Improving millet/cowpea intercropping in the semi-arid zone of Mali

* The original French paper 'Possibilites d'amélioration de l'association culturale mil-niébé en zones semi-arides au Mali' is an updated version of a paper published in Haque et al (1986).

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SUMMARY

THE MILLET/COWPEA intercropping system used in the semi-arid zone of Mali is on the decline. ILCA's studies of the system during 1981-85 showed that grain and biomass yields can be improved by manipulating the planting date, pattern, and density of the crops and by rotating sole millet with millet/cowpea intercrops.

Sowing millet and cowpea in separate holes on a ridge or on alternate ridges decreased millet grain yields less than when both crops were planted in the same hole. The optimum proportion of cowpea in the mixture was 15% without fertilizer and 45% when rock phosphate was applied. Rotating millet/cowpea intercrops with sole millet increased the grain yield of sole millet by 30%. Delayed sowing of the legume reduced interspecies competition, resulting in good grain and biomass yields. Cowpea proved to be more competitive than millet under dry conditions, while millet benefitted from intercropping in higher-rainfall areas.

INTRODUCTION

Millet (Pennisetum americanum) is intercropped with cowpea (Vigna unguiculata) on about 60% of the plots cultivated in semi-arid Mali (Diallo et al, 1985). Millet provides 70–90% of the food energy of the human population, and in some cases as much as 95% (Martin, 1985). Cowpea grain, which contains 20–25% protein, is valued as human food (Pugliese, 1984), and its haulms (14–30% net protein) are grazed by cattle during the dry season (Göh1, 1981; Skerman, 1982).

Because of unfavourable climatic conditions, shorter fallowing and declining soil fertility (Cissé and Hiernaux, 1984), millet grain production has stagnated at about 500 kg ha⁻¹ in recent years (Mali, 1984). Cowpea yields are also low, as its proportion in the mixture is only about 10% at planting and about half that at harvest when rainfall is poor.

The millet/cowpea intercropping system can contribute significantly to food and feed production, and to soil fertility on which this production depends. ILCA studied the traditional system at its research sites in Niono (200 mm average annual rainfall) and Banamba (700 mm annual rainfall) during 1981–85 to determine the possibilities for its improvement. This paper describes the effect of different planting patterns and densities on grain and biomass yields. The merits of rotating intercrops with monocrops and of delaying the planting of the legume are also discussed.
ENVIRONMENTAL CONSTRAINTS

Rainfall and soil moisture

Throughout the study period, annual rainfall recorded in Niono and Banamba was less than the long-term means for the two sites to 1980 (Table 1). Poor rainfall seriously affected plant growth and biomass yields in 1983 and 1984.

Table 1. Useful, total annual, and long-term mean rainfall for Niono and Banamba, central Mali, 1981–85.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall in Niono</th>
<th>Rainfall in Banamba</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Useful¹ (mm)</td>
<td>Total (mm)</td>
</tr>
<tr>
<td>1981</td>
<td>n.a.²</td>
<td>411</td>
</tr>
<tr>
<td>1982</td>
<td>n.a.</td>
<td>478</td>
</tr>
<tr>
<td>1983</td>
<td>196</td>
<td>250</td>
</tr>
<tr>
<td>1984</td>
<td>220</td>
<td>335</td>
</tr>
<tr>
<td>1985</td>
<td>n.a.</td>
<td>350</td>
</tr>
<tr>
<td>Long-term mean</td>
<td>483</td>
<td>573³</td>
</tr>
</tbody>
</table>

¹ Useful rainfall is rain which falls during the growing season.
² n.a. = not available.
³ Calculated over 35 years to 1980.
⁴ Calculated over 49 years to 1980.

Sources: Sivakumar et al (1984); Hulet and Gosseye (1986); Hulet (1986).

Soil with plant cover can retain 130–184 mm of moisture per m², but the useful rainfall at Niono provides between 100 and 159 mm at pF 4.2 (P.Gosseye, Sahel Programme, ILCA, Bamako, Mali). To determine the availability of moisture under different crop associations at the site, samples were taken in 1984 from a 1-m deep soil profile and analysed using a gravimetric method.

Figure 1 shows the soil moisture profiles under three millet/cowpea intercrops and sole millet and cowpea crops. The profiles varied according to crop and planting ratio: more soil moisture was available under millet (sole or at 75% of the mixture) than under the other cropping systems, but biomass production did not increase. The fact that millet uses soil moisture more efficiently than other crops was confirmed by Natarajan and Willey (1986) who found that sole or intercropped millet is more resistant to water stress than sorghum or groundnut.
Soil fertility

Most tropical soils are deficient in essential nutrients, particularly phosphorus (P) and nitrogen (N) (Boyer, 1970; Jones and Wild, 1975). The loamy sand soil in Niono contains <60 mg P kg⁻¹, 0.1–0.3% of carbon (C), and 0.01–0.02% of N, with a C:N ratio ranging from 5:1 to 30:1 depending on the depth of the soil (Hulet and Gosseye, 1986).

Intensive cultivation of sole millet on so fragile soils would deplete essential nutrients. The adverse effects of the system on soil fertility can be counteracted by intercropping with a legume that can fix substantial amounts of atmospheric N (Agboola, 1975). Cowpea, which was reported to fix N at rates varying from 8 kg ha⁻¹ year⁻¹ (IRRI, 1974), to 84 kg ha⁻¹ year⁻¹ (Johnson, 1970, quoted by Skerman, 1982), to as much as 240 kg ha⁻¹ year⁻¹ (Nutman, 1971, quoted by Rachie and Roberts, 1974), appears to benefit soil fertility.

The effect of different fertilizers on soil fertility and yields was also investigated. Commercial fertilizers are expensive and scarce in Mali, but these can be substituted with tilemsi, a rock
phosphate found in abundance in the country, or with simple superphosphate. *Tilemsi* is not cost-effective in areas with annual rainfall below 700 mm (Pieri, 1971), but simple superphosphate was found to be effective on various types of crops (Wilson et al, 1983; ICRISAT, 1984; Hulet and Gosseye, 1986).

**IMPROVEMENTS**

**Planting pattern**

In the traditional intercropping system, millet and cowpea are sown in the same seed hole (additive pattern). However, the two species can also be sown in alternate holes on the same ridge, or each can be planted separately on alternate ridges.

Table 2 shows the species associations and planting patterns tested in Niono during 1981–83 in five cropping sequences. Millet grain yields decreased by 20% when millet and cowpea were sown on alternate ridges, and by 30% when they were sown in the same hole (Figure 2). Since farmers in the semi-arid zone are primarily interested in millet production, the alternate-ridge pattern which resulted in less grain reduction should be promoted.

**Table 2. Species associations and planting patterns tested in five cropping sequences, Niono, central Mali, 1981–83.**

<table>
<thead>
<tr>
<th>Cropping sequence</th>
<th>Species association 1981</th>
<th>Species association 1982</th>
<th>Species association 1983</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Millet</td>
<td>Millet</td>
<td>millet</td>
</tr>
<tr>
<td>2</td>
<td>Millet+cowpea&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Millet</td>
<td>millet</td>
</tr>
<tr>
<td>3</td>
<td>Millet+cowpea</td>
<td>millet+cowpea</td>
<td>millet</td>
</tr>
<tr>
<td>4</td>
<td>millet/cowpea&lt;sup&gt;2&lt;/sup&gt;</td>
<td>millet/cowpea</td>
<td>millet</td>
</tr>
<tr>
<td>5</td>
<td>millet/cowpea</td>
<td>millet/cowpea</td>
<td>millet</td>
</tr>
</tbody>
</table>

<sup>1</sup> Sown in the same hole
<sup>2</sup> Sown on alternate ridges.
Interspecies competition could also be reduced by planting millet on two ridges and cowpea on the next two (Serafini, 1985). This model was used in Banamba in 1985, and the results of the experiments are discussed below under 'Timing of inter-cropping operations'.

**Planting density**

When the traditional additive system is used, the proportion of cowpea in the mixture is about 10% at planting and only about 4–5% at harvest. Our trials in Niono during 1981–83 demonstrated that when rock phosphate was applied at planting at the rate of 21 kg P ha⁻¹, the proportion of cowpea could be raised to 45% without significantly affecting the biomass and grain yields of millet. Without fertilizer, 15–30% cowpea in the mixture appeared to be acceptable, but when the cowpea proportion exceeded 30% the biomass and grain yields of millet were greatly reduced (Figure 3).
The optimum planting density of intercrops depends also on climatic conditions. Trials in Niono in 1984 (220 mm useful rainfall) showed that at a planting ratio of 50:50, the grain yield of cowpea decreased less than that of millet, indicating that cowpea is more competitive than millet under dry conditions (Figure 4). On the wetter Banamba site (406 mm useful rainfall), cowpea was not affected by the presence of millet, while millet benefitted from intercropping.

Figure 3. Effect of cowpea proportion in mixture and P application* on grain and biomass yields* of millet, Niono, central Mali, 1981–83.

*21 kg P ha\(^{-1}\) applied in 1981.

*Yields averaged over the 1981–83 period.
Crop rotation

Because results were masked by the drought in 1983, the trials failed to establish the extent to which consecutive cropping of sole millet affects soil fertility and yields. Figure 2 indicates that the grain and dry-matter yields of millet during 1981–83 were strongly correlated with rainfall in those years (Table 1). It also shows the beneficial effects of rotating millet/cowpea intercrops with sole millet: the production of sole millet increased by 100% after additive intercropping (sequence 2) and by 97% when sole millet followed intercropping on alternate ridges (sequence 4. Millet production in the third year of the rotation was atypical because of the overriding effect of the low rainfall in 1983.

Timing of intercropping operations

Simultaneous sowing of millet and cowpea has been observed to decrease millet production even when N is applied. The effects of planting date and fertilizer application on grain and dry-matter yields of millet and cowpea intercropped on alternate double ridges were tested in Banamba in 1985 (720 mm useful rainfall). Millet yields increased considerably and cowpea yields were adequate when cowpea planting was delayed by 1 week, and fertilizer was applied at the rates of 15 kg N ha⁻¹ and 21 kg P ha⁻¹ (Table 3).
Table 3. Effect of planting date of cowpea and fertilizer application on grain and biomass yields of millet and cowpea intercropped on alternate ridges, Banamba, central Mali, 1985.

<table>
<thead>
<tr>
<th>Cowpea Planting (weeks after millet)</th>
<th>Fertilizer application&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Millet</th>
<th>Cowpea</th>
<th>Millet/cowpea total biomass (kg DM ha&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grain</td>
<td>Stalks</td>
<td>Stubble</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(kg ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>(kg ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>(kg DM ha&lt;sup&gt;-1&lt;/sup&gt;)</td>
</tr>
<tr>
<td>0</td>
<td>P&lt;sub&gt;0&lt;/sub&gt;/N&lt;sub&gt;0&lt;/sub&gt;</td>
<td>732</td>
<td>289</td>
<td>2079</td>
</tr>
<tr>
<td>0</td>
<td>P&lt;sub&gt;0&lt;/sub&gt;/N&lt;sub&gt;15&lt;/sub&gt;</td>
<td>686</td>
<td>281</td>
<td>1733</td>
</tr>
<tr>
<td>0</td>
<td>P&lt;sub&gt;21&lt;/sub&gt;/N&lt;sub&gt;0&lt;/sub&gt;</td>
<td>1115</td>
<td>435</td>
<td>2495</td>
</tr>
<tr>
<td>0</td>
<td>P&lt;sub&gt;21&lt;/sub&gt;/N&lt;sub&gt;15&lt;/sub&gt;</td>
<td>875</td>
<td>351</td>
<td>2400</td>
</tr>
<tr>
<td>1</td>
<td>P&lt;sub&gt;0&lt;/sub&gt;/N&lt;sub&gt;0&lt;/sub&gt;</td>
<td>734</td>
<td>276</td>
<td>1586</td>
</tr>
<tr>
<td>1</td>
<td>P&lt;sub&gt;0&lt;/sub&gt;/N&lt;sub&gt;15&lt;/sub&gt;</td>
<td>1244</td>
<td>401</td>
<td>3048</td>
</tr>
<tr>
<td>1</td>
<td>P&lt;sub&gt;21&lt;/sub&gt;/N&lt;sub&gt;0&lt;/sub&gt;</td>
<td>1022</td>
<td>223</td>
<td>2317</td>
</tr>
<tr>
<td>1</td>
<td>P&lt;sub&gt;21&lt;/sub&gt;/N&lt;sub&gt;15&lt;/sub&gt;</td>
<td>1839</td>
<td>628</td>
<td>3557</td>
</tr>
<tr>
<td>F test&lt;sup&gt;b&lt;/sup&gt;</td>
<td>n.s.</td>
<td>n. s.</td>
<td>n. s.</td>
<td>n. s.</td>
</tr>
</tbody>
</table>

<sup>a</sup> Subscripts indicate the number of kg of P or N applied per hectare.

<sup>b</sup> n.s. = not significant. The results were not significant because of the high coefficients of variation for millet grain (59 %), millet stubble (54 %), cowpea grain (112 %) and cowpea haulm (42 %).

**CONCLUSIONS**

The contribution of the millet/cowpea intercropping system to food grain and fodder production in semi-arid Mali can be increased by manipulating the planting date, pattern and density of intercrops and the cropping sequence. The results of this study show that:

- Sowing millet and cowpea in alternate holes within a ridge or on alternate ridges reduced interspecies competition.
- In the traditional additive system, the optimum cowpea:millet ratio was 15:85. Alternate intercropping and a single application of rock phosphate in the first year of cultivation allowed the cowpea proportion in the mixture to be raised to 45% without significantly affecting millet yields. The optimum planting density also varied with climatic conditions: under dry conditions, millet was less competitive than cowpea, while under wetter conditions the cereal benefitted from intercropping.
• Rotating millet/cowpea intercrops with sole millet increased the production of the subsequent millet crop.
• Sowing cowpea 1 week after millet substantially reduced competition between the two species, particularly when moderate amounts of N and P were applied.

To sum up, technical improvements to the traditional intercropping system enable increases in both millet grain production and cowpea yields, particularly in the higher-rainfall areas. This confirms Fisher's observation (1977, quoted in Natarajan and Willey, 1986), but the qualification in terms of climatic conditions is probably more important for intercrops planted at a very high density or those with an increased need for water. Some researchers (e.g. Gregory and Reddy, 1982; Natarajan and Willey, 1986) maintain that because of the complementary utilisation of soil moisture by the root systems of intercrops, the system improves the efficiency of water use under severe water stress.

Serafini (1985) reported that the key issue in intercropping is planting date. Early sowing of millet or cowpea in alternate rows increased yields, particularly of cowpea, as did increasing the proportion of the legume in the mixture to 30%. Intercropping did not reduce millet yields significantly, except under poor rainfall conditions and low soil N. Sowing cowpea later than millet is recommended, but the time lag should not be too long as this might reduce cowpea yields. Moreover, if cowpea is harvested early enough, some N might become available to the cereal through the decomposition of the N-rich nodules of the cowpea.

The introduction of technical innovations into the traditional millet/cowpea intercropping system used in semi-arid Mali can have far-reaching economic and social consequences. Among these labour availability and labour division are factors which need to be thoroughly investigated to ensure that proposed innovations do not disrupt the tenuously maintained balance between the various components of the system.

REFERENCES


