28 | 13.7 |
| Poids de 100 grains (g) | 0.10 | 0.10 | 0.0 | 10 | 20 | 0.9 |
| Poids total de grains par plante (g) | 1450 | 361 | 1090 | 17 | 34 | 111 |

l'existence de différences hautement significatives entre les moyennes des familles $S_1$ pour les variables étudiées.

Les estimations des variances des 11 caractères et de leurs composantes sont présentées ainsi que les coefficients de variation (CV) correspondants dans le tableau 3. La variabilité phénotypique dans les familles de mil étudiées dépend des caractères considérés :

C.V. > 30% : production de grains par plante

C.V. 20 à 29% : longueur du drapeau, nombre de talles productives, poids total et de grains de la chandelle, poids de 100 grains,

C.V. 10 à 19% : largeur du drapeau, hauteur de la plante, longueur de la chandelle.

C.V. < 10% : date d'épiaison, largeur de la chandelle.

Afin de préciser la part de la variabilité totale due aux causes génétiques, nous avons estimé pour chacune des onze variables leur héritabilité au sens large. Puis nous avons calculé le progrès ou grain génétique qui représente la différence entre la valeur génotypique moyenne de la sous-population échantillonnée et celle de la population source. Ces deux paramètres (héritabilité et gain génétique) sont très utiles pour la conduite de la sélection. Ces différentes estimations sont présentées au tableau 4.

La date d'épiaison de la talle principale, la largeur du drapeau et les caractéristiques de la chandelle (longueur, largeur et poids) présentent les plus fortes valeurs d'héritabilité (0,67 à 0,83). Par contre certains caractères associés au rendement et le poids de 100 grains ont de faibles héritabilités.

Les progrès génétiques attendus en pourcentage des moyennes varient de 9 à 31%. Les plus fortes valeurs concernent le poids et la longueur de la chandelle principale. Suivent la longueur du drapeau (26%), le poids de grains par chandelle principale (23%) et la largeur du drapeau (21%), le poids de 100 grains possède la plus faible valeur (9%).

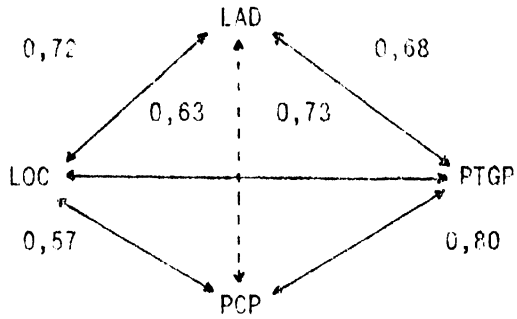
**Tableau 4. Héritabilité et progrès génétique des onze caractères.**

| | Héritabilité en % | Progrès génétique | Progrès génétique attendu en % de la moyenne |
|---|---|---|---|
| Date d'épiaison de la talle principale | 83 | 9.3 | 11 |
| Longueur du drapeau | 52 | 9.8 | 26 |
| Largeur du drapeau | 76 | 0.7 | 21 |
| Hauteur de la plante à maturité | 52 | 30.1 | 11 |
| Nombre de talle productives | 29 | 1.5 | 15 |
| Longueur de la chandelle | 82 | 7.7 | 31 |
| Largeur de la chandelle | 67 | 0.3 | 14 |
| Poids de la chandelle principale | 59 | 7.7 | 31 |
| Poids de grains par chandelle principale | 41 | 3.1 | 23 |
| Poids de 100 grains | 23 | 0.1 | 9 |
| Poids total de grains par plante | 25 | 19.5 | 18 |

## Discussion

Ce travail se proposait d'étudier quelques paramètres génétiques des mils de Côte d'Ivoire afin d'en proposer des stratégies de sélection.

Pour les onze caractères végétatifs et reproductifs étudiés dans 22 familles $S_1$, l'observation des coefficients de corrélation indique de nombreuses liaisons dont sept concernent le rendement. En effet, ce dernier est lié positivement d'une part avec des descripteurs de la structure de la plante (longueur et largeur de la feuille paniculaire, la hauteur de la plante à maturité et le nombre de talles utiles), et d'autre part avec les caractéristiques de la chandelle (longueur de la chandelle, poids de la chandelle principale et poids de grains par chandelle principale). Les inter-relations les plus marquantes avec le rendement sont schématisées ainsi:




L'existence d'une corrélation positive entre le poids total de grain par plantes et la hauteur de la plante ématurité est en accord avec les résultats obtenus par d'autres chercheurs (Pokhryial et coll. 1967, 1976; Singh et Murty 1973, Gupta et Dhillon 1974). Cette relation indique la difficulté d'une création de variété à haut rendement de taille réduite. Comstock et coll. (1949) ont montré que par une sélection récurrente réciproque on peut contourner cette difficulté et briser une telle liaison entre les deux caractères, ce qui crée un surcroît de variabilité exploitable.

L'absence de liaison significative entre la longueur et la largeur de la chandelle indiquerait leur indépendance.

La mise en évidence d'une liaison négative entre le poids de 100 grains et le nombre de talles utiles peut s'interpréter en terme de compensation au niveau des plantes à tallage réduit : elles pallient cette déficience par des grains plus lourds. En outre, le tallage dépend de la date de semis des mils photosensibles et rend difficile l'utilisation de ce caractère en sélection.

Des causes génétiques et physiologiques expliqueraient les différences de caractères mises en évidence comme par exemple :

o des liaisons entre les caractères végétatifs hauteur de la plante à maturité, longueur et largeur de la feuille paniculaire. Plus la plante est grande, plus sa feuile paniculaire est longue et large.

o des liaisons entre les caractéristiques de la chandelle principale (longueur, poids de la chandelle principale et poids de grains par chandelle principale).

Les analyses de la variance et de ses composantes montrent la grande variabilité génétique du matériel évalué. Cette variabilité génétique explique la bonne adaptation des mils ivoiriens aux diverses conditions de culture et de l'environnement :

o sols chimiquement pauvres et variables dans l'espace,
o pluies irrégulières dans leur importance et leur répartition,
o pratiques agronomiques diverses d'une sous-région à une autre.

A l'exception de la production de grains par plante, la plupart des variables ont des variances génotypiques supérieures aux variances résiduelles. L'héritabilité forte des caractères date d'épiaison de la talle principale, largeur de la feuille paniculaire et les caractéristiques de la chandelle principale (longueur, largeur et poids) met en relief leur transmission à la descendance. La forte héritabilité peut provenir aussi d'une faible variabilité du caractère intra $S_1$ (donc d'un haut degré de fixation du caractère).

Mises à part la date d'épiaison de la talle principale et la largeur de la chandelle principale, les autres caractères sont positivement liés au rendement et entre eux (Tableau 1). Il est donc possible d'établir un index ou note composite de sélection (Demarly 1977, Falconer 1981) qui intègre les variables largeur du drapeau (LAD), longueur de la chandelle (LOC) et poids total de la chandelle.

Un caractère à héritabilité faible comme le rendement est génétiquement et physiologiquement très complexe. Il a en général une variance additive faible (15% chez le cotonnier et 30% chez le maïs, Demarly 1977). C'est donc la variance de dominance qui a une part croissante dans la réalisation du rendement et de ses composantes. Dans leurs travaux sur le mil, Govil et coll. (1982) ont abouti à la même conclusion.

L'estimation du progrès génétique (fait ici en fonction d'un schéma de sélection basé sur k) constitue avec l'héritabilité et les coefficients de variation génotypique des indicateurs fort utiles pour le sélectionneur. Les valeurs les plus élevées ont été acquises dans notre cas pour les caractères : longueur de la feuille paniculaire, hauteur de la plante à maturité et poids de la chandelle principale. Ce sont les effets génétiques de type additivité qui expliquent les variations observées. Ils représentent la part constante qui participe à la réalisation d'un phénotype.

A la lumière de ces faits, il est nécessaire d'utiliser des schémas de sélection basés sur les méthodes d'amélioration inter-population (sélection récurrente et sélection récurrente réciproque) pour améliorer régulièrement le potentiel de production du mil. Ces schémas sont susceptibles d'exploiter les actions génétiques de type dominance et additivité (cas de la sélection récurrente réciproque). Celle-ci augmente non seulement la fréquence des gènes favorables mais maintient également les combinaisons géniques intéressantes et la variabilité génétique. Les mils de l'Est et ceux de l'Ouest qui se distinguent par leurs cycles et leurs caractéristiques de production pourraient ainsi être menés en amélioration réciproque en vue de créer des variétés-populations.

Par la sélection massale, il est possible d'améliorer rapidement les caractères fortement héritables qui sont liés entre eux tels que la date d'épiaison de la talle principale, la largeur de la feuille paniculaire, la longueur, la largeur et le poids de la chandelle principale. L'intérêt évident d'une telle stratégie est l'amélioration rapide et indirecte du rendement.

Remerciements

Cette étude est tirée des travaux de recherche sur le mil à l'Institut des Savanes (IDESSA), station de Ferkessédougou (Côte d'Ivoire). A la direction de l'institut et à travers elle au ministère de tutelle, j'exprime toute ma gratitude. Je voudrais aussi adresser au Prof. J. Pernes de l'Université de Paris XI (Orsay) et au Dr. A. Charrier de l'ORSTOM (Paris) mes vifs remerciements pour leurs suggestions très critiques.

## Bibliographie

Allard, R.W. 1960. Principles of plant breeding. John Willey & Sons, Inc. 485 pp.

Attey, Koffi, et Leblanc, J.M. 1979. Prospection des mils-sorghos-fonios en Côte d'Ivoire. Rapport de mission (IRAT-ORSTOM). 36 pp.

Brac de la Perrière, R. 1982. Contribution à l'évaluation, la conservation et le dévelopement du mil (*P. typhoides* Brum Stapf et Hubb) de Côte d'Ivoire. Thèse 3e cycle, spécialité Amélioration des Plantes, Paris XI, Orsay, 111 pp.

Comstock, R.E., Robinson, H.F., and Harvey, P.H. 1949. A breeding procedure designated to make maximum use of both general and specific combining ability. Agronomy Journal 41:360-367.

Demarly, Y. 1977. Génétique et amélioration des plantes. Masson, Paris, 287 pp.

Eckebil, J.P., Ross, W.M., Gardner, C.O., and Maranville, J.W. 1977. Heritability estimates, genetic correlations and predicted grains from S1 progeny tests in three grain sorghum randommating populations. Crop Sciences 17:373-377.

Falconer, D.S. 1981. Introduction to quantitative genetics. Longman Inc., New York, 340 pp.

Govil, J.N., Pokhriyal, S.C., and Murty, B.R. 1982. Full-sib and reciprocal recurrent selection in relation to pearl millet improvement. Theorical and Applied Genetics 62:25-30.

Gupta, V.P., and Dhillon, B.S. 1974. Variation and covariation of some plant and grain trials in pearl millet. Indian Journal of Agricultural Science 44:213-216.

Hallauer, A.R. 1970. Genetic variability for yield after four cycles of reciprocal recurrent selections in maize. Crop Sciences 10:482-845.

Kaul, M.L.H., and Bhan, A.K. 1974 Studies on some genetic parameters of rice (*Oryza sativa* L.). Theorical and Applied Genetics 44:178-183.

Leblanc, J.M., and Pernes, J. 1983. Enzyme polymorphism of *Pennisetum americanum* in Ivory Coast. Japanese Journal of Genetic 58:121-131.

Liang, G.H.L., Walter, T.L., Nickell, C.D., and Kho, Y.O. 1969. Heritability estimates and interrelationship among agronomic traits in grain sorghum (*Sorgum bicolor* (L.) Moench). Canadian Journal of Genetical Cytology 11:199-208.

Pokhriyal, S.C., Mangath, K.S., and Gangal, L.K. 1967. Genetic variability and correlation studies in pearl millet (*Pennisetum typhoides* (Burm. F.) Stapf and C.E. Hubb). Indian Journal of Agricultural Science. 37:77-82.

Pokhriyal, S.C., Mangath, K.S., and Pantil, R.R. 1976. Agronomic traits influencing seed yield in pearl millet. Indian Journal of Heredity 8:49-52.

Sarthe, M.L., Sharma, K.K., and Shrivastava, M.N. 1969. Study of yield attributes and heritability in some varieties of rice (*Oriza sativa* L.). Indian Journal of Agricultural Science 39:925-929.

Singh, B.B., and Murthy, B.R. 1973. A comparative analysis of biparental mating and selfing in pearl millet (*Pennisetum typhoides* (Burm.) S.H.). Nature of variation and changes in Association. Theorical and Applied Genetics 43:18-22.

Stuber, C.W., Moll, R.H., and Hanson, W.D. 1969. Genetic variances and interrelationships of six traits in a hybrid population of *Zea mays* L. Crop Science 6:455-459.

# Recurrent Selection in the Malian Pearl Millet Composite Souna x Sanio[1]

Oumar Niangado[2] and K. Anand Kumar[3]

**Abstract**

*One cycle of recurrent selection, using S1 progeny testing, was carried out on a Malian pearl millet composite Souna x Sanio. Using replicated S1 progeny evaluation at two locations, progenies were identified for variety development and recombination into C1 composite bulk. Based on performance of the progenies at individual locations and across two locations, five varieties were developed. Yield increases of the varieties, over the C0 composite ranged from 6% to 35%. Two promising varieties were identified for multilocational evaluation in Mali.*

**Résumé**

**Sélection récurrente dans la Composite du petit mil Malien Souna x Sanio**: *Un cycle de sélection récurrente à l'aide du test de descendance S1 avait été conduit sur la composite du petit mil Malien, Souna x Sanio. À l'aide d'une évaluation de la descendance S1 répétée dans deux localités, des descendances ont été identifiées pour développement et recombinaison dans l'ensemble de la Composite C1. A partir de la performance de ces descendances au niveau de chacune de ces localités et à travers deux localités, 5 variétés ont été developées. L'augmentation dans le rendement des variétés, sur la composite C0 était de 6% à 35%. Deux variétés promettantes ont été identifiées pour une évaluation multilocale au Mali.*

## Introduction

Recurrent selection is a cyclical scheme of plant selection by which frequencies of favorable genes are increased in plant populations. The basic objective of all recurrent selection methods is to systematically increase the frequency of desirable genes in a population so that opportunities to extract superior genotypes are enhanced (Hallauer 1981). The success of population breeding methods, particularly recurrent selection, in the improvement of maize populations has led to its application in the improvement of other cross-pollinated crops such as pearl millet (*Pennisetum glaucum* (L.) R.Br).

In West Africa mass selection and recurrent selection using $S_1$ testing, have been used in the improvement of pearl millet landrace populations. Niangado and Ouendeba (1987) cited examples of population improvement approaches to improve landraces in West Africa. Methods employed were mass selection, recurrent selection with topcross testing and recurrent selection with $S_1$ testing. In India, recurrent selection using full-sib selection on the World Composite, constituted in 1971 in Nigeria by the Institute for Agricultural Research, Ahmadou Bello University (Andrews et al. 1985) led to the development of variety WC-C75 (ICMV-1) which averaged 98% of the grain yield of the widely cultivated hybrid BJ 104 and was resistant to downy mildew (DM). This variety is now grown over one million ha in India.

Pearl millet has adequate genetic variability for reasonable progress to be made from selection. In West Africa, pearl millet breeders were successful in exploiting variability within landrace cultivars. Varieties derived through improving landrace cultivars, assured adaptation but did not show stable and consistent increases in grain yield, as the variation for yield contributing

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989

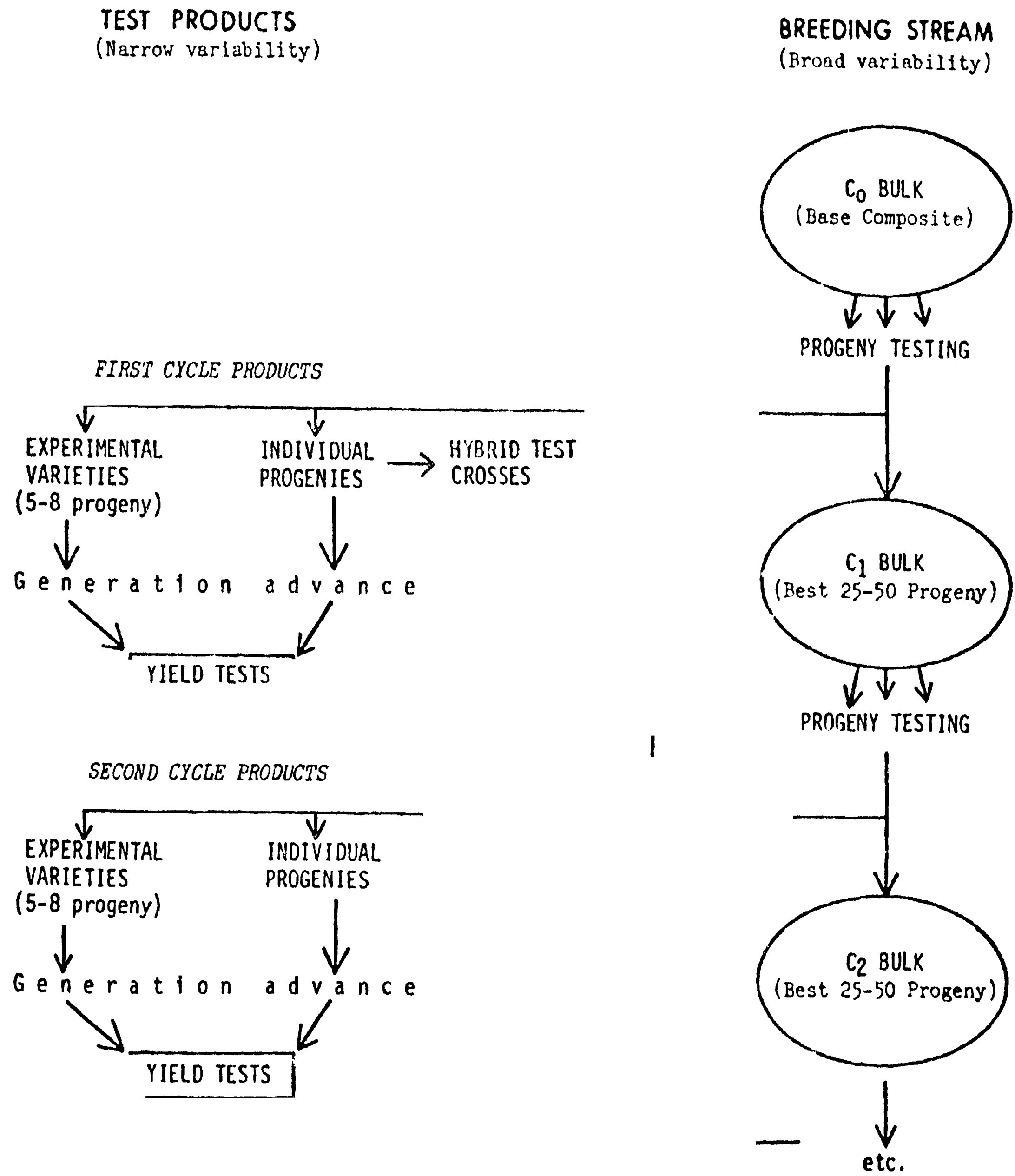
2. Selectionneur (Petit Mil) et Directuer, Station de Recherche Agricole, Cinzana, B.P. 214, Segou, Mali.

3. Selectionneur (Petit Mil), ICRISAT Centre Sahelian, B.P. 12404 Niamey, Niger.

characters within a landrace population was limited. To increase genetic diversity and exploit variability that is present among landrace populations there is a need to exploit variability generated from controlled crosses among elite and adapted landraces (Niangado and Ouendeba 1987).

Generally recurrent selection methods involve three operations: (1) development of progenies, (2) evaluation of progenies, and (3) recombination of superior progenies to synthesize the next cycle population bulk and develop varieties. A generalized scheme which follows these three operations for intra-population improvement in pearl millet is presented in Figure 1. In this scheme a composite (or a population) is regarded as a source of broad genetic variability. The succeeding cycle of the population is developed from the progenies of single plants whose genetic worth is judged not only by their phenotypic appearance but is actually measured by testing their progenies.

In this paper we describe the use of recurrent selection using $S_1$ progeny testing in the development of varieties from the pearl millet composite, Souna x Sanio, developed in Mali.




g.1. Generalized scheme for intrapopulation improvement in pearl millet.

## Materials and Methods

### Formation of the composite Souna x Sanio

Several accessions of Souna (early) and Sanio (late), collected in Mali in 1980, were crossed at the ICRISAT Center with an objective to combine the desirable attributes of the two groups of landrace populations. The $F_2$ populations ( 3 Souna x Sanio, 5 Sanio x Souna, and 10 Sanio x Souna de Siriakorola) were grown at Sotuba, Cinzana, Katibogou and Koporo-Keniepe in Mali in the rainy season of 1981. One hundred and three selfed heads were selected from these crosses at the four locations. Progenies from these selections were recombined through three generations of random mating in isolations to form the $C_0$ bulk of composite "Souna x Sanio".

The method used was $S_1$ progeny selection which involved two years or three seasons per cycle. This included the production of:

(1) $S_1$'s in the post-rainy season of 1987,
(2) evaluation of $S_1$ progenies in the postrainy season of 1987,
(3) evaluation of $S_1$ progenies in the rainy season of 1987 at two locations (Cinzana in Mali and ICRISAT Sahelian Center (ISC), Sadoré, Niger), and
(4) recombination of selected progenies to constitute varieties and the next cycle of the composite bulk in the postrainy season of 1988.

Yield evaluation of the constituted varieties was carried out at the same two locations in the rainy season of 1988.

### Production of $S_1$ Progenies

For the production of $S_1$'s, a large block (80 rows of 4.8 m length) of the $C_0$ bulk was planted at a row spacing of 75 cm between rows and 40 cm within row. There were a total of 1040 plants. Six hundred desirable plants were selfed using the main earhead. At harvest earheads that showed poor seedset, incomplete exertion, purple glumes, bristles, or that did not conform to the type were rejected. A total of 248 earheads were retained and individually threshed.

### $S_1$ Progeny Test

The $S_1$ progeny test contained 250 entries ( 248 progenies and 2 controls). The controls were bulk of Souna x Sanio composite and an improved variety. The test was laid out as a randomized block design with two replications. Observations at the two locations were recorded on time to 50% bloom, plant height, earhead length, number of plants plot$^{-1}$, head number plot$^{-1}$, number of plants infected with DM plot$^{-1}$ (only at Sadoré), and head yield plot$^{-1}$.

### Recombination of selected $S_1$ progenies

For the recombination of the selected progenies, remnant seed from the post rainy season harvest of 1987 was used. To recombine selected groups of progenies into varieties, each constituent progeny was planted as two to four rows having 26-52 individual plants. A bulk made up of equal quantities of all selected progenies for a particular variety was prepared and planted. To facilitate crossing, this bulk was planted, depending on the number of progenies selected for the development of a variety, repeatedly in blocks of 4-6 rows after every 6-8 progenies. Twelve to 18 earheads (main stem and tillers) and in the progeny rows and bulk were selfed. Pollen from a minimum of 10 earheads was drawn from the bulk rows and mixed. This "bulk" pollen was then equally divided into 10 fresh selfing bags and these were used to pollinate female heads in the progenies. At harvest, crossed heads were bulked together and threshed. After threshing, equal quantities of crossed seed from each of the progeny rows was mixed to form a variety.

## Evaluation of varieties for yield and downy mildew reaction

A yield trial containing five varieties developed from the selected groups of progenies, the Co bulk of Souna x Sanio composite and an improved variety were planted in a randomized block design with six replications at the two locations. Observations were recorded on time to 50% bloom, plant height, earhead length, hill number, head number and grain yield net plot$^{-1}$.

Table 1. Performance summary of S1 progenies of IER composite Souna x Sanio. IER, Cinzana, Mali, rainy season 1987.

| Character | All progenies | Progenies selected for: Variety development | Recombination | Controls: Composite bulk | Improved variety[1] |
|---|---|---|---|---|---|
| Number | 248 | 37 | 49 | 1 | 1 |
| Time to 50% bloom (days): | | | | | |
| Range | 50-65 | 51-61 | 51-61 | - | - |
| Mean ± SE | 56±1.54 | 56±0.4 | 56 | 53 | 53 |
| CV (%) | 3.7 | 4.5 | 4.3 | | |
| Plant height (cm): | | | | | |
| Range | 149-239 | 149-239 | 149-239 | | |
| Mean ± SE | 191±14.8 | 194±2.6 | 192±2.4 | 197 | 224 |
| CV (%) | 11.0 | 8.2 | 8.7 | | |
| Ear length (cm): | | | | | |
| Range | 2-43 | 22-34 | 22-34 | | |
| Mean ± SE | 26±2.6 | 27± | 27± | 26 | 44 |
| CV (%) | 14.2 | | | | |
| Head number/plot: | | | | | |
| Range | 9-58 | 25-57 | 26-58 | | |
| Mean ± SE | 28.5±4.6 | 37±0.9 | 36±0.8 | 35 | 37 |
| CV (%) | 22.9 | 16.1 | 16.0 | | |
| Head yield (g/plot)[2]: | | | | | |
| Range | 279-1477 | 1071-1464 | 1071-1477 | | |
| Mean ± SE | 853±157-6 | 1233±18.7 | 1234±16.8 | 1069 | 1468 |
| CV (%) | 26.1 | 9.2 | 9.5 | | |
| Selection differential (%) | - | 44.5 | 44.6 | | |
| % change over bulk yield: | | | | | |
| Range | 26-138 | 100-137 | 100-138 | | |
| Mean | 80 | 115 | 115 | 100 | 137 |

1. Improved variety was Pool-6.
2. Plot size 4.5 $m^2$.

## Results and Discussion

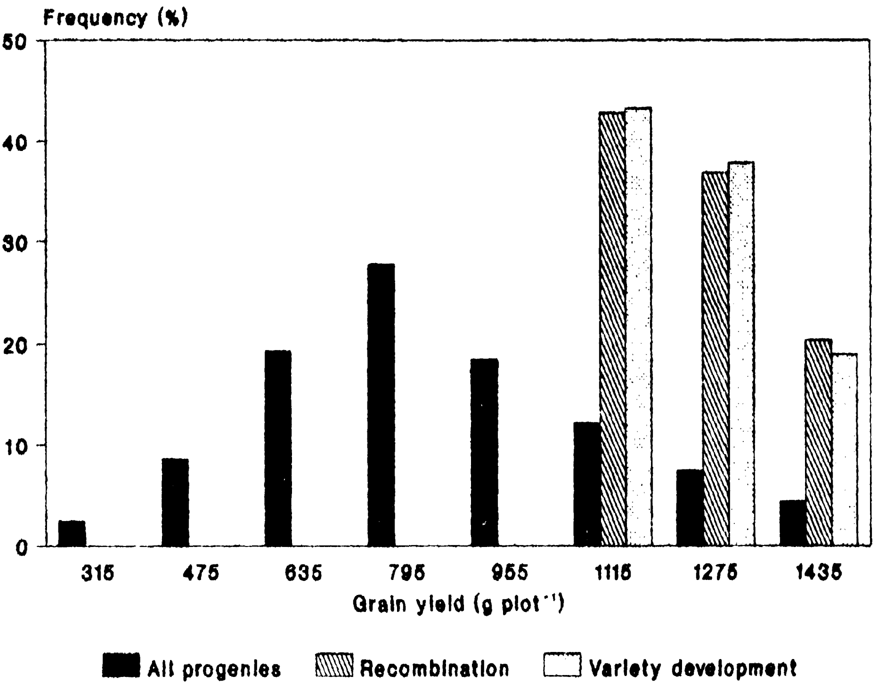
### $S_1$ Progeny Test

Results of the $S_1$ progeny tests carried out at Cinzana and Sadoré are given in Tables 1 and 2. At Cinzana the mean head yield was 853 g $plot^{-1}$ and of the composite $C_0$ bulk was 1069 g $plot^{-1}$. Fifty progenies gave yield equal and up to 138% of the $C_0$ bulk. Based on time to bloom, plant height, ear length, head number $plot^{-1}$, head yield and visual assessments, 37 progenies were selected for variety development and 49 for recombination into $C_1$ bulk (Fig. 2). The selection differential for head yield of the progenies selected for variety development was 44.5% and for recombination into $C_1$ bulk was 44.6%.

Table 2. Performance summary of S1 progenies of IER composite Souna x Sanio. ISC, Niger, rainy season 1987.

| Character | All progenies | Progenies selected for: Variety development | Progenies selected for: Recombination | Controls: Composite bulk | Controls: Improved variety[1] |
|---|---|---|---|---|---|
| Number | 248 | 30 | 57 | 1 | 1 |
| Time to 50% bloom (days): | | | | | |
| Range | 51-67 | 52-66 | 52-66 | | |
| Mean ± SE | 59±1.9 | 59±0.5 | 59±0.4 | 58 | 58 |
| CV (%) | 4.5 | 4.8 | 4.6 | | |
| Plant height (cm): | | | | | |
| Range | 127-222 | 147-222 | 141-223 | | |
| Mean ± SE | 169±12.2 | 185±3.3 | 180±2.4 | 167 | 239 |
| CV (%) | 10.2 | 9.8 | 10.1 | | |
| Ear length (cm): | | | | | |
| Range | 18-37 | 21-35 | 21-38 | | |
| Mean ± SE | 26±2.3 | 29±0.5 | 28±0.5 | 28 | 79 |
| CV (%) | 12.6 | 10.9 | 12.7 | | |
| Head number/plot: | | | | | |
| Range | 4-35 | 16-34 | 13-34 | | |
| Mean ± SE | 18±3.3 | 23±0.9 | 21±0.6 | | |
| CV (%) | 26.7 | 21.2 | 21.8 | 21 | 26 |
| Downy mildew (%): | | | | | |
| Range | 0-100 | - | - | | |
| Mean ± | 3.3 | 0 | 0 | 7 | 57 |
| CV (%) | | | | | |
| Head yield (g/plot)[2]: | | | | | |
| Range | 75-1338 | 725-1338 | 450-1338 | 650 | 1200 |
| Mean ± SE | 598±156 | 917±27 | 817±23.3 | | |
| CV (%) | 36.9 | 16.1 | 21.5 | | |
| Selection differential (%) | - | 53.3 | 36.6 | - | - |
| % change over bulk yield: | | | | | |
| Range | 11-205 | 112-205 | 69-206 | 100 | 185 |
| Mean | 92 | 141 | 126 | | |

1. Improved variety was CIVT.
2. Plot size 4.5 $m^2$.




ig.2. Histogram for grain yield for 248 $S_1$ progenies, progenies selected for ariety development and recombination, IER composite Souna x Sanio, Cinzana, ali, rainy season 1987.

**Table 3. Details of variety development from S1 progenies of IER composite, Souna x Sanio. Cinzana, Mali, and ISC, Niger, rainy season 1987.**

| Variety designation | Number of progenies | Location | Mean: Time to 50% flowering (days) | Plant height (cm) | Ear length (cm) | Head number/ plot | Head yield (g/plot) |
|---|---|---|---|---|---|---|---|
| SOSAP-S87 | 19 | Sadoré | 57 | 182 | 27 | 25 | 911 |
| SOSAT-S87 | 11 | Sadoré | 62 | 189 | 31 | 19 | 927 |
| All progenies | 248 | Sadoré | 59 | 169 | 26 | 18 | 598 |
| SOSAP-C87 | 14 | Cinzana | 53 | 187 | 27 | 37 | 1218 |
| SOSAT-C87 | 17 | Cinzana | 58 | 201 | 26 | 36 | 1224 |
| All progenies | 248 | Cinzana | 56 | 191 | 26 | 29 | 853 |
| SOSAP-A87 | 6 | Across | 57 | 181 | 28 | 30 | 988 |
| All progenies | 248 | Across | 58 | 180 | 26 | 23 | 726 |

1.Plot size 4.5 $m^2$.

At ISC, the mean head yield was 598 g plot$^{-1}$ and of the composite $C_{(0)}$ bulk 650 g plot $^{-1}$. One hundred progenies gave head yields equal and up to 205% of the $C_0$ bulk. Based on time to 50% bloom, plant height, ear length, head number plot$^{-1}$, head yield, DM incidence and visual assessments, 30 progenies were selected for variety development and 57 for recombination into $C_1$ bulk (Fig. 3). The selection differential for head yield was 53.3% for the progenies selected for variety development and 36.6% for recombination into $C_1$ bulk (Table 2).

Progenies selected for variety development were primarily grouped based on days to 50% bloom. Plant height and head length were secondary criteria to bring uniformity in the resulting varieties. All the progenies selected for variety development and recombination were free from DM at ISC.

As shown in Table 3, two varieties, an early (57 days to 50% bloom SOSAP-S88 = Souna x Sanio, P= Precoce, S= ISC, 88 year of first test ) and a late (62 days, SOSAT-S88) were constituted from the 30 progenies selected at ISC. Similarly an early (53 days, SOSAP-C88, C= Cinzana) and a late (58 days, SOSAT-C88) variety were developed from from 31 progenies selected at Cinzana. Six progenies performed well across both the locations (36% increase in mean head yield) and were also visually selected at both locations. These six progenies were used for the development of an across location variety (SOSAP-A88, A=Across).

Among the 106 progenies selected for recombination at the two locations (49 in Cinzana and 57 at ISC) 19 were common. Therefore, 87 progenies were retained for recombination to form the $C_1$ cycle of the composite (Figs. 2 and 3).

## Evaluation of Varieties

Results of evaluation of the five varieties along with the composite $C_0$ bulk and an improved variety at Cinzana and ISC are presented in Table 4. Grain yield increases over the composite bulk ranged from 6 to 35% across the two locations. Variety SOSAT-C88 (recombined from 17 late maturing progenies, Table 3) gave an overall mean yield of 2.87 t ha$^{-1}$ representing a 35% increase over the $C_0$ bulk. DM incidence in the yield trial at Cinzana was higher than that recorded in the DM nursery at ISC in the postrainy season. This variety also recorded the lowest DM incidence at Cinzana. Among the three early varieties, SOSAP-S88 gave a better performance and was more uniform. Variety SOSAT-C88 and SOSAP-C88 were retained for further multilocational trials in Mali.

## Conclusion

The use of recurrent selection using $S_1$ testing seems to have been successful in the development of varieties. Evaluation of different cycles of composite bulk would indicate whether progress has been made in genetically improving the composite *per se*. The base composite has variation for tillering, head length and plant height. Variation for flowering was relatively low. Evidence gathered at ICRISAT has shown that varieties do not markedly outperform the composite bulks from which they are derived. The yield increases recorded here over the bulk are significant. The possibility of these two selected varieties retaining the observed yield advantage over the $C_0$ bulk will be investigated further.

**Table 4. Performance of entries in the Malian Varieties Trial for grain yield and downy mildew (DM) incidence. ISC, Niger an Cinzana, Mali, rainy season 1988.**

| Entry | Location and grain yield (kg ha$^{-1}$) | | | Time to 50% flowering (days)[2] | DM incidence[1] | |
|---|---|---|---|---|---|---|
| | Mean | Sadoré | Cinzana | | Sadoré | Cinzana |
| SOSAT-C88 | 2.87 | 2.67 | 3.06 | 58 | 6 | 12 |
| SOSAP-S88 | 2.70 | 2.93 | 2.46 | 55 | 3 | 36 |
| SOSAP-A88 | 2.52 | 2.59 | 2.44 | 56 | 1 | 34 |
| SOSAP-C88 | 2.52 | 2.55 | 2.48 | 53 | 2 | 35 |
| SOSAT-S88 | 2.26 | 2.42 | 2.09 | 61 | 3 | 30 |
| Controls | | | | | | |
| Souna x Sanio bulk | 2.12 | 1.72 | 2.52 | 59 | 10 | 20 |
| Improved variety[3] | - | 2.65 | 2.18 | 57 | - | 20 |
| SE | - | +0.132 | +0.166 | ±0.74 | - | - |
| Mean | 2.48 | 2.50 | 2.46 | 57 | 4 | 27 |
| CV (%) | - | 12.9 | 16.5 | 3.2 | - | - |

1. DM incidence at ISC recorded 84 days after sowing in the DM nursery by the Pathologist in the post-rainy season. Mean plant population was 91. On the indicator (HHB 3) 58% DM was rocorded.
2. Time to flowering recorded at ISC.
3. Improved variety at ISC was CIVT and at Cinzana Pool-6.

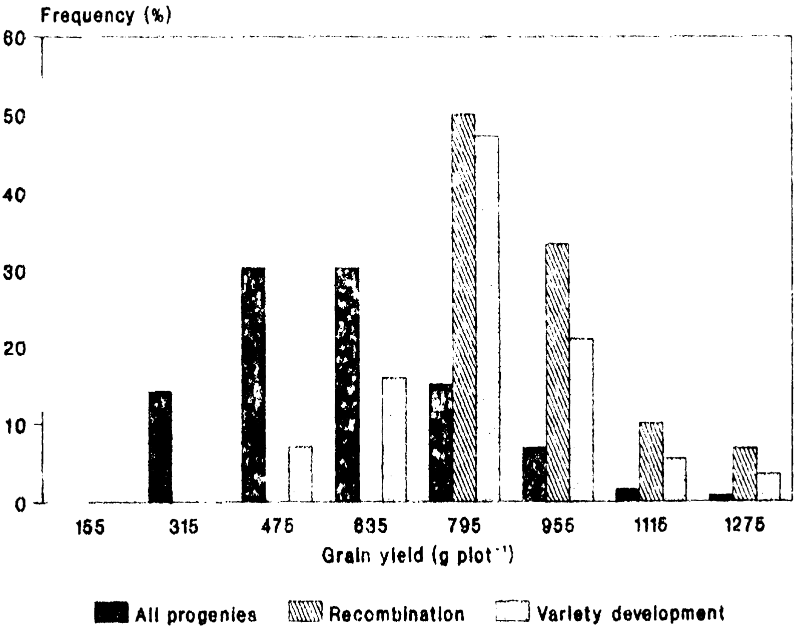



Fig.3. Histogram for grain yield for 248 $S_1$ progenies, progenies selected for variety development and recombination. IER composite Souna x Sanio. ISC, Niger, rainy season 1987.

## References


**Andrews, D.J., Gupta, S.C., and Pheru Singh.** 1985. Registration of WC-C75 pearl millet. Crop Science. 25. 199-200.

**Hallauer, A.R.** 1981. Selection and breeding methods. Pages 3-55 *In* Plant Breeding II (K.J. Frey, ed.), Iowa State University Press, Ames, Iowa, USA.

**Niangado, O., and Ouendeba, B.** 1987. Amelioration varietale du mil en Afrique de l'Ouest. Pages 83-94 *in* Proceedings of the International Pearl Millet Workshop, 7-11 April 1986, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

# Cultivar Performance in the Pearl Millet Zone A Trial (1982-88)[1]

S.O. Okiror[2]

**Abstract**

*The ICRISAT Millet Zone A Trial (IMZAT) was set up in 1979 to achieve two major objectives: to evaluate elite pearl millet cultivars from national and ICRISAT millet research programs for broad adaptability and stability across a broad range of environmental conditions in West Africa, and to serve as a means for reciprocal exchange and distribution of elite millet cultivars developed in millet improvement programs in the region.*

*Although a total of fifty-two cultivars have been tested in IMZAT over the period 1982-88, only twenty have been tested for two or more years. Cultivars performing very poorly in the first year of testing were immediately dropped from the trial. Grain yield and some agronomic data of entries are presented for two major purposes. First to summarize information on those cultivars that performed well at various locations to allow programs to choose those worth multilocational testing in their own countries. Secondly to assess progress in performance and adoption of the cultivars outside countries from which they were developed. Several cultivars have shown good adaptation at locations outside countries where they were developed. Cultivar IKMV 8201 developed in Burkina Faso was adopted for on-farm multilocational testing in Mali. Similarly ITMV 8304 from Niger was adopted in Sénégal. SE 2124 and INMV 8212 from Nigeria were adopted in Mali, and Cameroun, respectively for multilocational testing. Eleven other cultivars showed worthiness for multilocational testing in other countries than where they were developed. The IMZAT trial has been a valuable medium for exchange and distribution of new elite millet cultivars in millet improvement programs in West Africa.*

**Résumé**

**La performance des cultivars evalués dans l'essai sur le petit mil pour la Zone A (1982-88).** *L'essai sur le mil de l'ICRISAT pour la Zone A (IMZAT) a été mis en oeuvre en 1979 avec comme objectifs: l'évaluation des cultivars élites du petit mil de l'ICRISAT et des programmes de recherche nationaux pour une plus grande adaptabilité et stabilité à travers un large éventail des conditions du milieu en Afrique de l'Ouest, et servir de moyens d'échange réciproque et de distribution des cultivars élites du mil dévelopés dans les programmes d'amélioration du mil dans la région.*

*Quoiqu'un total de 52 cultivars aient été testés pour leur rendement au cours de la période 1982-88, seulement 22 ont pu être testés pendant deux ans ou plus dans le cadre de l'IMZAT. Les cultivars ayant une très faible performance au cours de la première année du test ont été immédiatement abandonnés. Le rendement en grain ainsi que d'autres données agronomiques des 20 entrées sont présentées pour deux raisons principales. Premièrement, pour résumer les informations sur les cultivars ayant donné une bonne performance dans diverses localités afin de permettre aux différents programmes de choisir les cultivars pour des tests multilocaux dans leurs propres pays. Deuxièment, pour évaluer le progrès global dans la performance et l'adoption des cultivars hors des pays dans lesquels ils ont été develeopés. Plusieurs cultivars ont été jugés assez bon pour adaptation dans des localités autres que celles de leurs pays d'origine. Le cultivar IKMV 8201 dévelopé au Burkina Faso a été adopté au Mali pour un test multilocal au champ. L'ITMV 8304 du Niger a été également adopté au Sénégal. Les cultivars SE 2124 et INMV 8212 du Nigéria ont été adoptés respectivement au Mali et au Cameroun, pour de tests multilocaux. 11 autres cultivars ont été jugés assez bons pour des tests multilocaux dans des pays autres que ceux dans lesquels ils ont été dévelopés. La pépinière IMZAT a été un moyen très précieux d'échange et de distribution de nouveaux cultivars élites dans les programmes d'amélioration du mil en Afrique de l'Ouest.*

## Introduction

Multilocational evaluation exposes cultivars to different soil and climatic conditions, and, disease and insect pest environments. Use of multilocations for screening and testing of cultivars can reduce the number of years necessary to identify adapted, superior cultivars since diversity in locations to a certain extent substitutes for environmental variation in years.

The ICRISAT Millet Zone A Trial (IMZAT) then called the Pearl Millet West African Regional Trial (PMART) was set up in 1979. The IMZAT is a multilocational yield evaluation trial intended for the drier locations of

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1989.

2. Millet Breeder, ICRISAT Sahelian Center, B.P. 12404 Niamey, Niger.

pearl millet (*Pennisetum americanum* (L.) R.Br.) growing areas (Zone A) in West Africa. Zone A was defined as having average annual rainfall of 300-600 mm with a short crop growing season of about 75-100 days. Zone B, a wetter zone (600-900 mm) has a longer crop growing season of 100-120 days. IMZAT, therefore, was organized for testing shorter duration elite cultivars developed at ICRISAT and national millet improvement programs in West Africa. It is a cooperative trial conducted by both national and ICRISAT programs in West Africa.

The main objectives of IMZAT are:

a) to test and select for adaptability and stability of yield of elite pearl millet genotypes in a range of environments across millet growing countries in West Africa.
b) to serve as a means of exchange and distribution of elite genotypes for direct use in the national and ICRISAT millet improvement programs in the West African region.

The purpose of this paper is to summarize yield of cultivars that have been evaluated for two or more years in IMZAT during the period 1982-88. This information could be useful to programs in choosing IMZAT cultivars for multilocational evaluation within their countries. The summary also gives an opportunity to assess the extent to which the cultivars have been distributed among the research programs.

## Methods and Materials

### Locations

During the period 1982-88, IMZAT was conducted at fifteen sites in eight countries in West Africa (Table 1). The number of sites used each year varied from a high of ten in 1986 to a low of six in 1987 and 1988. IMZAT was conducted for two or more years at Kamboinse, Maroua, Bawku, Koporo, Cinzana, Sadoré, Maradi, Bengou, Kano, Samaru, Nioro, Bambey, and Lugua. It was conducted for only one year at Sapu and Kolo sites.

**Table 1. Countries and test sites where IMZAT was conducted in West Africa, 1982-88.**

| | | Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Test site | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | Total |
| B. Faso | Kamboinse | x | x | - | x | x | x | x | 6 |
| Cameroun | Maroua | x | x | x | - | - | - | - | 3 |
| Gambia | Sapu | - | - | - | - | x | - | - | 1 |
| Ghana | Bawku | - | - | - | - | x | x | x | 3 |
| Mali | Koporo | - | x | x | x | x | - | - | 4 |
| | Cinzana | - | - | x | x | x | - | x | 4 |
| Niger | Sadoré | x | x | x | x | x | x | x | 7 |
| | Maradi | x | x | x | x | x | - | - | 5 |
| | Bengou | - | - | - | x | x | x | x | 4 |
| | Kolo | - | - | - | - | - | x | - | 1 |
| Nigeria | Kano | x | x | - | - | - | - | - | 2 |
| | Samaru | - | - | - | x | x | x | x | 4 |
| Sénégal | Noro | x | x | x | x | - | - | - | 4 |
| | Bambey | x | x | x | x | x | - | x | 6 |
| | Lugua | x | x | - | - | - | - | - | 2 |
| | Total | 8 | 9 | 7 | 9 | 10 | 6 | 7 | - |

x Indicates actual years in which IMZAT was conducted.

## Cultivars

A total of 52 different millet cultivars were contributed and yield evaluated in IMZAT over 1982-88. The initial trial philosophy was to evaluate each new entry for a maximum of two years, after which it would be either promoted to the regional testing program or dropped. Cultivars performing too poorly in the first year of testing were dropped after that one year. Table 2 lists the cultivars evaluated for two or more years in IMZAT. The contributing institutions also are listed.

Two of the cultivars (IKMV 8201 and IKMC01) were bred in the ICRISAT/INERA programs in Kamboinse, Burkina Faso. Three cultivars (C 12 L, CT 2 and T 18 L) were developed in INRAN, Niger and four (ITMV 8001, ITMV 8002, ITMV 8003 and ITMV 8304) were developed in the ICRISAT/INRAN program. Two cultivars from the ISC (ICMS IS 85327 and ICMV IS 85333) are the newest addition to IMZAT. Three cultivars from the IAR, Nigeria (Nigerian Composite, SE 360 and SE 2124) were evaluated, and four from the ICRISAT/IAR program (INMV 8206, INMV 8210, INMV 8212 and INMV 8220). The ICRISAT/ISRA program contributed two cultivars (IBMV 8301 and IBMV 8302) to IMZAT during 1982-88.

**Table 2. Millet cultivars yield evaluated for two or more years in IMZAT, 1982-88.**

| Millet cultivar | Contributor institution | Years 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | Total |
|---|---|---|---|---|---|---|---|---|---|
| IKMV 8201 | ICRISAT/INERA | - | x | x | x | x | x | x | 6 |
| IKMC-1 | ICRISAT/INERA | - | - | - | x | x | - | - | 2 |
| C 12 L | INRAN | - | - | - | - | x | x | x | 3 |
| CT-2 | INRAN | - | - | - | - | x | x | x | 3 |
| T 18 L | INRAN | - | - | - | - | x | x | x | 3 |
| ITMV 8001 | ICRISAT/INRAN | - | x | - | - | x | - | - | 2 |
| ITMV 8002 | ICRISAT/INRAN | x | x | - | - | - | - | - | 2 |
| ITMV 8003 | ICRISAT/INRAN | - | x | - | x | - | - | x | 3 |
| ITMV 8304 | ICRISAT/INRAN | - | - | x | x | x | x | x | 5 |
| ICMVIS 85327 | ISC | - | - | - | - | - | x | x | 2 |
| ICMVIS 85333 | ISC | - | - | - | - | - | x | x | 2 |
| NIG. COMP. | IAR | x | x | - | - | - | - | - | 2 |
| SE 360 | IAR | - | - | - | - | x | x | - | 2 |
| SE 2124 | IAR | - | - | - | - | x | x | x | 3 |
| INMV 8206 | ICRISAT/IAR | x | - | - | - | x | x | - | 3 |
| INMV 8210 | ICRISAT/IAR | x | x | x | - | - | - | - | 3 |
| INMV 8212 | ICRISAT/IAR | - | x | x | - | x | - | - | 3 |
| INMV 8220 | ICRISAT/IAR | - | x | x | - | - | - | - | 2 |
| IBMV 8301 | ICRISAT/ISRA | - | x | x | - |  | - | - | 2 |
| IBMV 8302 | ICRISAT/ISRA | - | x | x | - | - | - | - | 2 |
| Total | | 4 | 10 | 7 | 4 | 11 | 10 | 9 | - |

x Indicates the actual years when each cultivar was yield evaluated

## Design and Trial Management

With the exception of 1982, when IMZAT included fourteen entries that were evaluated in a random block design, IMZAT always contained sixteen entries evaluated in a balanced lattice design. Four to six replications were used. Local improved or local farmers' variety was used by each cooperator as control at his respective site.

Recommended plot size was six rows of 5 m length with row to row spacing of 0.75-1.00 m. Within-row plant/hill spacing used by each cooperator was that normally used in their respective programs. Rates of organic fertilizers applied were those recommended in each respective country. Weeding and other trial management practices were carried out when necessary and managed by the cooperating scientist.

## Results

### Grain Yield

Grain yields are presented only on those cultivars that were evaluated for two or more years. Cultivars evaluated for only one year are assumed to have been dropped due to poor yields. Only those sites where IMZAT was conducted for at least two years are data presented. Yield data are presented on a site basis since the analysis of variance generally showed high genotype x location interactions (Table 3-13). This enables each cooperator to focus on their results under its specific crop conditions. Some cultivars are recommended for further testing based on their yield relative to that of the local control variety used and the average yield in the trial.

**Kamboinse, Burkina Faso:** With the exception of 1982, mean grain yields at Kamboinse were higher than 1 000 kg $ha^{-1}$ (Table 3). The control varieties used have varied. Of the twelve cultivars reported at this location two (IKMV 8201 and IKMC-1) were developed in Burkina Faso. Both varieties were bred in the INERA/ICRISAT program at Burkina Faso. These two cultivars have performed very well and have been released for large scale on-farm testing in Burkina Faso. IKMV 8201 yielded more than 30% higher than the control in 1983 and 1985. It has been adopted also for multilocational testing in Mali by the Malian millet improvement program. Other cultivars yielding similar to or higher than the controls and are considered for further testing in Burkina Faso include ITMV 8001 and ITMV 8304 from the INRAN/ICRISAT programs in Niger, Nigeria Composite SE 360 and SE 2124 from the IAR program in Nigeria, and INMV 8212 from the IAR/ICRISAT programs in Nigeria.

Table 3. Grain yield kg $ha^{-1}$ of millet cultivars yield evaluated for two or more years in IMZAT at Kamboinse, Burkina Faso, 1982-87.

| | Years | | | | |
|---|---|---|---|---|---|
| Cultivar | 1982 | 1983 | 1985 | 1986 | 1987 |
| IKMV 8201[1] | - | 1410 | 1907 | - | 1578 |
| IKMC-1[1] | - | - | 1486 | 1940 | 1482 |
| C 12 L | - | - | - | 1550 | 1340 |
| CT-2 | - | - | - | 1300 | 1507 |
| T 18 L | - | - | - | 1780 | 1211 |
| ITMV 8001[1] | - | 1120 | - | 1730 | - |
| ITMV 8304[1] | - | - | - | 2330 | 1812 |
| NIG. COMP[1] | 1640 | 1120 | - | - | - |
| SE 360[1] | - | | - | 2020 | 1503 |
| SE 2124[1] | - | - | - | 2220 | 1486 |
| INMV 8206 | - | - | - | 1580 | 806 |
| INMV 8212[1] | - | 1300 | - | 1720 | - |
| Control | 1490 (KDMC) | 520 (KDMC) | 1458 (Improved) | 1880 (Improved) | 1578 (IKMV 8201) |
| Trial mean | 987 | 1184 | 1232 | 1750 | 1424 |
| SE | ±575 | ±218 | ±132 | ±160 | ±89 |
| CV (%) | 46 | 15 | 23 | 18 | 13 |

[1] Cultivars recommended for further testing.
() Gives name or type of control variety.

**Maroua, Cameroun:** The IMZAT trial was conducted for three years at Maroua. Yield trial means were 2500 kg ha$^{-1}$ in 1982 and 1983 indicating good cropping season. In 1984 the trial mean was 889 kg ha$^{-1}$ and was associated with a coefficient of variation of 55% (Table 4). Four cultivars have been evaluated for two years at this location. Three of these (IKMV 8201, INMV 8212, and Nigerian Composite) may be recommended for further evaluation in Cameroun. INMV 8212 was recommended for on-farm testing in Cameroun in 1985.

**Table 4. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated for two or more years in IMZAT at Maroua, Cameroun, 1982-84.**

| | Years | | |
|---|---|---|---|
| CULTIVAR | 1982 | 1983 | 1984 |
| IKMV 8201[1] | - | 3096 | 1140 |
| INMV 8212[1] | - | 3174 | 740 |
| NIG. COMP[1] | 2700 | 3000 | - |
| IBMV 8301[1] | - | 2490 | 1072 |
| Control | 2260 (Farmers') | 3000 (Farmers') | 718 (Farmers') |
| Trial mean | 2527 | 2603 | 889 |
| SE | ns | ±748 | ±137 |
| CV (%) | 28 | 23 | 55 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety

**Bawku, Ghana:** Trial means at Bawku were higher than 1 000 kg ha$^{-1}$ in 1986 and 1987 with the CV's of 14% and 23% (Table 5). Yields were very low in 1988, and CV's high (44%) due to late planting and bird damage. From the three years of data, however, the cultivars SE 360, C 12 L, and ICMV IS 85333 could be recommended for further evaluation in Ghana.

**Table 5. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated in IMZAT at Bawku, Ghana, 1986-88.**

| | Years | | |
|---|---|---|---|
| Cultivar | 1986 | 1987 | 1988 |
| SE 360[1] | 1590 | 1055 | - |
| SE 2124[1] | 1300 | 873 | 132 |
| INMV 8206[1] | 1200 | 1372 | - |
| C 12 L[1] | 1290 | 1354 | 194 |
| CT-2[1] | 1470 | 1068 | 129 |
| T 18 L[1] | 1230 | 575 | 113 |
| ITMV 8003[1] | 1540 | 1031 | 88 |
| IKMV 8201[1] | - | 1077 | 191 |
| ICMV IS 85333[1] | - | 1099 | 193 |
| ICMV IS 85327 | - | 986 | 121 |
| Control | 1650 (Farmers') | 265 (Improved) | 126 (Improved) |
| Trial mean | 1430 | 1022 | 162 |
| SE | ±100 | ±59 | ±36 |
| CV (%) | 14 | 23 | 44 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Koporo, Mali:** Of the six cultivars yield evaluated for two or more years at Koporo, only IKMV 8201 performed well, yielding 16% and 69% higher than the control varieties in 1983 and 1984 (Table 6). The yield data in 1986 were associated with a CV of 50% and the control variety yielded highest. The cultivar IKMV 8201 has been adopted for multilocational testing in Mali.

**Table 6. Grain yield (kg $ha^{-1}$) of millet cultivars in IMZAT at Koporo, Mali, 1983-86.**

| Cultivar | Years | | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 |
| IKMV 8201[1] | 1180 | - | 1440 | 1020 |
| IKMC-1[1] | - | - | 1288 | 780 |
| ITMV 8304[1] | - | 1230 | 1447 | 600 |
| ITMV 8001[1]1 | 470 | - | - | 920 |
| INMV 8212[1] | 680 | - | - | 970 |
| IBMV 8301[1] | 1190 | 1150 | - | - |
| Control | 1020 (Farmers') | 1290 (Farmers') | 856 (Farmers') | 1160 (Farmers') |
| Trial mean | 770 | 1195 | - | 1010 |
| SE | ±386 | ±142 | ±164 | ±250 |
| CV (%) | 23 | 31 | 28 | 50 |

1 Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Cinzana, Mali:** Over the three years, the IMZAT trial was conducted at Cinzana, the trial means have been higher than 1 600 kg $ha^{-1}$ (Table 7). The coefficients of variation were 24%, 15%, and 14%, respectively. Seven cultivars were evaluated for two or more years. Of these SE 2124, CT 2, and C 12 L were considered for further evaluation in Mali. SE 2124 has been adopted already for on-farm testing in Mali.

**Table 7. Grain yield (kg $ha^{-1}$) of millet cultivars evaluated in IMZAT at Cinzana, Mali, 1985, 1986, and 1988.**

| Cultivar | Years | | |
|---|---|---|---|
| | 1985 | 1986 | 1988 |
| SE 2124[1] | - | 1900 | 1545 |
| T 18 L[1] | - | 2010 | 1754 |
| CT-2[1] | - | 1750 | 2010 |
| C 12 L[1] | - | 2040 | 1900 |
| ITMV 8304[1] | 2040 | 1620 | 2033 |
| IKMV 8201[1] | 1709 | 1430 | 1521 |
| IKMC-1[1] | 1929 | 1450 | - |
| Control | 2190 (Farmers') | 1710 (Farmers') | 2132 (Improved) |
| Trial mean | 1746 | 1610 | 1783 |
| SE | ±206 | ±120 | ±125 |
| CV (%) | 24 | 15 | 14 |

1 Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Sadoré, Niger**: Fourteen cultivars were evaluated for two or more years at Sadoré (Table 8). Generally the coefficients of variation have been high at Sadoré ranging from 13-48%. Although trial means have varied greatly (below 1 000 kg $ha^{-1}$ in three years and above 1 200 kg $ha^{-1}$ in other 3 years) the yield of control cultivars was consistently higher than 1 100 kg $ha^{-1}$ in 1984-88. None of the entries except CT 2 in 1987 yielded equal to or higher than the local control.

**Table 8. Grain yield (kg $ha^{-1}$) of millet cultivars yield evaluated for two or more years in IMZAT at Sadoré, Niger, 1983-88.**

| Cultivar | Years 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|
| IKMV 8201 | 665 | - | 1280 | 610 | 274 | 2199 |
| IKMC-1 | - | - | - | 970 | 474 | - |
| ITMV 8003 | 726 | - | - | - | - | 1724 |
| ITMV 8001 | 859 | - | - | 890 | - | - |
| C 12 L | - | - | - | 980 | 628 | 2069 |
| CT-2 | - | - | - | 890 | 1133 | 1931 |
| T 18 L | - | - | - | 670 | 878 | 1856 |
| INMV 8212 | 668 | - | - | 880 | - | - |
| INMV 8206 | - | - | - | 650 | 271 | - |
| INMV 8220 | 692 | 1170 | - | - | - | - |
| SE 2124 | - | - | - | 850 | 547 | 2190 |
| SE 360 | - | - | - | 850 | 708 | - |
| ICMV IS 85333 | - | - | - | - | 778 | 2299 |
| ICMV IS 85327 | - | - | - | - | 901 | 2159 |
| Control | 949 (Farmers') | 1350 (Farmers') | 2350 (Farmers') | 1790 (CIVT) | 1125 (CIVT) | 2437 (CIVT) |
| Trial mean | 720 | 1253 | 1500 | 880 | 688 | 2032 |
| SE | ±270 | ±92 | ±226 | ±60 | ±166 | ±129 |
| CV (%) | 30 | 21 | 30 | 43 | 48 | 13 |

() Gives name or type of control variety.

**Maradi, Niger**: Of the seven cultivars evaluated for two or more years at Maradi, four of them (ITMV 8001, ITMV 8304, Nigerian Composite and INMV 8210) were promising enough to recommend for multilocational evaluation in Niger (Table 9). ITMV 8304 has been released as a variety in Niger, and seed of the same cultivar was requested for multilocational evaluation in Sénégal.

**Table 9. Grain yield (kg $ha^{-1}$) of millet cultivars yield evaluated for two or more years in IMZAT at Maradi, Niger, 1982-86.**

| Cultivar | Years 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|
| ITMV 8001[1] | 770 | - | - | - | 930 |
| ITMV 8304[1] | | - | 1310 | 2518 | 560 |
| NIG. COMP[1] | 2120 | 742 | - | - | - |
| INMV 8210[1] | - | 780 | 1030 | - | - |
| IKMV 8201 | - | 686 | - | 1767 | 770 |
| IKMC-1 | - | - | - | 1951 | 770 |
| IBMV 8301 | - | 561 | 980 | - | - |
| Control | 2200 (CIVT) | 672 (Farmers') | 1040 (Farmers') | 2315 (Farmers') | 860 (Farmers') |
| Trial mean | 1812 | 688 | - | 1905 | 810 |
| SE | ±333 | ns | ±120 | ±146 | ±120 |
| CV (%) | 14 | 30 | 34 | 15 | 52 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Bengou, Niger**: Yield data at Bengou site were good and the CVs were relatively low (16-25%) over the four years the trial was conducted. Trial mean yields ranged from 1742-2190 kg ha$^{-1}$ (Table 10). Yields of control varieties ranged from 1752-2500 kg ha$^{-1}$. At this location five cultivars, (IKMV 8201, ITMV 8304, ICMV IS 85327, ICMV IS 85333, and SE 2124) appeared worth multilocational testing in Niger.

**Table 10. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated for two or more years in IMZAT at Bengou, Niger, 1985-88.**

| Cultivar | Years 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|
| IKMV 8201[1] | 2470 | 2260 | 2070 | 2176 |
| IKMC-1 | 2230 | 1800 | 1860 | - |
| C 12 L | - | 2070 | 1800 | 1936 |
| CT-2 | - | 1640 | 2180 | 1348 |
| T 18 L | - | 1830 | 2010 | 1861 |
| ITMV 8304[1] | 2530 | 1950 | 2150 | 1786 |
| ICMV IS 85327[1] | - | - | 2280 | 2010 |
| ICMV IS 85333[1] | - | - | 2420 | 1801 |
| SE 360 | - | 1760 | 2610 | - |
| SE 2124[1] | - | 2160 | 2600 | 1700 |
| INMV 8206 | - | 2160 | 2040 | - |
| Control | 2250 (Farmers') | 2160 (CIVT) | 2500 (CIVT) | 1752 (CIVT) |
| Trial mean | 2084 | 1960 | 2190 | 1742 |
| SE | ±151 | ±150 | ±174 | ±220 |
| CV (%) | 17 | 16 | 16 | 25 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Samaru, Nigeria**: The CVs in IMZAT at Samaru were high and ranged from 37-48% over the four years the trial was conducted (Table 11). Based on their yields relative to the control, however, eight of the cultivars deserved more intensive evaluation in Nigeria. These cultivars were: IKMV 8201, IKMC-1, ITMV 8003, ITMV 8304, ICMV IS 85333, SE360, SE 2124, and INMV 8206. The cultivars SE 360 and SE 2124, however, are already being released as varieties for growing by farmers.

**Table 11. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated for two or more years in IMZAT at Samaru, Nigeria, 1985-88.**

| Cultivar | Years 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|
| IKMV 8201[1] | 1900 | - | 847 | 542 |
| IKMC-1[1] | 2101 | - | 695 | - |
| C 12 L | - | 770 | 569 | 431 |
| CT-2 | - | 940 | 604 | 375 |
| T 18 L | - | 690 | 351 | 222 |
| ITMV 8003[1] | - | 1390 | - | 611 |
| ITMV 8304[1] | - | - | 701 | 556 |
| ICMV IS 85333[1] | - | - | 667 | 472 |
| ICMV IS 85327 | - | - | 549 | 444 |
| SE 360[1] | - | 1620 | 674 | - |
| SE 2124[1] | - | 1347 | 750 | 500 |
| INMV 8206[1] | - | 1850 | 847 | - |
| Control | 1110 (Farmers') | 1080 (Farmers') | 583 (Nig.Comp) | 417 (Improved) |
| Trial mean | 966 | 1220 | 640 | 457 |
| SE | ±182 | ±230 | ±155 | ±110 |
| CV (%) | 38 | 37 | 48 | 48 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

**Nioro, Sénégal**: Only two cultivars (INMV 8201 and INMV 8212) have been evaluated for two or more years at Nioro site. These cultivars yielded similar to the local control and are recommended for further testing at this location (Table 12).

**Table 12. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated for two or more years in the IMZAT at Nioro, Sénégal, 1982-84.**

| Cultivar | Years | | |
|---|---|---|---|
| | 1982 | 1983 | 1984 |
| INMV 8210[1] | - | 644 | 2460 |
| INMV 8212[1] | 3462 | 606 | 2150 |
| Control | 365 | 651 | 2180 |
| Trial mean | 3557 | 662 | 2268 |
| SE | ±524 | ±124 | ±200 |
| CV (%) | 13 | 53 | 26 |

[1] Cultivars recommended for further yield evaluation.

**Bambey, Sénégal**: Of the ten cultivars evaluated for two or more years at Bambey, two (ITMV 8001 and INMV 8220) performed well enough to warrant further evaluation (Table 13). The control variety at this location consistently yielded higher than 1200 kg ha$^{-1}$ while the trial means remained above 1000 kg ha$^{-1}$.

**Table 13. Grain yield (kg ha$^{-1}$) of millet cultivars yield evaluated in IMZAT at Bambey, Sénégal, 1983-6 and 1988.**

| Cultivar | Years | | | | |
|---|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 | 1988 |
| IKMV 8201 | - | - | - | 1900 | 1188 |
| IKMC-1 | - | - | 1661 | 1740 | - |
| C 12 L | - | - | - | - | 933 |
| CT-2 | - | - | - | 2060 | 1106 |
| T 18 L | - | - | - | 2560 | 631 |
| ITMV 8001[1] | 1381 | - | - | 2590 | - |
| ITMV 8304 | - | - | - | 2290 | 1218 |
| INMV 8220[1] | 1458 | 1300 | - | - | - |
| SE 2124 | - | - | - | 1950 | 884 |
| IBMV 8302 | 1457 | 1180 | - | - | - |
| Control | 1388 (Souna III) | 1280 (Souna III) | 1430 (Farmers') | 2290 (Farmers') | 1424 (Improved) |
| Trial mean | 1423 | 1225 | 1546 | 1160 | 1019 |
| SE | ±191 | ±128 | ±140 | ±180 | ±115 |
| CV (%) | 37 | 30 | 32 | 16 | 23 |

[1] Cultivars recommended for further yield evaluation.
() Gives name or type of control variety.

## Days to flowering, plant height and ear length data

Data on days to flowering, plant height, and ear length are summarized for all locations and presented only for the sixteen cultivars that are recommended for further evaluation (Table 14). Where the data are not given as a range it indicates availability of the data from one site only.

**Table 14. Number of days to flowering, plant height, and ear length of some millet cultivars in IMZAT over sites[1].**

| Cultivar | Days to flower | Plant height (cm) | Ear length (cm) |
|---|---|---|---|
| IKMV 8201 | 52-64 | 170-249 | 30-38 |
| IKMC-1 | 53 | 222 | 31 |
| C 12 L | 55-60 | 192-226 | 42 |
| CT-2 | 54-60 | 196-223 | 40-64 |
| ITMV 8001 | 53-58 | 223 | 53 |
| ITMV 8003 | 51-58 | 208-223 | 44-44 |
| ITMV 8304 | 52-66 | 206-252 | 30-34 |
| ICMV IS 75327 | 59-63 | 183-187 | 58-66 |
| ICMV IS 85333 | 57-66 | 185-278 | 50-61 |
| NIG.COMP | | | |
| SE 360 | 50-58 | 215 | 51-55 |
| SE 2124 | 52-59 | 187-262 | 38-48 |
| INMV 8206 | 48 | 229 | 29 |
| INMV 8210 | - | - | - |
| INMV 8212 | 50 | 205 | - |
| INMV 8220 | 53 | 207 | 38 |

[1]. Data are given as ranges to include values from all sites; single value indicates single site data while a dash indicates that no data was taken.

Earlier in the conduct of IMZAT it was observed that millet disease data recorded from a yield trial, such as IMZAT, under natural disease conditions were not reliable for identifying resistant cultivars. A corresponding disease nursery, West African Downy Mildew Observation Nursery (WADMON) was organized to test the IMZAT entries under artificially inoculated disease conditions in disease hot spot sites in West Africa. Thus, disease data from IMZAT are not included in this report. Also in the ISC Millet Agronomy Program, the IMZAT entries are evaluated for seedling establishment under drought conditions, and for terminal drought resistance. As the techniques are developed and refined, the millet entomology program at the ISC also plans to evaluate IMZAT entries for major disease pests.

Generally the cultivars flowered in 55-66 days after planting and thus maturing in less than 100 days. This maturity cycle fits well within the crop growing season in Zone A. The cultivars did not vary much in plant height which averaged 200 cm or slightly higher. There were large differences in ear length. Cultivars with short ears were bred from INERA/ICRISAT program at Kamboinse (IKMV 8201 and IKMC-1) and the IAR/ICRISAT Samaru program (INMV 8206, INMV 8210, INMV 8212 and INMV 8220). Their ear length ranged from 29-38 cm. The cultivars bred in INRAN and ICRISAT programs in Niger generally showed ear lengths of more than 40 cm.

## Discussion and Conclusion

Although the cultivars contributed to IMZAT between 1982-88 were only from Burkina Faso, Niger, and Nigeria, some of these cultivars did well also in Cameroun, Ghana, Mali, and Sénégal (Table 15). Cultivars C 12 L, CT 2, ICMV IS 85327, ICMV IS 85333 from Niger and SE 360 from Nigeria deserved further evaluation in Ghana. IKMV 8201 and SE 2124 developed from Burkina Faso and Nigeria, respectively were recommended for on-farm testing in Mali. C 12 L and CT 2 also from Niger may be recommended for further evaluation in Mali. Seed of ITMV 8201 bred in Niger was requested for and sent for multilocational testing in Sénégal. Other cultivars with promise in Sénégal included ITMV 8001 from Niger, and INMV 8210, INMV 8212 from Nigeria. Cultivar INMV 8212 from Nigeria was in on-farm trials in Cameroun in 1986, and IKMV 8201 and Nigerian Composite were found warranting further evaluation in Cameroun. In addition to IKMV 8201 and IKMC-1 that have gone to large scale on-farm testing, the cultivars ITMV 8304 from Niger, Nigerian Composite, SE 360, and SE 2124 from Nigeria have performed well in Burkina Faso. In Niger ITMV 8001 and ITMV 8304 were released, while ICMV IS 85327 and ICMV IS 85333 are being tested multilocationally in Niger. Also Nigerian Composite, SE 2124 and INMV 8210 from Nigeria have performance in Niger. SE 360 and SE 2124 from Nigeria are in the process of release in the country. Cultivars IKMV 8201 and ITMV 8304 from Niger, and INMV 8206 from Nigeria also showed high potential.

It is quite apparent that IMZAT has been an effective means of exchange and distribution of elite millet cultivars among the research programs in the region. Some cultivars from other programs were taken for direct testing for release in other programs. Also IMZAT provided opportunities to select for broad adaptation while permitting rapid elimination of poor performing genotypes. These advantages for continuing the IMZAT trial are apparent.

**Table 15. Summary of IMZAT cultivars adopted or suggested for further yield evaluation in seven West African countries.**

| | | Country[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Where recommended | | | | | | | |
| Cultivar | Where developed | BKF | CMR | GHN | MLI | NIG | NGA | SEN | Total |
| IKMV 8201 | BKF | (x) | x | - | (x) | - | x | - | 4 |
| IKMC-1 | BKF | (x) | - | - | - | - | x | - | 2 |
| C 12 L | NIG | - | - | x | x | - | - | - | 2 |
| CT-2 | NIG | - | - | x | x | - | - | - | 2 |
| ITMV 8001 | NIG | - | - | - | - | (x) | - | x | 2 |
| ITMV 8003 | NIG | - | - | - | - | - | x | - | 1 |
| ITMV 8304 | NIG | x | - | - | - | (x) | x | (x) | 3 |
| ICMV IS 85327 | NIG | - | - | x | - | x | - | - | 2 |
| ICMV IS 85333 | NGA | - | - | x | - | x | x | - | 3 |
| NIG. COMP | NGA | x | x | - | - | x | - | - | 3 |
| SE 360 | NGA | x | - | x | - | - | (x) | - | 3 |
| SE 2124 | NGA | x | - | - | (x) | x | (x) | - | 4 |
| INMV 8206 | NGA | - | - | - | - | - | x | - | 1 |
| INMV 8210 | NGA | - | - | - | - | x | - | x | 2 |
| INMV 8212 | NGA | - | (x) | - | - | - | - | x | 2 |
| INMV 8220 | NGA | - | - | - | - | - | - | x | 1 |
| Total | | | | | | | | | |

[1] BKF = Burkina Faso, CMR = Cameroun, GHN = Ghana, MLI = Mali, NIG = Niger, NGA = Nigeria, SEN = Sénégal.

x Cultivars recommended for further evaluation in each respective country

(x) Cultivars already released, or in on-farm or multilocational testing in respective countries.

## Acknowledgment

ICRISAT and the author wish to express their thanks and appreciation to the following institutions for their participation in conducting and/or contributing entry cultivars to IMZAT:

- o Institut d'Etudes et de Recherches Agronomiques (INERA) Burkina Faso;
- o Institut de Recherches Agronomiques (IRA), Cameroun;
- o Faculty of Agriculture, University of Gambia;

- o Deutsche Gesselschaft für Technishe Zusammenarbeit (GTZ) GmbH and the Upper Regional Agricultural Development and Extension Project (URADEP) Ghana;
- o Institut d'Economie Rurale (IER), Mali;
- o Institut National de Recherches Agronomiques du Niger (INRAN), Niger Republic;
- o Institute for Agricultural Research (IAR), Nigeria;
- o Institut Sénégalais de Recherches Agronomiques (ISRA), Sénégal.

Our thanks also go to the following millet scientists who have cooperated in conducting of IMZAT: A. Cox at the Faculty of Agriculture, Gambia; O.P. Dangi at IITA-Maroua; A. Fofana at ISRA; W. Froelich at GTZ-Ghana; S.C. Gupta at ICRISAT/ISRA until 1985; 'J. Naino at INRAN; O. Niangado at IER; Mme N'Doye at ISRA; C.C. Nwasike at IAR; B. Ouendeba at INRAN; M.C. Sedogo at INERA, and B.B.Singh at ICRISAT/INRAN until 1985.

# Breeding of Full Season Photoperiod Sensitive Pearl Millet Varieties[1]

S.N. Lohani[2]

**Abstract**

*Evaluation of a range of germplasm accessions in Burkina Faso indicated that full season photoperiod sensitive (PS) genotypes are adapted to relatively high rainfall zones as photoperiod sensitivity allows flexibility in planting dates. Early maturing photoperiod less sensitive (PLS) genotypes or day neutral (DN) varieties appear to be suitable for late planting situations in high rainfall zones. In this paper, general observations on crosses between full season PS and early PLS or DN genotypes are presented. It was observed that PS late genotypes were slow in initial growth. There was a preponderance of early flowering segregates in crosses between PS and PLS and DN parents. Earliness was found to be dominant or partially dominant over lateness. Mean days to heading for fully hairy or partially hairy leaf surface segregates was significantly higher than for smooth leafed plants. Results suggest that it is relatively easy to breed early maturing PLS or DN varieties, but requires a major effort to breed full season late PS varieties. It will be necessary to screen a large population and continue recurrent selection to concentrate genes with desired degree of late maturity and photoperiod sensitivity in combination with other characters of interest.*

**Résumé**

**Sélection des variétés du petit mil de pleine saison sensibles au photopériodisme:** *L'évaluation d'un certain nombre d'accessions phyto-génétiques au Burkina Faso a indiqué que les génotypes sensibles au photopériodisme en saison pleine sont adaptés aux zones à pluviométrie relativement élevée, comme la sensibilité à celui-ci rend les dates de semis flexibles. Les génotypes précoces moins sensibles au photopériodisme ou des variétés à photopériodisme indifférent semblent être plus convenables pour des semis tardifs dans les zones à pluviométrie élevée. Dans ce document, des observations d'ordre général sur les croisements entre les génotypes sensibles, et moins sensibles en saison pleine, au photopériodisme ou les génotypes précoces à photopériodisme indifférent ont été présentés. Il a été observé que les génotypes tardifs sensibles au photopériodisme étaient lents au stade initial de leur développement. Il y avait une prépondérance au stade précoce de floraison entre les parents ségrégués sensibles et moins sensibles au photopériodisme et les parents à photopériodisme indifférent. Il a été constaté que la précocité était dominante ou partiellement dominant sur la tardivité. Les jours minimum à l'épiaison des variétés ségréguées de la surface foliaire entièrement ou partiellement poilus étaient considérablement plus élevés que pour les plantes aux feuilles lisses. Il ressort des résultats obtenus qu'il est relativement facile de sélectionner des variétés précoces moins sensibles au photopériodisme et celles à photopériodisme indifférent, mais un effort énorme est nécessaire pour sélectionner les variétés de pleine saison sensibles au photopériodisme. Il sera nécessaire de cribler une large population et de continuer la sélection récurrente afin de concentrer les gènes avec le dégré désiré de maturité tardive et la sensibilité au photopériodisme en combinaison avec d'autres caractères intéressants.*

## Introduction

The major thrust of the ICRISAT West African Pearl Millet Improvement Program for the transition zone (700-1000 mm rainfall) was to develop full season pearl millet (*Pennisetum glaucum* (L.) R.Br.) varieties for normal planting conditions with the secondary objective of developing early maturing varieties for late planting condition (Lohani 1984). This research was initially located at Kamboinse Agricultural Station (12°28' N lat.), Burkina Faso, a collaborative program with INERA. The commonly grown full season cultivars in 700-1100 mm rainfall regions of Burkina Faso take 120-150 days to mature, being progressively late with higher rainfall. Cultivars

1. Paper presented at the Regional Pearl Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 04-07 Sep 1989.

2. Principal Millet Breeder, ICRISAT West African Sorghum Improvement Program (WASIP), Pearl Millet Improvement Program for Transition zone, B.P. Bamako, Mali.

of similar or longer growth duration are found in high rainfall regions of other West African countries. One notable exception is the early maturing (70-80 days) cultivar, 'Iniadi', grown to some extent in south eastern parts of Burkina Faso and bordering regions of Togo, Benin and Ghana. Iniadi is planted early in the season (often mixed with late millet) for a quick harvest to fill the 'hunger gap' before the main season's harvest. The full season cultivars are qualitative photoperiod sensitive (PS) or short day sensitive with flowering occurring around a fixed date towards the end of the rainy season from a variable planting date, which is determined by seasonal rainfall and planting conditions. Early maturing cultivar type, 'Iniadi', shows weakly quantitative sensitive to day length and is here classified as day neutral (DN). "Kapelga", a PS late cultivar of central Burkina Faso, takes around 105 and 45 days to flower for June 1 and September 1 planting in the field at Kamboinse. For these planting dates (or any planting in between) and conditions, 'Iniadi' flowers between 45 to 58 days.

Observation over years of farmers' practices, as well as research results, in Burkina Faso, showed adaptive value of full season PS genotypes in the relatively high rainfall zones. Photoperiod sensitivity allows flexibility of planting date, which is an important crop adaptation, as planting date is dependent on adequate moisture which is determined by the erratic start of the rains. Flowering towards the end of rainy season permits an escape from certain kinds of insect damage (eating of floral parts, grain sucking and scratching) and poor seed set. Such problems greatly reduces yields of early maturing photoperiod less sensitive or DN varietyies flowering during peak rains. Early maturing varieties may be suitable for late planting condition in the transition zone.

In pursuit of stable, high yielding pearl millet varieties, the transition program has adopted both population and pedigree breeding methods. Results of selection and population improvement in local cultivars has led to the development of some full season and early maturing varieties for various rainfall zones and planting conditions of Burkina Faso (Lohani and Pako 988). Germplasm diversification and breeding has continued, and some approaches and selection results from crosses between full season PS and early photoperiod less sensitive (PLS) or DN genotypes will be presented in this paper.

## Selection Criteria for Crosses

Crosses between the early and late types are especially important for introgression of genes from otherwise isolated types due to their different flowering. The aim was to select progenies of appropriate maturity duration that combined desirable characters such as local adaptation, diseases resistance, desirable food quality, yield components and stability of yield.

A series of crosses were made between PS local cultivars and early maturing (75-90 days) and PLS or DN selections from West Africa. For practical breeding purpose under field condition, the very early and very late plants of the segregating population were thought to have a photoperiod sensitive response of the respective parents (PS and PLS or DN genotypes), with a range of sensitivity and maturity in between these plants. Observations on a large number of crosses showed the value of the cross between contrasting parents, like PS and PLS or DN genotypes (crosses between PS genotypes of 120-170 days duration rarely yielded superior segregates). Among the early maturing genotypes some notable parents with good combining ability were EBK 77, MPS 7936 (Gero type from Nigeria), P449 KS, P242 KS (Souna type from Mali) and GT 85, GT 79 (Iniadi type from Togo). Transgressive segregates for yield components in Kapelga x Iniadi cross was most impressive. It became also obvious, however, that the task of selecting lines of desired level of flowering and photoperiod sensitivity from crosses was not an easy one, a result of both genetic and environmental causes.

There was a preponderance of early flowering segregates in crosses between PS and PLS/DN parents. Earliness is dominant or partially dominant over lateness. Burton and Powell (1968) concluded that several genes acting additively, without dominance, condition photoperiodism in pearl millet. Results of genetic studies on the cross, Kapelga x GT 79, suggested that at least two genes with complementary effects are involved to control photoperiod sensitivity/late flowering (ICRISAT/Upper Volta 1983). It is easy to breed early maturing PLS or DN varieties, but much patience and judicious selection is required to breed a full-season PS variety. It will be necessary to screen large population and continue recurrent selection to concentrate genes (in population) with desired degree of late maturity and photoperiod sensitivity in combination with other characters of interest.

Moisture stress greatly delays flowering of pearl millet, thus confounding genetic differences for this character under rainfed condition with intermittent drought spells. Breeding material should be sown early in the season (early June at Kamboinse) to allow maximum spread of flowering. Irrigation should be carried out as required to remove moisture stress. Progenies of plants selected for flowering under non-stress condition can be evaluated later for drought tolerance/resistance under field conditions. At Kamboinse irrigation facilities were limited and planting could not always be carried out at the optimum time. An effort was made to adapt to the situation. Early generation breeding materials for important studies were preferably sown in the lower end of the field with a deeper soil and greater water holding capacity, or in a field near the "bas fond" (low lying field where water accumulated after heavy showers) where crop saving irrigation was possible. By this strategy a reliable genetic study on cross, Kapelga x GT 79, was carried out (ICRISAT/Upper Volta 1983) and selection of superior advanced lines of relatively late maturity were made.

The initial growth of PS late genotypes was observed to be slow in contrast to the vigorous growth of DN or PLS early maturing genotypes. Selection of slow growing plants in non-stress condition may increase the frequency of PS genotypes. It is likely that slow growing PS genotypes are at competitive disadvantage when segregating material (or a mixture of genotype of different growth pattern) are sown in hills with several seeds and that thinning to one plant/hill tends to retain the more vigorous early genotypes. Differential growth will be enhanced if stress occurs before thinning. Screening under extend daylength condition using artificial lights may allow separation of PS from PLS or DN types. Establishment of such a screening setup is planned at the present program site.

## Early generation selection using leaf surface hairiness

In a genetic study of the cross, Kapelga x GT 79 (ICRISAT/Upper Volta 1983), observation of $F_2$ plants showed that the mean days to heading for hairy or partially hairy leafed plants were significantly higher than the same for the smooth leafed plants (Table 1). Kapelga and GT 79 had hairy (HL) and smooth leaves (SL), respectively. The range of heading days in each class for each type indicates that these characters may be used to increase the proportion of late heading plants at an early stage of the breeding program. Late headed selections (29 $F_4$ progenies from this cross; ICRISAT/Burkina Faso 1985) were recombined to get a composite population IKM 85/86/RPI on which recurrent selection work is continuing. Average values of some characters of the selected lines and the parents are given in Table 2.

Early screening based on leaf surface hairiness was attempted in recurrent selection of one composite population RP 1004 (ICRISAT/Burkina Faso 1985). RP 1004 was derived by recombining relatively late $F_3$ progenies from a cross, Kapelga x GT 85. Results of yield trials showed that RP 1004 mostly flowered from 21-27 August for planting dates that ranged from 12 June to 6 July, indicating it was photoperiod sensitive, but not late enough for normal planting conditions in central Burkina Faso. RP 1004 was densely sown in a nursery bed during the off-season and 1025 selected seedlings (mostly HL and some SL) were transplanted and selfed. Further selection was made based on mature plants and head size characters. Progenies of 247 selected HL plants and 75 SL plants were evaluated in the 1985 cropping season along with Kapelga and GT 85 as repetitive checks. Segregation in progeny lines (usually of HL plant) for leaf surface character were noted. The lines were grouped into three categories: 1) all HL plants, 2) all SL plants and 3) heterogeneous for leaf surface ie. both HL and SL plants occurred. The number of lines in each category, average, range and variance for time to flowering, fertile tillers, plants height and head measurements are given in Table 3. It can be seen that lines with HL tended to be late where as lines with SL were relatively early (as observed in Kapelga x GT 79 cross). Early screening for leaf hairiness increased the frequency of relatively late flowering PS lines.

**Table 1. Plant observation on leaf hairiness and days to heading of F2 plants of Kapelga x GT 79 cross and the parents. Kamboinse, Burkina Faso, 1983.**

| Leaf hairiness | Time to heading (days)[1] Mean | Range | No. of plants |
|---|---|---|---|
| **F2 plants** | | | |
| Smooth | 61.38a | 44-95 | 217 |
| Full hairy | 79.40b | 55-101 | 66 |
| Partially hairy | 82.84b | 68-97 | 13 |
| **Parents** | | | |
| GT 79 (smooth) | 49.22 | 41-60 | 48 |
| Kapelga (hairy) | 92.58 | 87-95 | 56 |

Mean having a letter in common are not significantly different (P<0.05).

[1] Complete head emergence of the main tiller. Flowering occurs 2-3 days after heading.

**Table 2. Average of some characters of selected late flowering lines (F4) and parents[1]. Kamboinse, Burkina Faso, 1985.**

| Group | Days (date) to 50% flowering | Fertile tiller no. | Height (cm) | Head Length (cm) | Head Diameter widest (cm) | Head Diameter narrow (cm[2]) |
|---|---|---|---|---|---|---|
| Selected F4 lines | 82(16/9) | 6.34 | 270 | 31.25 | 2.00 | 1.29 |
| **Parents** | | | | | | |
| Kapelga | 83(17/9) | 8.01 | 310 | 28.06 | 1.81 | 1.09 |
| GT 79 | 52(17/8) | 3.26 | 200 | 25.92 | 2.19 | 1.38 |

[1] Number of selected F4 lines and parent rows (representative checks) were 29, 16 and 14, respectively. The nursery was sown on 27 Jun 1985.

[2] One cm inward from the head tip.

Table 3. Mean (x), variance ($s^2$) and range of various plant characters for RP 1004 derived smooth leaf surface progenies (SL), heterogeneous leaf surface progenies (Het), hairy leafed progenies (HL), and parents (GT 85, Kapelga). Kamboinse, Burkina Faso, 1985.

| | SL | Het | HL | GT 85 | Kapelga |
|---|---|---|---|---|---|
| **Time to 50% flowering (days)** | | | | | |
| x | 64.11 | 67.02 | 70.38 | 52.35 | 83.38 |
| $s^2$ | 26.29 | 24.14 | 32.74 | 3.63 | 8.42 |
| Range | 55-82 | 54-83 | 59-88 | 51-58 | 78-87 |
| n | 73 | 102 | 149 | 14 | 13 |
| **Number of fertile tillers $plant^{-1}$** | | | | | |
| x | 4.08 | 3.96 | 3.84 | 2.39 | 5.17 |
| $s^2$ | 1.87 | 1.616 | 1.629 | 0.086 | 0.310 |
| Range | 1.4-7.0 | 1.6-7.6 | 1.6-7.6 | 1.8-2.8 | 4.0-6.2 |
| n | 72 | 99 | 149 | 14 | 13 |
| **Plant height (cm)** | | | | | |
| x | 202 | 205 | 210 | 172 | 267 |
| $s^2$ | 773 | 706 | 703 | 71 | 61 |
| Range | 132-278 | 150-270 | 148-280 | 160-185 | 254-280 |
| n | 72 | 99 | 49 | 14 | 13 |
| **Head length (cm)** | | | | | |
| x | 32.03 | 32.38 | 31.76 | 22.92 | 26.15 |
| $s^2$ | 37.08 | 31.77 | 31.72 | 3.76 | 1.80 |
| Range | 21.48 | 21-48 | 20-45 | 20-26 | 24-28 |
| n | 73 | 96 | 135 | 14 | 13 |
| **Head diameter (cm) at widest point** | | | | | |
| x | 2.247 | 2.216 | 2.139 | 2.202 | 1.543 |
| $s^2$ | 0.093 | 0.091 | 0.065 | 0.021 | 0.013 |
| Range | 1.54-2.98 | 1.72-3.28 | 1.54-2.90 | 2.00-2.50 | 1.38-1.78 |
| n | 71 | 96 | 135 | 14 | 13 |
| **Head diameter (cm) at 1 cm inward from head tip** | | | | | |
| x | 1.495 | 1.485 | 1.453 | 1.554 | 1.131 |
| $s^2$ | 0.044 | 0.032 | 0.038 | 0.008 | 0.005 |
| Range | 1.07-1.94 | 1.14-1.94 | 1.08-2.23 | 1.42-1.68 | 1.01-1.25 |
| n | 71 | 96 | 135 | 14 | 13 |

Note 1. The material was planted (single row 4 m long plot spaced 75 cm apart, 11 plants $plot^{-1}$) on 27 June 1985 at Kamboinse. Reasonable growing conditions prevailed until the third week of September.

Note 2. Heterogeneous leaf surface progenies indicate that both SL and HL plants occurred in the progeny row.

Note 3. Plot values are means of all the plants for time to flowering, and randomly observed five plants for fertile tiller, plant height and head (primary tiller) measurements.

Recombinants with increased head size and numbers of fertile tillers in a GT 85 like background occurred, as well as recombinants with an increased head size in Kapelga like backgrounds. A total of 48 lines were selected based on maturity duration, plant and agronomic scores, head size, and disease ratings. The greater proportion of selections were from the relatively late maturing set of lines although some early maturing lines with excellent characters were also obtained. Six experimental varieties involving a limited number of lines (2 to 6) of different maturity and one composite population of the 23 best late flowering HL lines were reconstituted.

## Early generation selection based on slow growth character

Based on observations that late-flowering PS genotypes generally grow slowly, whereas early flowering genotypes grow rapidly, attempt was made to increase the frequency of late flowering plants in the segregating material by selection for slow growth up to six weeks after sowing (ICRISAT Sahelian Center 1988). A $F_2$ bulk seed lot of five crosses (with one common late parent and other early parents) that was known to yield late segregates was sown at high density in a nursery bed in the 1986 crop season. About 3500 2-week old seedlings were transplanted out at 8.8 plants $m^2$. Seedlings of Kapelga and GT 79 were transplanted as repetitive controls. The nursery was irrigated when required. Plants with early vigorous growth could be easily identified and were uprooted from the nursery beginning at two weeks following transplanting. Over 200 slow-growing plants that flowered in September were selected and harvested for $F_3$ evaluation. The frequency of $F_3$ lines for various flowering dates in 1987 showed that early vegetative selection for relatively late flowering was highly effective (Table 4). Selfed seed was harvested from 35 selected lines based on earhead characters, agronomic score and disease reaction.

Table 4. Frequency of F3 progenies in five flowering-date classes, Kamboinsa, Burkina Faso, 1987[1].

| Period of flowering | Frequency | No. of progenies selected |
|---|---|---|
| 1-5 Sep | 9 | |
| 6-10 Sep | 45 | |
| 11-15 Sep | 111 | 22 |
| 16-20 Sep | 22 | 3 |
| 21-25 Sep | 44 | 4 |

[1] Planted on 8 July 1987. Control GT 79 flowered on 19 August and control Kapelga on 21 September

## References

**Burton, G.W., and Powell, J.B.** 1968. Pearl millet breeding and cytogenetics. Advances Agrononmy 20:49-89.

**ICRISAT** (International Crops Research Institute for the Semi-Arid Tropics). 1983. Annual Report 1983. Ougadougou, Burkina Faso (Upper Volta): Cooperative Program ICRISAT/Burkina Faso (Upper Volta).

**ICRISAT** (International Crops Research Institute for the Semi-Arid Tropics). 1985. Annual Report 1985. Ougadougou, Burkina Faso: Cooperative Program ICRISAT/ Burkina Faso.

**ICRISAT** (International Crops Research Institute for the Semi-Arid Tropics) 1988. ICRISAT Sahelian Center West African Program Annual Report 1983. B.P. 12404 Niamey, Niger: ICRISAT Sahelian Center.

**Lohani, S.N.** 1985. Pearl millet production and improvement in Burkina Faso (Upper Volta). Pages 199-211 *in* Record of the Regional workshop on Pearl Millet Improvement 31 Aug-4 Sep 1984, ICRISAT Sahelian Center, B.P. 12404 Niamey, Niger.

**Lohani, S.N., and Pako, S.** 1988. Improving pearl millets for yield and downy mildew resistance in Burkina Faso. Presented at Regional Pearl Millet Workshop, ICRISAT-IAR/ABU, Samaru, Zaria, Nigeria, 15-19 Aug 1988.

# Highlights of Millet Research at the Lake Chad Research Institute, Maidiguri, Nigeria[1]

B.K. Kaigama and M.C. Ikwelle[2]

**Abstract**

*This paper outlines the importance of pearl millet in the savanna areas of northern Nigeria. Lake Chad Research Institute has been given the mandate for the improvement of this crop in this area. Current research includes characterization of millet germplasm materials and varietal testing. The results of a variety at Malamfatori are reported.*

**Résumé**

**Lumière sur la Recherche du Mil à l'Institut de Recherche du Lac Tchad, Maiduguri, Nigéria.** *Ce document met l'accent sur l'importance du petit mil dans les savanes du nord Nigérian. L'Institut de Recherche du Lac Tchad (LCRI) a été mandaté d'améliorer cette variété dans cette région. La recherche actuelle comprend la caractérisation du matériel génétique du mil et du test variétal. Les résultats d'une variété à Malamfatori sont rapportés.*

## Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br. is a major staple food crop in the savanna areas of the northern states of Nigeria. As a food crop, it is second in importance only to sorghum (*Sorghum bicolor* (L.) Moench). It is grown mainly by subsistence farmers whose farm holdings range from 0.2 to 2 ha. In the far north where the total annual rainfall is low, pearl millet supersedes sorghum in importance and dominates farmers' fields.

The purpose of this paper is mainly to give an over-view of the research on pearl millet currently going on in the Lake Chad Research Institute (LCRI) and give projections for future work.

## Germplasm Materials

The LCRI has a number of new mandates. Among others there are the genetic improvement of pearl millet, wheat (*Triticum aestivum* (L.)) and barley (*Hordeum vulgare* (L.)) in Nigeria. The work on millet research has hitherto been carried out by the Institute for Agricultural Research (IAR), Zaria. As a result of the change in mandates, millet germplasm materials from IAR have recently been handed over to LCRI. A total of 409 lines/varieties were collected from Zaria and planted out in nursery plots in Maiduguri this season to characterize the materials for subsequent breeding program. The materials are currently in the field and are doing well.

## ICRISAT/IAR Cooperative Trials

One pearl millet cooperative trial between ICRISAT and IAR was passed on from IAR and planted in Maiduguri. A total of 26 entries from Nigeria and Niger including an improved local check were contained in the trial. The materials have shown excellent performance in this location. They are at the heading stage of growth now.

---

1. Paper presented at the Regional Millet Workshop, ICRISAT Sahelian Center, Sadoré, Niger, 4-7 Sep 1988.

2. Agronomist and Physiologist/Agronomist, Lake Chad Research Institute, P.M.B. 1293 Maiduguri, Nigeria.

## Millet Variety Trial

Some work on millet variety testing has been carried out at the Institute. This involves 22 entries tested in five locations covering Maiduguri, Malamfatori, Ngalda, Dadin-Kowa and Dambca in the north-east of Nigeria. The result of the trial in Malamfatori during the 1988 wet season is presented in Table 1.

There were no significant varietal differences in plant height, but significant differences were observed in grain yield. There was ample rainfall during the 1988 growing season amounting to 265 mm, evenly distributed during the growing season. All the plants were more than 2 m tall and height ranged from 209.2 to 279.4 cm tall with a CV of 10.56%. The highest grain yield was recorded by GBC which gave a mean yield of 3.100 kg ha$^{-1}$ followed by INMV 20 and INMV 55 with 2.488 and 2.438 kg ha$^{-1}$, respectively. Varieties that yielded up to 2 000 kg ha$^{-1}$ included SE 361, the local check, INMV 49 and INMV 212. Only seven entries in the trial yielded less than 2 000 kg ha$^{-1}$. With sufficient rainfall to support the crop, this environment can give a good crop of pearl millet. However, there is a need to develop drought tolerant materials for this area which is prone to drought and has erratic rainfall.

## Collaboration

LCRI looks forward to collaborative work on millet improvement between the Institute and ICRISAT. There is an urgent need for cooperation in collection and distribution of germplasm, materials in order to form a broad genetic base for a successful millet breeding and development program.

**Table 1. Mean performance of pearl millet varieties in Malamfatori, Nigeria, wet season 1988.**

| Variety | Plant height (cm) | Grain yield (kg ha$^{-1}$) |
|---|---|---|
| INMV 60 | 221 | 2 190 |
| GDC | 239 | 1 430 |
| Nig. Composite | 272 | 2 050 |
| INMV 49 | 241 | 2 400 |
| INMV 36 | 270 | 2 030 |
| INMV 212 | 246 | 2 400 |
| Ex-Borno | 271 | 2 270 |
| INMV 62 | 252 | 1 825 |
| INMV 47 | 248 | 2 270 |
| INMV 40 | 248 | 2 030 |
| INMV 3 | 228 | 1 720 |
| INMV 12 | 225 | 1 830 |
| INMV 46 | 257 | 1 930 |
| INMV 118 | 250 | 2 100 |
| GBC | 279 | 2 100 |
| INMV 23 | 246 | 1 855 |
| INMV 32 | 249 | 1 940 |
| INMV 55 | 243 | 2 430 |
| INMV 20 | 229 | 2 400 |
| INMV 42 | 210 | 1 590 |
| S.E. 361 | 247 | 2 420 |
| Local check | 212 | 2 420 |
| 0.05 | ns | 804 |
| 0.01 | | 807 |
| CV (%) | 10.7 | 22.0 |

# CLOSING SESSION

## Draft Constitution for the Western and Central Africa Network on Millet Research

In accordance with the recommendations made by the representatives of Benin, Burkina Faso, Cameroun, Côte d'Ivoire, The Gambia, Ghana, Guinea Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Togo and INSAH at the Regional Millet Workshop held at Zaria (Nigeria) from 15 to 19 August, 1988, the Regional Millet Workshop held at Sadoré, Niger, from 4 to 7 September, 1989 hereby sets up a Western and Central African Network on millet research.

The following countries and institutions were present at this workshop: Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, Chad, ICRISAT, INSAH and SAFGRAD.

### Objectives of the Network

This network will:

- strengthen the structures and the national agricultural research systems on millet;
- ensure the training of scientists and technicians;
- enhance a lasting and multilateral collaboration between the national, regional and international research structures;
- ensure the dissemination of scientific information, regular contacts between scientists of Central and Western Africa;
- determine the common constraints and strategies for multidisciplinary research;
- facilitate exchange of technologies between national, regional and international research programs;
- ensure the transfer of research achievements at farmers' level through tests and demonstrations in farmers' fields; and
- see to the collaboration between the different networks existing within the sub-region.

### The Controlling and Executing Bodies of the Network

The controlling and executing bodies of the network are:

- the Workshop (supreme body)
- the Executive Committee
- the Coordination

## Duties of the Different Bodies of the Network

### The Workshop of the Network

The Workshop is the supreme body of the network. It determines the major areas of activities of the network, elects the members of the Executive Committee and supervises its activities. It holds its meetings once every two years.

During the transition period and pending the availability of adequate funds, ICRISAT is designated as coordinator of the network with the agreement of the Executive Committee, INSAH and SAFGRAD.

The network authorizes ICRISAT, INSAH and SAFGRAD to procure the necessary funds on its behalf for the purposes of carrying out the duties of the network.

### The Executive Committee

The Executive Committee will have the following duties:

- set up priorities of the network's research activities and will submit those to the workshop;
- give directives for the attainment of the objectives of the network and supervise their execution;
- ensure that appropriate means are made available to national programs for the purposes of carrying out the duties assigned to the network;
- suggest a program for the utilization of the funds that will be made available to the network taking into account the priorities set out;
- see to the implementation of all the recommendations and resolutions arrived at during meetings within the framework of the network;
- nominate two secretaries (1 anglophone and 1 francophone) for the session during each meeting of the network;
- supervise the activities of the coordinator;
- make a report to the workshop (supreme body) for which its is answerable for the management of the funds at its disposal; and
- the Executive Committee to meet every year.

The Executive Committee will be composed as follows:

- 1 Chairman
- 5 members from the national research programs on a multi-disciplinary basis,
- 1 Coordinator.

ICRISAT, INSAH and SAFGRAD and any other institution engaged in millet research will be admitted as observers. The Executive Committee is elected by the general assembly of the network for a period of two years and renewable only once for a half-term. The Executive Committee elects its chairman for one term renewable only once.

## The Coordination

The coordinator will have the following duties:

- o record the proceedings of workshops;
- o write out minutes of meetings of the Executive Committee; and
- o organize and follow up the activities of the network.

## Constraints to Millet Production

The constraints to millet production vary depending on the following agro-ecological zones:

| Agro-ecological Zones | Constraints | | |
|---|---|---|---|
| | Biotic | Abiotic | Socio-economic |
| Sahelian Zone | Insects<br>Striga<br>Low productivity | Drought<br>Poor soil fertility | Poor purchasing power<br>Unorganized markets |
| Sudanian Zone | Diseases (mildew, smut, ergot)<br>Striga, weeds<br>Low yielding ability of local cultivars | Poor soil fertility<br>Irregular rainfall | " |
| Northern Guinean Zone | Diseases (mildew, smut, ergot)<br>Striga, weeds<br>Low yielding ability of local cultivars | | " |

## Mechanisms and Action Plans for Network

Apart from the programs for improving productivity in the different leading national centers, the network will conduct preliminary and advanced trials, and also trials and tests in farmers' fields.

| Subjects | Centers C1 | Centers C2 |
|---|---|---|
| Drought | Maradi, Louga, Dori, Maiduguri | Kopro and Bema |
| Diseases (mildew, smut) | Ferke, Bambey, Kamboinse, Cinzana, Zaria, Kolo, Maroua | |
| Insects | Kolo, Dori, Bambey, Sotuba, Kamboinse | Ferke |

**Members of the Executive Committee**

During its session held on 07 September, 1989, the General Meeting of the Network elected the following people as members of the Executive Committee:

| | | |
|---|---|---|
| Merrs. | NIANGADO Oumar | Mali |
| | ZANGRE Roger | Burkina Faso |
| | NAINO Jika | Niger |
| | BENINGA Marboua | Côte d'Ivoire |
| | IKWELLE M.C. | Nigeria |
| | MBAYE Demba Farba | Senegal |

ICRISAT will submit the name of the coordinator later. This was endorsed on September 07, 1989 at Sadoré, Niger.

**Document Constitutif du Réseau Ouest et Centre Africains**

**de Recherche sur le Mil**

En application des recommendations formulées par les représentants du Bénin, du Burkina Faso, du Cameroun, de la Côote d'Ivoire, de la Gambie, du Ghana, de la Guinée Bisau, du Mali, de la Mauritanie, du Niger, du Nigeria, du Sénégal, du Togo et de l'INSAH à l'atelier régional mil tenu à Zaria (Nigeria) du 15 au 19 Août 1988, l'atelier régional mil tenu à Sadoré (Niamey-Niger) du 04 au 07 Septembre 1989 décide de la création d'un Réseau Ouest et Centre Africains de rechercche sur le mil.

Les pays et institutions suivants étaient présents à cet atelier : Bénin, Burkina Faso, Côte d'Ivoire, Gambie, Ghana, Mali, Niger, Nigeria, Sénégal, Tchad, Togo, ICRISAT, INSAH et SAFGRAD.

**Objectifs du Réseau**

Ce réseau sera chargé de :

o renforcer les structures et les systèmes nationaux de recherche agronomique sur le mil;

o assurer la formation des chercheurs et des techniciens;

o développer la collaboration multilatérale et durable entre structures nationales, régionales et internationales de recherche;

o assurer la circulation de l'information scientifique, les rencontres entre chercheurs des pays de l'Afrique de l'Ouest et du Centre;

o définir les contraintes communes et les stratégies de recherche multidisciplinaire;

o faciliter les échanges des technologies entre programmes nationaux, régionaux et internationaux de recherche;

o veiller au transfert des acquis de la recherche au niveau des paysans par des tests et demonstrations en milieu paysan; et

o veiller à la collaboration entre les différents réseaux existant dans la sous région.

**Organes de Contrôle et d'Exécution du Réseau**

Les organes de contrôle et d'exécution du réseau sont :

o l'atelier (instance suprême),

o le comité exécutif,

o la coordination.

**Attributions des Organes du Réseau**

L'Atelier du Réseau

L'atelier est l'organe suprême du réseau. Il définit les grandes lignes des activités du réseau, élit les membres du comité exécutif et contrôle ses activités. Il se réunit une fois tous les deux ans.

Pendant la phase transitoire et dans l'attente des moyens propres, l'atelier donne mandat à l'ICRISAT de pourvoir au poste de coordonnateur du réseau après accord du comité exécutif, de l'INSAH et du SAFGRAD.

Il autorise l'ICRISAT, l'INSAH et le SAFGRAD à rechercher en son nom les fonds nécessaires au fonctionnement du réseau.

Le Comité Exécutif

Le comité exécutif aura les fonctions suivantes :

- proposer et hiérarchiser les activités de recherche du réseau qui seront soumises à l'atelier;
- fournir des directives sur l'exécution des objectifs assignés au réseau et en assurer la supervision;
- s'assurer que les moyens appropriés sont mis à la disposition des programmes nationaux pour l'exécution des tâches définies par le réseau;
- proposer un programme d'utilisation des fonds qui seront mis à la disposition du réseau en tenant compte des priorités retenues;
- veiller à l'exécution de toutes les recommendations et résolutions adoptées lors des réunions du réseau;
- le comité désignera deux secrétaires (1 anglophone et 1 francophone) de séance à chacune de ses réunions;
- contrôler les activités du coordonnateur;
- rendre compte à l'atelier (instance suprême) devant lequel il est responsable de la gestion des fonds mis à sa disposition; et
- le comité exécutif se réunit tous les ans.

Le comité exécutif se compose comme suit :

1 Président issu d'un programme national de recherche;

5 Membres émanant également des programmes nationaux de recherche sur une base multidisciplinaire; et

1 Coordonnateur.

Seront admis à titre d'observateurs l'ICRISAT, l'INSAH, le SAFGRAD et toute autre institution intéressée par la recherche sur le mil. Le comité exécutif est élu par l'assemblée générale du réseau pour deux ans et rééligible pour moitié une seule fois. Le comité exécutif élit son propre président pour un mandat de deux ans renouvelable une seule fois.

## La Coordination

Le coordonnateur est chargé de :

- o l'élaboration du proceeding des ateliers;
- o la rédaction des procès verbaux des réunions du comité exécutif; et
- o l'animation et le suivi des activités du réseau.

## Contraintes à la Culture du Mil

Les contraintes à la culture du mil sont différentes selon les zones agro écologiques qui sont :

| Zones agroécologiques | Contraintes | | |
|---|---|---|---|
| | Biotiques | Abiotiques | Socio économique |
| Zone sahélienne | Insectes<br>Striqa<br>Faible productivité des variétés locales | Sécheresse<br>Sols non fertiles | Faible pouvoir d'achat<br>inorganisation des marchés |
| Zone soudanaise | Maladies (mildiou, charbon, ergot)<br>Striga, mauvaises herbes<br>Faible productivité des variétés locales | Faible fertilité des sols<br>Irrégularité des pluies. | " |
| Zone nord guinéenne | Maladies (mildiou, charbon, ergot)<br>Strigra, mauvaises herbes<br>Faible productivité des variétés locales | | " |

## Mécanismes et Plans d'Action du Réseau

Outre les programmes d'amélioration de la productivité dans les différents centres leaders nationaux, le réseau réalisera des essais préliminaires, des essais avancés et des essais et tests en milieu réel.

| Sujets | Centres | |
|---|---|---|
| | C1 | C2 |
| Sécheresse | Maradi, Louga, Dori, Maiduguri | Koporo et Béma |
| Maladies (mildiou, charbon) | Ferké, Bambey, Kamboinsé, Cinzana, Zaria, Kolo, Maroua | |
| Insectes | Kolo, Dori, Bambey, Sotuba, Kamboinsé | Ferké |

## Membres du Comité Exécutif

L'assemblée générale du réseau, lors de sa séance du 7 Septembre 1989, a élu les membres suivants :

MM. NIANGADO Oumar, Mali,
ZANGRE Roger, Burkina Faso,
JIKA Naino, Niger,
BENINGA Marboua, Côte d'Ivoire,
IKWELLE M.C. Nigeria,
MBAYE Demba Farba, Sénégal.

L'ICRISAT donnera ultérieurement le nom du coordonnateur. Fait à Sadoré, Niger, le 7 Septembre 1989.

# PARTICIPANTS

**Bénin**

**Dossou-Yovo, Sigisbert**
Responsable du Programme du Mil,
Sorgho et Fonio
Station Ina
B.P. 03
N'Dali

**Yehouenou, Alphonse**
Responsable Programme Lutte Phytosanitaire
Station Ina
B.P.03
N'Dali

**Burkina Faso**

**Menyonga, Joseph**
Coordinator for International Cooperation
SAFGRAD
B.P. 1783
Ougadougou

**Mme Sedogo, Marie Cécile**
Sélectionneur
INERA
B.P. 7192
Ougadougou

**Somé, Salibo Jean Arsène**
Assistant à l'IDR
Université Ouagadougou
B.P. 7021
Ougadougou

**Zangré, G. Roger**
Sélectionneur
INERA
B.P. 7192
Ouagadougou

**Chad**

**Bichara, Daoussa Cherif**
Directeur National
Projet Production de Semences
Ministère de l'Agriculture,
Secretariat d'Etat
s/c FAO, B.P. 101
N'Djamena

**Dar, Gaourang**
Chef de ferme de Déle
Production de Semences
Ministère de l'Agriculture,
Secretariat d'Etat
B.P. 442
N'Djamena

**Côte d'Ivoire**

**Beninga, Marboua Békoye**
Sélectionneur
IDESSA
B.P. 121
Ferkéssédougou

**Gambia (The)**

**Jallow, Moustapha**
Research Officer (Entomologist)
Ministry of Agriculture
Department of Agricultural Research
(Upland Cereals Program)
Yundum
Banjul

**Joff, Momodou**
Research Officer (Agronomist)
Department of Agriculture
Yundum
Banjul

**Mbenga, Musa**
Research Officer (Plant Breeder)
Ministry of Agriculture
Department of Agricultural Research
Yundum
Banjul

**Ghana**

**Buah, S.S.**
Assistant Research Officer
Crops Research Institute/GTZ
Nyankpala Agriculutral Experiment Statior
P.O. Box 52
Tamale

**Frey, Eckart**
Agronomist
Crops Research Institute/GTZ
Nyankpala Agricultural Experiment Station
P.O. Box 9698 Kotoka Int. Airport
Accra

**Mali**

**Diourté, Mamourou**
Pathologue du sorgho et du mil
Institut d'Economie Rurale
IER/DRA/SRCVO
B.P. 438 Sotuba
Bamako

**Kéré, Adolphe**
Coordonateur Projet Regional Mil, Sorgho, Niébé et Maïs
Institut du Sahel (INSAH)
B.P. 1530
Bamako

**Lohani, Shiva, N.**
Millet Breeder
Transition Zone Breeding
ICRISAT West African Sorghum Program
B.P. 320
Bamako

**Netoyo, Laomaibao**
Directeur Département Recherche sur Milieu et l'Agriculture
Institut du Sahel
B.P 1530
Bamako

**Niangado, Oumar**
Directeur de la station Cinzana
Institut d'Economie Rurale
SRA Cinzana
B.P. 214
Ségou

**Ouologuem, Binogo**
Sélectionneur du mil
Institut d'Economie Rurale
IER/DRA/SRCVO
B.P. 438 Sotuba
Bamako

**Niger**

**Amoukou, Adamou Ibrahim**
Généticien
ORSTOM
Faculté Agronomie
B.P. 11416
Niamey

**Bieler, Peter**
PhD student
PMIP/Agronomy
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Cissé, Alhader**
Assistant de Recherche
PMIP/Pathology
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Fussell, L.K.**
Agronomist/Physiologist
PMIP/Agronomy
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Gonda, Jada**
Selectionneur
Institut National de Recherches Agronomiques du Niger
Station de Recherche INRAN Tarna
B.P. 240
Maradi

**Halidou, Boubacar**
Phytopathologue
Institut National de Recherches Agronomiques du Niger
Station de Recherche INRAN Kolo
B.P. 429
Niamey

**Jika, Naino**
Directeur de la Station Kolo
Institut National de Recherches Agronomiques du Niger
Station de Recherche INRAN Kolo
B.P. 429
Niamey

**Kollo, Abdourhamane Issoufou**
Phytopathologue
Institut National de Recherches Agronomiques du Niger
Station de Recherche INRAN Kolo
B.P. 429
Niamey

**Kumar, Anand K.**
Program Leader PMIP
PMIP/Breeding
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Laurense, Alida**
Entomologiste
Département de Formation
en Protection des Végétaux
Centre AGRHYMET/CILSS/Pays-Bas
B.P. 12625
Niamey

**Lukefahr, Maurice James**
Entomologist
PMIP/Entomology
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Mamalo, Abdoulkarim**
Technicien Supérieur
PMIP/Entomolgy
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Marchais, Louis**
Généticien
ORSTOM
ICRISAT Sahelian Center
P.B. 12404
Niamey

**Nwanze, Kanayo F.**
Entomologist
Cereals Program
ICRISAT Center
Patancheru P.O.
Andhra Pradesh 502 324

**Okiror, Shadrach O.**
Breeder
PMIP/Regional Breeding Program
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Osman, Mouhamed A.**
Post doctoral student
PMIP/Pathology
ICRISAT Sahelian Center
B.P. 12404
Niamey

**Ouendeba, Botourou**
Breeder
Institut National de Recherches
Agronomiques du Niger
Station de Recherche INRAN Kolo
B.P. 429
Niamey

**Werder, Josef**
Pathologist
PMIP/Pathology
ICRISAT Sahelian Center
B.P. 12404
Niamey

## Nigeria

**Elemo, K.A.**
Agronomist
Agronomy Department
IAR/ABU
P.M.B. 1044
Zaria

**Ikwelle, M.C.**
Agronomist
Lake Chad Research Institute
P.M.B. 1293
Maiduguri

**Kaigama, B.K.**
Director of LCRI
Lake Chad Research Institute
P.M.B. 1293
Maiduguri

**Labe, D.A.**
Millet Agronomist
Institute for Agricultural
Research/Ahmadu Bello University
P.M.B. 1044
Zaria

**Nwasike, Chris C.**
Breeder
Instiute for Agricultural
Research/Ahmadu Bello University
P.M.B. 1044
Zaria

**Uyovbisere, Edward, O.**
Research Fellow
Department of Soil Science
Faculty of Agriculture
Institute for Agricultural Research
P.M.B. 1044
Zaria

## Sénégal

**Fofana, A.**
Sélectionneur
ISRA/CNRA
B.P. 51
Bambey

**M'Baye, Demba Farba**
Coordonateur Programme Mil
ISRA/CNRA
B.P. 51
Bambey

**Togo**

**Mpo, Batoussi**
Chargé du Programme Sorgho-Mil
Direction de la Recherche Agronomique
B.P. 2318
Lomé