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LOW INPUT TECHNOLOGY OPTIONS FOR MILLET-BASED CROPPING SYSTEMS IN THE SAHEL

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SUMMARY

Pearl millet is a staple cereal cultivated mainly by subsistence farmers on 14 million ha of the West African semi-arid tropics. Increasing pressure on the land has reduced the length of the fallow periods, which are necessary to restore soil fertility, resulting in declining yields. To investigate ways of reversing this decline, three systems combining phosphorus fertilizer application, improved varieties of millet and cowpea, and improved agronomic practices were compared with the traditional millet–cowpea intercrop system in a three year experiment. The most productive system involved the rotation of fertilized millet and cowpea. Pre-sowing tillage increased hay and fodder yields in all the improved systems. The application of fertilizer increased the amount of available phosphorus in the soil. Soil pH declined somewhat in all treatments, although the initially low soil organic matter did not change.

Sistemas de mijo de bajo consumo en el Sahel

RESUMEN

El mijo perlado es un cereal básico cultivado principalmente para la propia subsistencia de los agricultores en 14 millones de hectáreas en la zona tropical semiárida del Africa Occidental. La creciente necesidad de uso de la tierra ha reducido los períodos de barbecho necesarios para restablecer la fertilidad del suelo, con la consecuente reducción en el rendimiento de los cultivos. A fin de investigar la forma de revertir este proceso, se compararon tres sistemas con combinaciones de aplicación de fertilizante de fósforo, variedades mejoradas de mijo y caupí, y mejores prácticas agrícolas, en un experimento de tres años de duración con el sistema tradicional de siembra simultánea de mijo/caupí. El sistema más productivo fue la rotación de mijo y caupí con uso de fertilizante. La labranza de la tierra previa a la siembra incrementó el rendimiento de paja y forraje en todos los sistemas mejorados. La aplicación de fertilizante aumentó la cantidad de fósforo disponible en la tierra. En todos los tratamientos se observó cierta reducción en el pH del suelo, si bien no hubo cambios en el inicialmente bajo contenido de materia orgánica del suelo.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a major staple cereal cultivated on 14 million ha of the poorer soils of the West African semi-arid tropical Sahelian and Sudanian ecological zones, mainly by subsistence farmers. Millet grain is primarily used for human consumption, but the straw and leaves are important for building construction and animal feed. A high proportion of millet fields are

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intercropped with other cereals or legumes: 70% to 92% in Burkina Faso (Sawadogo *et al.*, 1985), and up to 87% in Niger (Swinton *et al.*, 1984). In the northern parts of the zone, where the annual rainfall is less than 600 mm, millet is most commonly intercropped with cowpea (*Vigna unguiculata* (L.) Walp) or groundnut (*Arachis hypogaea* L.). The millet is normally sown first and is the dominant crop. It is well adapted to the harsh climate, but millet-based subsistence cropping systems receive few if any inputs of fertilizer or crop protection.

Millet yields are therefore low, but the traditional practice of extended fallow periods has in the past restored soil fertility (Jones and Wild, 1975). With increasing pressure on the land, these fallow periods have been shortened, thus destabilizing the system. For instance, in Niger, the area of millet has increased from 1.7 to 3.2 m ha over a 25 year period, while average grain yields have declined from 530 to 345 kg ha^{-1} as production has expanded into increasingly marginal land (SEDES, 1987).

On the chemically poor sandy soils phosphorus is the main limiting factor, an application of 13 kg ha^{-1} producing a one- to three-fold increase in millet yields (Bationo and Mokwunye, 1991). Response to nitrogen fertilizer is only observed after adequate levels of phosphorus have been supplied and is even then affected by uncertain rainfall amount and distribution; nitrogen recovery rates are generally poor, with considerable volatilization and leaching losses (Christianson *et al.*, 1988). However, the requirement for nitrogen fertilizer can be reduced or eliminated by growing a leguminous forage crop before the cereal (Radke *et al.*, 1988). This practice has been successfully used in the region for the millet and cowpea system (Giri and De, 1979; ICRISAT, 1990).

Nutrient deficiency is aggravated by the poor physical properties of the sandy soils. Pre-sowing ridging and sowing on ridges have improved stand establishment, survival and yields, particularly when combined with the application of fertilizer (Klaij and Hoogmoed, 1993).

This paper describes work in which the use of phosphorus fertilizer, improved varieties of millet and cowpea, rotation, and animal traction for pre-sowing tillage and inter-row weeding, was evaluated in a single experiment in terms of yield and soil fertility parameters.

MATERIALS AND METHODS

The experiment was conducted from 1987 to 1989 at Birni N'Konni (13°48'N, 5°15'E, altitude 272 m), about 350 km east of Niamey, Niger. The mean annual rainfall between 1961 and 1990 was 476 mm with a monomodal distribution. The average date of the onset of the rains was 7 June and of the end of the rains, 21 September.

The soil was a fine loamy, mixed, isohyperthermic Aridic Haplustalf. The proportion of sand decreased from 91.9% at the surface to 86.6% at a depth of 2 m, while the clay content increased from 2.7 to 10.5%. The bulk density was 1.62 g cm^{-3}. The topsoil was very friable, greatly facilitating tillage and weeding when

wet. The soil water content was 0.28 cm^3 cm^{-3} at an effective pressure of 1 kl 0.12 cm^3 cm^{-3} at 10 kPa, and 0.03 cm^3 cm^{-3} at 1500 kPa. *In situ* field capacity o similar soil was found to be 0.10 cm^3 cm^{-3}. Cation exchange capacity was l (0.7–1.9 cmol kg^{-1}). Previously cowpea had been grown on the experimental s in 1985, after which it was kept fallow. Surface soil samples in May 1987 showe pH (KCl) of 5.8, soil organic matter 0.21%, Bray P_1 11.1 mg kg^{-1}, and to nitrogen content 181 mg kg^{-1}.

The experiment compared: a traditional cowpea-millet system with a wid spaced intercrop, and with no inputs of fertilizer or pesticide, all operations be manual; an improved continuous cropping system of sole cowpea and sole mill with animal traction for land preparation and inter-row weeding; an impro rotational cropping system of cowpea and millet, with the plots rotated betw crops, and animal traction for land preparation and inter-row weeding; and improved rotational cropping system of cowpea and millet, rotating the pl between crops, but using hand labour for all farming operations.

To facilitate statistical analysis the two phases of the rotation were grown each year (Preece, 1986) providing seven treatments for the statistical analysis each year. The design was a randomized complete block with four replicatio The plot size was 10 × 50 m.

The traditional system used the local pearl millet landrace, sown in pockets 1.5 × 1.5 m intervals. The intercropped cowpea (a prostrate local type) was so at approximately 1.5 × 1.5 m intervals with four or five seeds per pocket. T crops were planted on ridges approximately 0.10 m high, the result of tradition hand weeding in the previous season.

The other systems used improved varieties (millet cv. CIVT and cowpea c TN 5-78), sown at 1.5 × 0.75 m and 0.75 × 0.35 m (two or three seeds per pocke respectively. The cowpeas were protected against insects by spraying wi Cymbush Super Electrodyn ®. Phosphorus at a rate of 13 kg P ha^{-1} (as trip superphosphate) was broadcast before land preparation, which was done aft the first rains had wetted the soil to tillage depth.

Initial crop stands, stands at harvest, millet grain and stover, and cowpea gra and hay yields were measured each season from an area of 75 m^2 within each plo Striga (*Striga hermonthica* (Del.) Benth.) plants were counted in the millet plot Composite soil samples of 10 borings (0–0.15 m depth) taken diagonally acro each plot were collected each year after harvest for determination of soil pH organic C, Bray P_1 and total nitrogen.

RESULTS AND DISCUSSION

The 1987 season was exceptional, with the onset of the rains delayed by five week and only 52% of the expected total rainfall. The onset of the rains and distributio of rainfall was normal in 1988 and 1989 (Table 1).

The areas of millet and cowpea harvested in the rotational system were onl half the total area harvested in the traditional intercrops. For a comparison o

Table 1 *Rainfall (mm) at the experimental site, 1987–1989*

	1987	1988	1989
1–10 June	1.1	62.4	5.0
11–20 June	3.0	1.4	22.5
21–30 June	4.0	72.0	46.1
1–10 July	0.0	9.0	21.5
11–20 July	32.0	65.6	68.0
21–31 July	33.8	48.2	29.0
1–10 August	32.5	40.0	89.9
11–20 August	41.7	89.3	90.6
21–31 August	71.5	67.0	18.3
1–10 September	18.4	37.9	37.8
11–20 September	13.4	35.3	0.0
21–31 September	4.9	3.8	0.0
1–10 October	0.0	0.0	19.5
Total	256.3	531.9	448.2

these sole crop systems with the intercrops it was therefore necessary to compare the total yield ha^{-1} of the intercrops with the sum of the mean yields ha^{-1} of the millet and cowpea components of the sole crops (Table 2).

Following farmers' practice in the Sahel, millet was sown with the first rains in the traditional system. This was usually about one week before the improved systems were sown (Table 3). However, in 1987 the traditional sowing failed on the first three attempts, and finally the short season variety CIVT was sown four days after the sowing of millet in the improved systems.

Initial crop stands and their survival were excellent in all plots, even in 1987 because of an excellent distribution of the limited rainfall, but all the crops suffered drought stress throughout their growth period that year and this must have depressed yields. Nevertheless, fertilizer application and higher plant populations resulted in higher millet yields in all three years (Table 2), confirming that these are the primary factors limiting millet yields in the region (Fussell *et al.*, 1987). However, the yield components of the traditional and the improved systems cannot be compared directly, because of the differences in the ratio of grain to hay in the two varieties used. After the first crop year, the grain yield of millet was greater when rotations were used than in the continuous sole crop systems, probably because the sole crops needed more nitrogen fertilizer. The benefits of rotation were less pronounced in the case of fodder production. There were consistently larger hay and fodder yields over the three years when animal traction was used, probably because of the pre-sowing tillage.

There was no striga infestation in 1987, and levels of infestation in the other years were variable (0 to 21.6 striga plants m^{-2} in 1988, and 0 to 15.6 plants m^{-2} in 1989). There was no correlation between these levels of infestation and grain yield, probably because they were relatively low.

Soil organic matter, total nitrogen and pH did not differ between treatments, but in the course of three years cropping the mean total soil nitrogen content after

Table 2. *Pearl millet and cowpea yields (t ha^{-1}), 1987–1989*

	Grain			Fodder		
	1987	1988	1989	1987	1988	1989
Continuous cropping						
Intercrop with traditional varieties and methods						
Millet	0.26	1.06	0.70	1.08	1.52	1.95
Cowpea	0.01	0.00	0.05	0.71	2.95	0.65
Total	0.27	1.06	0.75	1.79	4.47	2.60
Sole crop with improved varieties and inputs and animal traction						
Millet	1.04	0.96	0.98	2.73	1.50	1.62
Cowpea	0.43	1.27	1.28	1.63	4.00	2.08
Mean	0.74	1.12	1.13	2.18	2.75	1.85
Rotations using sole crops with improved varieties and inputs						
Animal traction						
Millet	0.98	1.79	1.77	2.40	2.80	2.89
Cowpea	0.48	1.39	1.37	1.50	3.44	2.17
Mean	0.73	1.59	1.57	1.95	3.12	2.53
Manual cultivation						
Millet	0.85	1.93	1.44	1.55	2.95	2.57
Cowpea	0.60	1.40	1.42	1.23	2.45	1.82
Mean	0.73	1.67	1.43	1.39	2.70	2.20
SE millet	0.07	0.18	0.16	0.16	0.16	0.29
SE cowpea	0.04	0.09	0.11	0.13	0.54	0.24

Table 3. *Dates of sowing and harvest of the crops in the experiment, 1987–1989*

	1987		1988		1989	
	Sowing	Harvest	Sowing	Harvest	Sowing	Harv
Traditional						
Millet	21 July†	13 Oct.	2 June	19 Sept.	11 June	19 Se
Cowpea	5 August	8 Oct.	25 June	21 Oct.	26 June	11 O
Improved						
Millet	17 July	13 Oct.	8 June	19 Sept.	22 June	19 Se
Cowpea	18 July	8 Oct.	25 June	26 Sept.	26 June	26 Se

†Three failed sowings in the month of June.

harvest declined from 160 to 125 mg kg^{-1} of soil, and pH fell from 5.79 to 5.55, though no change in organic matter content was observed. Soil phosphorus levels were lower in the traditional treatment, and had fallen to 9.0 mg kg^{-1} by 1989, though even this level was greater than the 7.9 mg kg^{-1} considered sufficient for 90% of maximum attainable millet yield under similar soil and climatic conditions (Bationo and Mokwunye, 1991). It seems likely, however, that continued cropping under the traditional system would ultimately lead to decreased crop yields because of phosphorus deficiency. In contrast, the phosphorus level of the improved treatments, to which phosphorus fertilizer was added annually, increased to 17.7 mg P kg^{-1} by 1989.

Note. Use of trade names in this paper does not constitute endorsement of or discrimination against any product by the Institute.

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