Pearl Millet in African Agriculture

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Abstract

About one third of the world's millet is grown in Africa, about 70% of which is grown in West Africa. Pearl millet is the major millet grown in Africa. In relative terms pearl millet is more important to the agricultural systems and economies of Africa than in other regions of the world.

Millet production has increased at only 0.7% a year during the last two decades, the slowest growth rate among food crops. Furthermore, the growth has been primarily due to increase in cultivated areas, indicating that technological innovations have not had much impact on aggregate millet productivity.

Pearl millet is used mainly as a grain-like flour (couscous), a dough (tô), and a porridge (tura, boule).

Abiotic constraints to increased millet production include the low and erratic rainfall in a short growing season, sandstorms, high [illegible], high air and soil temperatures, poor soils with low levels of natural fertility, traditional management practices such as low crop densities, and no fertilization.

Biotic constraints include the low genetic yield potential of local landraces, the effects of diseases such as downy mildew, the parasitic weed Striga, and grain-eating birds.

Pearl millet is traditionally grown as an intercrop with a legume such as cowpea or groundnut. In such situations economic returns are much higher than for a pure crop millet.

Prospects for millet production are increasing as research on the crop expands.

Résumé

Rôle du mil dans l'agriculture africaine : *Près d'un tiers de la production mondiale du mil provient de l'Afrique, en particulier l'Afrique de l'Ouest qui fournit 70% de la production du continent. La principale espèce cultivée est* **Pennisetum americanum**. *Le mil joue un rôle plus important dans l'agriculture et les économies africaines que dans d'autres parties du monde.*

La production de mil s'est accrue de seulement 0,7% par an au cours de ces deux dernières décennies, soit le plus faible taux de croissance parmi les cultures vivrières. Cette croissance est plutôt due à l'expansion de la superficie cultivée, ce qui signifie que les innovations technologiques n'ont pas eu d'impact significatif sur la productivité.

Le mil est consommé sous forme de semoule (couscous), de pâte (tô) et de bouillie (tura, boule).

Les contraintes abiotiques à l'augmentation de la production sont : la pluviométrie faible et imprévisible pendant une courte saison de culture, les vents de sable, des pluies très intenses, des températures atmosphériques et du sol élevées, des sols peu fertiles, des pratiques traditionnelles, notamment une faible densité de semis et aucun apport d'engrais.

Parmi les contraintes biotiques, il faut signaler le faible potentiel de rendement génétique des variétés traditionnelles ainsi que les effets des maladies telles que le mildiou, de la mauvaise herbe striga *et des oiseaux granivores.*

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Submitted as CP 380 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Proceedings of the International Pearl Millet Workshop, 7-11 April 1986, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

En culture traditionnelle, le mil est cultivé en association avec une légumineuse telle que le niébé et l'arachide. Dans ce cas le rendement est plus élevé par rapport à une culture pure de mil.

L'intensification de la recherche sur le mil permettra d'améliorer les perspectives de production de cette espèce.

rea, Production, and Use of Millet

mportance of the Crop

Vorld production of all millets is about 29 million t, of which about 35% is produced in Africa (Table 1). The major African producers are Nigeria (about 31% of the African production) and Niger (about 12%); both in West Africa. Other major producers are Burkina Faso, Chad, Mali, and Senegal in West Africa, and Sudan and Uganda in East Africa.

Pearl millet (*Pennisetum americanum*) is the major millet grown in Africa. Apart from Uganda, which grows mainly finger millet, *Elusine corocana* (ICRISAT 1980), all the major African producers listed in Table 1 produce primarily pearl millet.

In all the major African millet-producing countries, the crop is of considerable importance in the agricultural system, and accounts for over one-third of total cereal output (Table 1). This contrasts with other areas of the world where large quantities of millets are produced, but in which they usually account for less than 10% of total cereal output. For example, India grows one-third of the world's millet, but the crop only represents about 7% of total cereal production. About 65% of Indian millet production is pearl millet. In relative terms pearl millet is more important to the agricultural systems and economies of Africa than in other regions of the world.

Aggregate Production and Growth Rates

Sub-Saharan Africa (SSA) is the only part of the developing world in which the index of per capita food production has declined during the last two decades (World Bank 1984). Of all the subregions of SSA, West Africa has shown the slowest growth rate for total food production. Per capita production of all crops in West Africa has declined, except for rice, which is a minor staple in the region.

Table 1. Average annual area, production, and yield of millets and percentage of total cereal production by major producing countries in Africa as well as major regions of the world, in 1974-76 and 1980-82.

Region, country	Area ('000 ha)		Cereal Production (%)		Production ('000 mt)		Yield (kg ha⁻¹)	
	74-76	80-82	74-76	80-82	74-76	80-82	74-76	80-82
Africa	15218	16247	13.9	13.8	9630	10249	633	619
Burkina Faso	857	870	31.7	32.1	364	387	425	441
Chad[1]	959	1160	87.8	88.0	520	593	542	510
Mali[1]	1212	1425	70.1	76.9	852	868	702	615
Niger	2150	3060	74.0	76.5	828	1321	385	432
Nigeria	4800	5230	34.5	32.4	2843	3220	592	636
Senegal[1]	1004	938	79.7	80.7	658	642	655	705
Sudan	1126	1120	15.8	12.3	416	393	370	345
Uganda	498	303	38.2	42.1	613	489	1232	1615
Asia	25212	23450	3.0	2.5	16718	16445	663	701
India	18338	18096	7.6	6.7	9042	9426	493	521
South America	211	167	0.4	0.3	241	193	1141	1157
USSR	2914	2807	1.4	1.1	2410	1791	827	637
World	43610	43050	2.1	1.8	29062	28733	666	668

1. Includes sorghum.
Source: FAO Production Yearbook 1982.

The poor performance in foo[illegible]duction is due in large measure to the very l[illegible]nd sometimes negative rates of growth for the major staples, i.e., millet and sorghum (*Sorghum bicolor* L.) as well as groundnut (*Arachis hypogea* L.) (Table 2).

Millet recorded the lowest growth rate of all food crops, except for groundnuts, during the past two decades. Its growth rate of only 0.7% a^{-1} was substantially lower than the population growth rate of about 2.5% a^{-1} during the same period.

Crop Use

Pearl millet grain in Africa is grown primarily for human consumption. There are three primary methods of using the grain: as a grain-like flour (couscous), a dough (tô), or a gruel (fura, boule, etc.). In West Africa, millet couscous is eaten mainly by the Peuhl, and is thus common in the regions where they live in Senegal, Gambia, and northern Nigeria. After decortication the grain is pounded into flour. Couscous is made by steaming the flour on a mat over an open pot, then sun drying. At mealtimes the couscous is boiled and served with a vegetable, fish, or meat sauce.

Among the other major ethnic groups in the Sahel (Bambara, Germa, Mossi, etc.) millet is more often consumed as *tô*. Millet flour is cooked with water and an alkaline solution to make a thick paste or dough. The alkaline solution is made from burned millet straw. This is eaten by dipping into a meat or vegetable sauce.

To prepare the gruel or porridge (fura, boule, etc.,) millet flour is boiled with water. Milk, sugar, pepper, or salt may or may not be added. Fura is usually eaten as a secondary meal in the mornings or midday, although in times of scarcity it may be the only meal eaten.

At the onset of harvest immature millet heads are occassionally roasted and eaten as a snack. Millet cakes (slightly fermented millet flour deep fried in vegetable oil) are often sold in markets and urban areas. Another minor use of millet is in beer making.

Pearl millet straw has a number of important traditional uses in Africa. In areas where millet is the staple food, the straw is the most important building material for granaries and as a fencing material. It is also used to feed cattle and is sometimes harvested and stored for use as livestock feed during the dry season.

Table 2. Annual growth of major agricultural commodities in sub-Saharan Africa.

Commodity	Growth rate a⁻¹ (%) 1969-71 to 1977-79	1977-79 to 1980-82	1969-71 to 1980-82
Cereals	1.3	1.9	1.5
Maize	1.3	0.8	1.2
Millet	0.4	1.6	0.7
Rice (paddy)	2.9	1.7	2.5
Sorghum	1.6	3.5	2.1
Wheat	-0.2	3.9	0.9
Oil & Oilseeds			
Coconuts	0.9	-0.8	0.5
Groundnuts	-0.9	-3.6	-1.7
Palm oil	2.2	1.3	2.0
Others			
Pulses	1.1	3.8	1.8
Roots and tubers	1.8	1.7	1.8

Source: World Bank 1984, Table 22.

Environmental Resources of the Area

Because of its adaptability to drought, pearl millet is grown in the regions of sub-Saharan Africa which have an alternately wet and dry climate. Since 70% of pearl millet in Africa is grown in West Africa, a major emphasis will be placed on West Africa in this section.

The low productivity of pearl millet in Africa is largely due to the harsh environment in which it is grown. Rainfall and soils are the major environmental resources that merit detailed analysis in the efforts to increase millet production.

Rainfall

The bulk of African pearl millet is grown in the regions with annual rainfall ranging from 200-800 mm (Fig. 1). In West Africa, the rainfall gradient is very steep. Rains are usually limited to the summer months of May-Oct, and aridity prevails during the rest of the year.

Rainfall in the millet growing regions of Africa is not only low, but erratic. Large variations in time and space occur. The coefficient of variation of annual rainfall ranges from 20-30%. For example, mean annual rainfall in Niamey in Niger is 560 mm

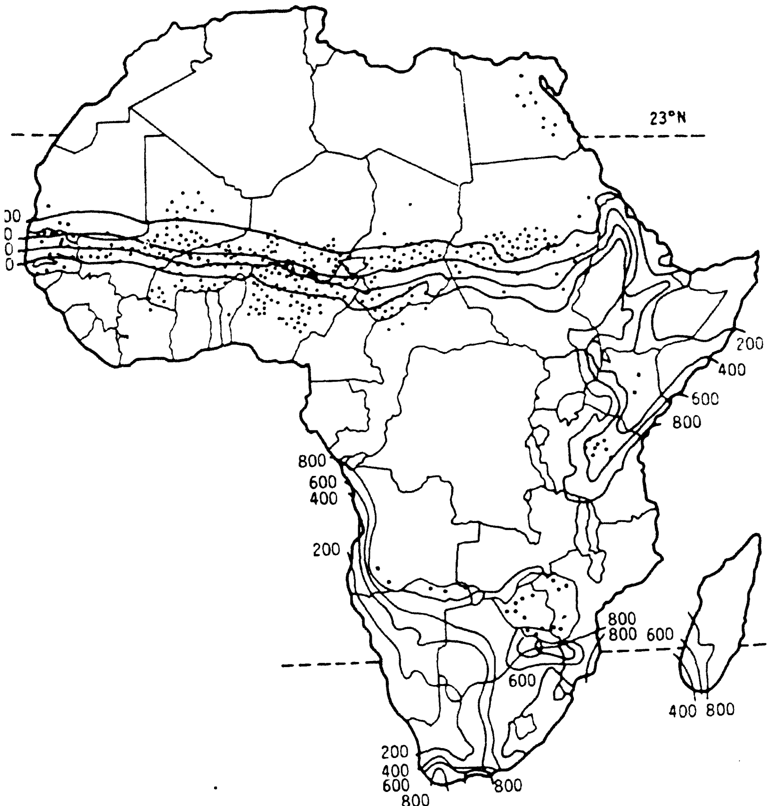

Figure 1. Area planted to pearl millet in 1978 in relation to mean annual rainfall (mm) in Africa. Each dot equals 20 000 ha (Bidinger et al. 1982).

over the last 80 years (Fig. 2), with a coefficient of variation of 26%.

Rainfall varies not only annually but also from month to month within the same year. Using the criterion of a mean annual rainfall of 560 mm, Niamey had an above-normal year in 1964, a normal year in 1968, and a below-normal year in 1972. However the rains terminated in early September in both 1964 and 1968 while in 1972 they continued until 18 Oct. These sorts of variations greatly affect crop production.

Furthermore, rain in West Africa often occurs in short but intense storms. Rainfall intensities usually range from 20-60 mm h^{-1} with high values reaching 120-160 mm h^{-1}. On soils with lower infiltration rates, much of the water from such intense rains could run off, leading to low effective rainfall heavy soil loss.

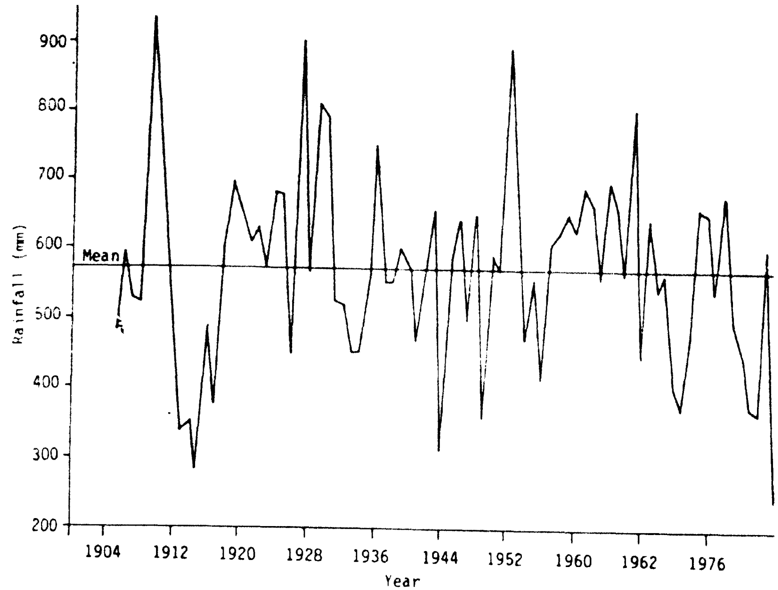

Figure 2. Annual rainfall variability of Niamey

Growing Season

The variability in the annual and monthly rainfall opens to question the utility of the traditional practice of describing a crop-growing region using these figures. Average length of the growing season in the millet-growing regions of West Africa ranges from 60 d on the edge of Sahara to 150 d in the south. Of course, in drought years such as 1984, the growing season could be much shorter and lead to crop failure. Long-term daily rainfall data could be analyzed to provide meaningful information on the environmental risks to cropping. For example, the dates of beginning and ending of the rainy season and the length of the growing season have been used to highlight the differences in cropping potential between Kaolack (Senegal), and Ouagadougou (Burkina Faso), two locations with approximately the same mean annual rainfall (Table 3). The growing season at Kaolack is shorter than that at Ouagadougou by

Table 3. Average dates of beginning and ending of rains and length of growing season at Kaolack and Ouagadougou.

Location (Rainfall)	Beginning of rains		Ending of rains		Length of the growing season	
	Date	s.d.[1]	Date	s.d.	Days	s.d.
Kaolack (800 mm)	23 Jun	14	27 Sep	12	97	18
Ouagadougou (830 mm)	31 May	16	24 Sep	12	117	21

1. s.d. = standard deviation.

20 d. Obviously, crop breeders should pay more attention to the average length of the growing season than to mean annual rainfall.

Drought Probabilities

Although millet is grown in drought-prone environments, precise information does not exist on the nature of climatic droughts in West Africa during its growth cycle. Assuming that the sowing date coincides with the calculated beginning date of the rainy season (Table 3, for example), the average length of dry periods at 10-day intervals during the crop growth cycle can be computed. Such calculations show that in the millet-growing regions of West Africa, the probabilities of drought are high during the crop-establishment and grain-filling phases.

Temperature

Ong and Monteith (1985) have shown that temperature has a major effect on the rate at which crops grow. Germination, leaf and spikelet initiation, tillering, and grain filling have been shown to have pronounced differences in their responses to optimum and maximum temperatures.

Maximum temperatures vary from 28-42°C during the millet-growing season in West Africa. In the central and southern regions of West Africa, maximum temperatures are generally less than 35°C and sometimes as low as 30°C, whereas in the north they are almost always higher than 35°C. The minimum temperatures range from 15-28°C (Konate 1984). These data suggest that in the northern regions of West Africa maximum temperatures exceed optimum values, especially during germination and grain-filling periods. High air temperatures lead to high soil temperatures. In the sandy soil of Niger, surface soil temperatures (at 2 mm) in June were reported to reach 45-50°C after a rain, which led to low stand survival (ICRISAT 1984a).

Soils

The major soil type on which millet is grown in the Sahelian zone of West Africa is the coarse-textured soils containing more than 65% sand and less than 18% clay (Swindale 1982). They occur extensively on flat to undulating topography developed under aeolian and alluvial sands. Low fertility, lack of water, and poor physical condition are important constraints to the use of these soils, which are low in organic matter, N, and P (Jones and Wild 1975, Ahn 1970). Soils in Niger for example, are very sandy with the sand fraction usually exceeding 92% (Table 4). The soils are acidic and average water-holding capacity varies, depending upon depth, from 75-150 mm.

Poor fertility is a major problem in the sandy soils of the Sahel. Organic matter content and cation exchange capacity of these soils are very low (Table 4). Nitrogen management can be difficult because the soil has a low buffering capacity (Swindale 1982). To produce stable yields, the low phosphorus content of these soils needs to be improved by application of phosphorus fertilizers. Allowing arable land to lie fallow to recover fertility without added fertilizers is a traditional practice followed by subsistence farmers. But the number of fallow years between crops has been reduced because of growing population pressures in recent years, and has led to a decline in soil fertility. Jones and Wild (1975) comment that questions cannot yet be answered on the possibilities of continuous cropping on these soils.

Table 4. Some physical and chemical properties of soils at three locations in the millet growing areas of Niger.

	Locations		
Soil characteristics	Sadoré[1]	Gobery[2]	Gaya[3]
Soil texture (%)			
Sand	94	95	66
Silt	1	3	23
Clay	5	2	11
pH			
Water (1:1)	5.3	5.2	5.4
KCL	4.3	4.3	4.9
Organic matter (%)	0.2	0.3	0.8
Total N (%)	0.01	0.02	0.03
C:N ratio	10	9	18
Phosphorus			
Total (%)	48	-	84
Available P (Bray 1) (ppm P)	3.2	2.6	2.5
Exchangeable cations (meq 100 g^{-1})			
Ca	0.60	1.00	2.40
Mg	0.30	0.20	1.00
K	0.06	0.08	0.13
Na	0.00	-	0.00
CEC (meq 100 g^{-1})	0.96	1.28	3.53
Base saturation (%)	86	-	98

1. 13° 18'N 2° 21'E; 560 mm rainfall a^{-1}
2. 13° 5'N 2° 54'E; 600 mm rainfall a^{-1}
3. 11° 59'N 3° 30'E; 840 mm rainfall a^{-1}

Poor structural stability of the sandy soils is also a major constraint (Swindale 1982), since the soils are susceptible to wind erosion when they are dry. Early in the rainy season, sand is carried in the air at high wind speeds just before the rains arrive, physically damages the emerging seedlings (sand blasting), and is deposited over them. The weight of the sand coupled with high soil temperatures often causes high seedling mortality, with resultant poor crop establishment. As the soil dries there is a tendency for the surface horizon to harden, which causes a permeability problem.

Soils with higher clay content and greater water-holding capacity occur in the Sudanian and Northern Guinean Zones of West Africa and elsewhere in eastern and southern Africa. These soils with higher fertility and better physical condition are rarely used for sole crop millet. Millet is planted in association with sorghum or maize (*Zea mays* L.), the principal crops in these areas.

Crop Production Systems

Pearl millet in Africa is grown largely by subsistence farmers and is usually intercropped with other cereals, especially sorghum, and/or a legume, usually cowpea (*Vigna unguiculata* L. Walp.). In the Northern Guinean Zone of West Africa where sorghum is a more important crop than millet, sole-crop millet is virtually unknown. Thus, in their surveys in the Nigerian savanna, Norman et al. (1982) found virtually no sole-crop millet, although millet mixtures occupied about one-third of the cultivated area. Moving northward through the Sudan to the Sahel zone, the proportion of sole cropping increases. For example Singh et al. (1984) report 0.4-5.0% in the Sudanian Zone of Burkina Faso, while Gbiriche and Schipprack (1985) report 17% from northern Ghana. The proportion rises to 30-50% in villages in the Sahelian Zone of Niger (ICRISAT 1986). Some of the common management practices under these two systems are described below.

Millet as a Pure Crop

Most of the millet crop in West Africa is planted with virtually no prior land preparation. The use of animal traction for cultivation in West Africa decreases from the subhumid to the semi-arid zones. In a major part of the millet-growing region, use of animal traction for preparatory cultivation is not common and soils are seldom plowed.

As a rainfed crop, pearl millet is sown with the first rains during the growing season. In West Africa the crop is sown in Apr-May in the Southern Zone and May-Jun in the Northern Zone. In higher rainfall areas it is not uncommon to delay the sowing of millet. Photosensitive late millet varieties in Ghana are planted in Jun-Jul, mature on stored moisture, and are harvested in Nov-Dec (Gbiriche and Schipprack 1985). In the bimodal rainfall belt near the equator in East Africa, millet is planted with either the early or late rains, in either March or August (Rachie and Majmudar 1980).

Most millets grown in West Africa fall into two groups, early and late (Table 5). The choice of the appropriate variety in a given zone is dictated by the available length of the growing season, with the early millets grown in general in the low-rainfall northern regions and the late types in the more humid southern regions.

Millet is sown in hills 45 × 45 cm to 100 × 100 cm apart. Spacings of 100 × 200 cm or even 200 × 200 cm are sometimes used. A hand-held hoe or "dhaba" is used to open the holes, seeds are thrown in, and the hole is covered with the heel of the foot. The number of seeds sown in each hill varies enormously. In a stand-establishment study in three villages of Niger up to 400 seeds have been found in a single hill (P. Soman, ICRISAT Center, India, personal communication).

Traditionally farmers sow low populations, about 5000-7000 hills ha^{-1}. Because of problems with wind erosion and crop establishment, or failure of early rains, farmers are often forced to repeat sowing, sometimes up to three times. The stand is progressively thinned during weedings once the plants have reached 15 cm.

Interculture and weeding are primarily done using hand tools. This places severe demands on available labor and limits the area that could be weeded. If more area is sown than the farmer and his family can cope with, some of the farm is abandoned to weeds, which lowers productivity (Bourke 1963).

Diseases and insect pests have been known to cause yield losses of up to 50%. Birds and *Striga*, a parasitic weed, also cause severe damage from time to time. Systematic use of insecticides or fungicides is not a common practice in traditional farming systems.

Table 5. Millet types and maturity durations reported from different countries in West Africa.

Country	Millet type	Average duration (d)	Reference
Niger	Early	75- 95	Naino et al. (1985)
	Late	120-130	
Nigeria	Gero	70-100	Nwasike (1985)
	Maiwa	> 120	
	Dauro	> 120	
Senegal	Souna	75- 90	Gupta (1985)
	Sanio	120-150	
Burkina Faso	Iniadi	75- 90	Lohani (1985)
	Late	130-170	
Mali	Souna	75- 90	Niangado et al (1985)
	Sanio	110-120	
Ghana	Early	90-110	Gbiriche and Schipprack (1985)
	Late	120-140	
Ivory Coast	Early	90	Beninga (1985)
	Late	150	
Gambia	Suno	80- 90	Cox (1985)
	Sanio	140	
Togo	Early	80-100	Kpodar (1985)
	Late	140-160	

Under the subsistence-level millet farming in West Africa, yields are generally low even in regions with sufficient rainfall. Yields ranging from 100-600 kg ha^{-1} under farmers' conditions are often reported. Fertilizer is rarely used except in special agricultural development projects.

Millet in Intercropping

As indicated earlier, pearl millet in West Africa is more commonly grown in association with cowpea, groundnut, sorghum, maize, or sorrel (*Hibiscus sabdarifa*). Evidence for one or more of these systems in all West African countries is given by Moustapha and Adjahossou (1985), Beninga (1985), Niangado et al. (1985), Naino et al. (1985), Mabissoumi (1985), Sawadogo and Kabore (1985), Bbuyemusoke (1985), Gbiriche and Schipprack (1985), and Reddy and Gonda (1985).

The choice of component crops in the intercrop often depends on the farmers' past experience and objectives, food habits, availability of seed, soil type, and market demands (Mamane 1980). However millet/cowpea is the most prevalent intercropping system, especially in the Sahelian Zone of West Africa.

Plant density in the intercrop depends upon soil fertility and previous harvests (Reddy and Gonda 1985). Under farmers' conditions plant densities are usually low. In baseline studies in Burkina Faso, Matlon (1984) observed low densities of cowpea from 1000-8000 plants ha^{-1}, although optimum densities are much higher at 15 000 plants ha^{-1}. In the millet/sorghum intercrop, sorghum densities are often low, and the variety choice is based on earliness and succulence of stems or grains since the sorghum is generally consumed soon after harvest (Sawadogo and Kabore 1985). In Mali, introduced varieties of millet and cowpea are not better adapted than the local varieties in the intercropping system (Simpara 1985). The same conclusions were drawn from farmers' tests in Burkina Faso (Sawadogo and Kabore 1985).

Component crops in the intercrop are often sown in separate rows, although sowing in the same row or hill is not uncommon. In certain regions triangular sowing is adopted (Reddy and Gonda 1985), with manure placed in the centre of the triangle. In the Maradi region of Niger, millet and cowpea in the millet/sorghum/cowpea intercrop are sown alternately in the same direction while sorghum is sown perpendicular to rows of the other two crops.

The sowing date depends upon the arrival of rains and labor availability. Millet, the primary crop in the intercrop system, is sown with the first rains at the end of May or early June, while the associated crop of sorghum or cowpea is sown 2-3 weeks later at the end of the first weeding (Sawadogo and Kabore 1985), or after an effective rainfall. Labor availability is recognized as a more important constraint than availability of land for intercropping in Niger (Reddy and Gonda 1985).

Millet yields have usually been reported to be higher under intercropping than under sole cropping. Data from ICRISAT's long-term village studies in western Niger show that intercropped millet yields were higher than pure crop millet yields. Swinton et al. (1985) also found that intercropped millet and sorghum yields were as good or better than monocropped millet or sorghum in other regions of Niger. In Burkina Faso, Sawadogo and Kab (1985) reported that millet/cowpea yields were hig than millet yields in sole cropping.

Economics of Millet Production

In 1975 Norman highlighted the economic advantage of intercropping in traditional African farming systems. He showed that in northern Nigeria, both average gross and net returns per unit area were about 60% higher from crop mixtures than sole crops, and increased with the number of crops. But Norman's data were from the Northern Guinean Zone, where millet is a subsidiary crop that is only grown in mixtures.

In 1982, ICRISAT began a long-term socioeconomic study in two villages in western Niger in the heart of the millet-growing zone of West Africa. Sole-crop millet is grown on 30-50% of the gross cropped area depending on season and rainfall. The 1982-83 data are from an area where long-term expected rainfall is 450-550 mm (Virmani et al. 1980), but in which actual rainfall in the 2 years was 50-80% of the total. Soils are uniformly sandy with irregular topography.

Under traditional farming conditions, average millet grain yields were very low, ranging from 130-285 kg ha^{-1}, while cowpea grain yields were virtually zero (Table 6). Millet yields were higher in intercrops than in pure crop stands. At the low plant densities used by farmers, and since cowpea is usually planted about 3 weeks after millet, the cowpea does not reduce the millet yield. Rather, it contributes hay which increases the gross income. Thus total output of millet/cowpea intercrops was usually at least double that of a sole-crop millet.

Intercrops containing sorghum also produced higher millet yields than sole-crop millet. But this was because such intercrops are generally planted in lower-lying areas where farmers expect that there will be adequate moisture to meet the higher needs of sorghum. Their expectations were not fulfilled in 1982 and 1983, and the sorghum produced no grain.

Labor use on millet/cowpea intercrops was at least one-third higher than for sole-crop millet because of the need to plant cowpea after millet, to weed between millet as well as cowpea rows, and to harvest cowpea. No more than 10% of the labor was hired, confirming that the farms are mainly traditional family farms.

Gross margins were calculated by deducting all variable costs (mainly the value of seed and hired labor), from gross output. Gross margins ha^{-1} averaged 11 000 F CFA for sole-crop millet (about 350 F CFA = US$ 1 at present exchange rates). The gross margin ha^{-1} was at least 20% higher for the millet/sorghum and millet/sorrel intercrops, and over 80% higher wherever there was cowpea in the intercrop. Returns to family labor, measured by gross margin per hour were also much higher for intercrops, than for sole-crop millet. It is clear that under traditional farming conditions in western Niger, economic returns are substantially higher for intercropped than sole-cropped millet.

Constraints to Increased Millet Production

Constraints to increased millet production in Africa can be classified into abiotic and biotic constraints.

Abiotic Constraints

- Low and erratic rainfall in a short season, leading to drought periods of varying lengths.
- Sand storms, high-intensity rains, and high soil temperatures cause poor seedling establishment.
- Poor soils with low levels of natural fertility and low water holding capacities.
- Traditional management practices such as low crop densities, nonuse of fertilizers, or poor or no tillage.
- Lack of household capital and poor credit and input delivery systems limit the scope to improve management practices.

Biotic Constraints

- Low genetic yield potential of landraces which respond poorly to improved management.
- Diseases such as downy mildew and smut.
- Insect pests such as stem borer and earhead caterpillar.
- Parasitism by *Striga*.
- Grain-eating birds.

The challenge facing millet researchers is to develop improved technology which could mitigate the adverse effects of these constraints, and that would be within the reach of small-scale, resource-poor farmers in Africa.

Summary

Millet is grown in regions of Africa with rainfall ranging from 200-800 mm and with a growing sea-

Table 6. Productivity of alternative millet based cropping systems in western Niger, 1982/1983.

	Cropping System[1]						
	M	M C	M S	M C S	M C S L	M L	M C L
Ha Farm⁻¹	4.4	3.3	0.6	0.6	0.5	0.9	1.2
Family Labor Use (man-hour equivalents ha⁻¹)[2]							
Male	108.3	143.5	110.5	205.5	189.2	127.9	178.7
Female	5.4	8.9	6.8	11.5	14.0	7.3	8.0
Child	14.2	20.6	11.1	33.8	20.0	11.0	25.1
Total	120.8	162.7	122.9	233.9	213.2	140.7	199.3
Hired Labor Use (man-hour equivalents ha⁻¹)							
Male	11.9	15.2	8.9	9.7	21.5	7.3	11.9
Female	0.2	0.1	0.3	2.3	0.2	0.2	0.5
Child	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	12.1	15.3	9.3	12.0	21.7	7.5	12.4
Fert (kg ha⁻¹)	1.2	5.9	0.0	0.7	0.0	3.7	2.2
Seed (kg ha⁻¹)							
Millet	4.8	5.4	5.3	7.1	6.4	4.7	11.3
Cowpea	0.0	0.8	0.0	1.2	0.6	0.0	0.7
Sorghum	0.0	0.0	0.5	1.5	0.6	0.0	0.0
Sorrell	0.0	0.0	0.0	0.0	0.3	0.4	0.3
Total Cost (F CFA)	1707.3	2765.7	1519.3	2949.5	2936.9	1228.0	2414.8
Grain yield (kg ha⁻¹)							
Millet	128.5	215.4	155.0	283.9	240.8	143.5	224.7
Cowpea	0.0	2.7	0.0	7.7	1.0	0.0	0.8
Sorghum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorrell	0.0	0.0	0.0	0.0	0.0	1.4	0.7
Harvested hay/straw output (kg ha⁻¹)							
Millet	0.9	1.9	0.8	5.9	1.3	1.0	2.8
Cowpea	0.0	30.5	0.0	73.6	65.7	0.0	54.2
Sorghum	0.0	0.0	5.1	2.0	11.5	0.0	0.0
Value of output (F CFA ha⁻¹)[3]							
Grain	12686	21007	16797	29499	25522	14328	21914
Straw	5	2823	38	6812	6164	10	5013
Total	12692	23830	16834	36311	31687	14337	26927
Gross margin (F CFA)							
Per ha	10985	21064	15315	33361	28750	13109	24513
Per hour	91	129	125	143	135	93	123

1. Crops in system : M = millet, Ċ = cowpea, S = sorghum, L = sorrell
2. 1 man-hour equivalent = 1 man-hour = 1 woman-hour = 0.5 child-hour
3. FCFA = Unit of currency in West Africa.

son from 60-150 d. About 70% of African pearl millet crop is produced in West Africa.

Millet is primarily grown by subsistence farmers under harsh environmental conditions in intercrop systems with other cereals and legumes, on small-scale family farms. There are many abiotic and biotic constraints to increased millet production.

Millet is the staple food in some of the poo countries and regions of Africa, but its produc has increased at only 0.7% a⁻¹ during the last decades. This is much less than the popul growth rate, and is the lowest growth rate crops in the region. Furthermore, these have been due mainly to increases in cultiv

rather than to yield increases, showing that technological innovations have not yet had much impact on millet productivity. What are the prospects for the future?

After a survey of the evolving technical and social conditions of African agriculture and an evaluation of the stock of technological innovations, Matlon and Spencer (1984) concluded that with the exception of limited high potential zones, the set of new technologies is most often inappropriate. Their use could not bring about a substantial increase in aggregate supply. From a recent review of appropriate technologies for farmers in the semi-arid zones of West Africa (Ohm and Nagy 1985), it is evident that available technologies for millet are still inadequate.

But recent research results show that there is some promise for the future. For example, on-farm tests in Niger have shown that low to medium doses of phosphorus fertilizer can be profitable when applied to traditional varieties (ICRISAT 1984b, 1985, 1986). Improved millet varieties which perform as well as traditional varieties under traditional management, but perform significantly better under improved management, are being tested. These and other developments which auger well for the future are discussed by Fussell et al. (1987).

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