

Microfertilizing sorghum and pearl millet in Mali

Agronomic, economic and social feasibility

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Abstract: Microfertilizing, consisting of applying small amounts of mineral fertilizer to the planting hole or pocket, was tested in Mali. Yields of sorghum increased by 34% and 52% compared with the control after applying 0.3 g of fertilizer per pocket for the years 2000 and 2001 respectively. For pearl millet, the corresponding yield increase was 48% and 67% for 2001 and 2003 respectively. Higher yield increases were observed when 6 g of fertilizer was applied per pocket than when 0.3 g of fertilizer was applied. The value–cost ratio varied from 3.4 to 11.9 in the 0.3 g treatment, and from 0.43 to 1.17 in the 6 g treatment. Application of 0.3 g of fertilizer appeals to farmers because of the good return on investment, low financial risk, low cash outlay and low workload required.

Keywords: pearl millet; sorghum; microfertilizing; value–cost ratio; farmers' adoption

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Soil fertility is an issue of national concern in African countries, where the agricultural sector often represents as much as 50% of gross domestic product (GDP). Soil fertility management is also an important component of the Poverty Reduction Strategy Plan (PRSP) for those countries – including Mali, where sorghum and pearl millet are major subsistence crops.

Soil fertility in Mali is affected by the low natural fertility of most soils (Pieri, 1989), low use of organic and mineral fertilizer, reductions in fallow periods (Hoefsloot *et al*, 1993) and removal of crop residues (van der Pol, 1992). In 2002, the average fertilizer use per hectare in Mali was only 9 kg/ha (FAOstat, 2006), and most of this was used on cotton and rice. Fertilizer use on millet is considered unprofitable due to the high price of fertilizer and the low price of grain (IER, 1996). Low fertilizer use in the Sahel is also related to the fluctuating grain price, lack of capital and poorly developed infrastructure (Muehlig-Versen *et al*, 2003). A survey of millet fields in

the Segou area showed that the nutrient balance was negative for nitrogen, phosphorus and potassium. The N balance was –14 kg/ha per year in village fields and –32 kg/ha per year in bush fields (Dembele *et al*, 2000). As livestock densities tend to be high in drylands, it is often assumed that animal manure is available in sufficient quantities to meet plant nutrient demand. However, farmers do not have access to manure in sufficient quantities (Dembele *et al*, 2000).

Soil fertility management is not only an agronomic issue, but it is also strongly related to economic and social issues. Poor farmers are typically risk-averse, and crop failures are common due to drought, *Striga*, bird attacks, locust and other pests and diseases. In addition, the farmers cannot afford to make large investments in soil fertility. The objective of this study was therefore to test microfertilization, which is considered to be a low-cost method of fertilizer application. Microfertilizing can be defined as the application of a small amount of fertilizer

in the planting hole at the time of sowing. The study, which was undertaken in close collaboration with NGOs and farmers, assesses microfertilizing from both agronomic and socioeconomic points of view.

Materials and methods

The study was undertaken in Macina in the Segou region of central Mali; in Bafaloubé in the Kaye region of western Mali; and in Koro in the Mopti region. Pearl millet is the dominant crop in Koro and Macina, whereas sorghum is the major crop in Bafaloubé. Koro and Macina are situated on the 600 mm isohyet and Bafaloubé is on the 800 mm isohyet. Rainfall in Bafaloubé was 662 and 579 mm in 2000 and 2001 respectively; in Macina, there was 652 mm in 2001 and in Koro, 474 mm in 2003. These rainfall data were not recorded in exactly the same locations where the on-farm tests were undertaken. A participatory rural appraisal (PRA) study undertaken in 1999 identified soil fertility as one of the farmers' most serious constraints. Based on this finding, a project was developed to address the agronomic performance of different microfertilizing methods and to study the economic and social feasibility of microfertilizing.

The following fertilizing methods were tested:

- farmers' method (control without fertilizer);
- 0.3 g of fertilizer per pocket: this method consists of mixing seeds and fertilizer in a ratio of 1:1 before planting; and
- point application of 6 g of fertilizer per pocket.

Applying 0.3 g of fertilizer per pocket is equivalent to 3 kg/ha of fertilizer in Koro, where there are about 10,000 hills (planting holes) per hectare, and 7.5 kg of fertilizer/ha in Macina and Bafaloubé, where there are about 25,000 hills per hectare. The method of applying 6 g of fertilizer per pocket is equivalent to 60 kg/ha of fertilizer in Koro/Bankass and about 150 kg per hectare in Bafaloubé and Macina. The rate of 0.3 g of fertilizer per pocket was the rate used by a farmer in Boungou Marka in Macina, while the 6 g application rate was equivalent to the recommendation from the Integrated Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

In Bafaloubé, 18 experiments were carried out each year. The number of experiments harvested was 13 and 14 for 2000 and 2001 respectively. Not all experiments were harvested because some farmers did not respect the protocol established and in some sites there were crop failures. In Koro, all the plots sown were harvested. In Macina, the results presented are based on the plots harvested by the non-governmental organization, CARE.

Di-ammonium phosphate was the mineral fertilizer used in 2000 in Bafaloubé. In 2001, 2002 and 2003, NPK 15-15-15 fertilizer was used. The plot size for each treatment was 50 × 50 metres. There were no replications in farmers' fields, and each farmer was considered a replicate in the statistical analysis. The statistical analysis was undertaken using analysis of variance.

Each farmer sowed all the treatments on the same day. In Macina, the pearl millet variety Toroniou was used. Sorghum was the crop used in Bafaloubé. The other

farming operations were carried out according to the farmers' regular practice.

The economic performance of the different treatments was assessed on the basis of value–cost ratio (VCR):

$$\text{VCR} = \frac{\text{value of yield increase}}{\text{cost of fertilizer}}$$

In each participating village, the farmers appointed a committee for the project and a chairman for the committee. These committees organized visits to demonstration sites, collected requests for fertilizer and organized the purchase of fertilizer. After each season, the 40 to 100 committee members from different villages met at a zonal workshop to share their experiences. These workshops also planned the actions to be undertaken in the following year. Regional committees were also established. In most of the villages originally selected, there was a development agent from CARE and the Stromme Foundation. Farmer-to-farmer visits within and between villages, field days, regional workshops and radio diffusion were used to scale up the results from the study.

Labour use and the appropriateness of the different microfertilizing methods were based on discussions in focus groups in the selected villages.

Results

Results are presented in relation to yield, economic performance, farmers' assessment and farmers' adoption.

Yields from microdosing of fertilizer

There was a significant effect of fertilizer application on sorghum yield in all three years (see Table 1 for 2000 and 2001 results). The highest yield was obtained in the 6 g fertilizer treatment in all the sites. For sorghum, yields increased by 34% and 52% compared with the control under the 0.3 g treatment for 2000 and 2001 respectively, whereas under the 6 g fertilizer treatment, yield increased over the control by 84% and 74% for 2000 and 2001. Yield increased by 37 kg of grain per kg of fertilizer under the 0.3 g treatment for both years, whereas under the 6 g treatment, yields increased by 4.7 and 2.6 kg for 2000 and 2001 respectively.

Yield levels were generally lower for pearl millet than for sorghum (see Table 2). The 0.3 g treatment increased millet yield by 48% and 67% as compared with the control for 2001 and 2003 respectively, whereas the 6 g fertilizer treatment increased the yields over the control by 123% and 143% for 2001 and 2003. Yield increase as kg of grain per kg of fertilizer for the 0.3 g treatment was 13.4 and 47.6 for 2001 and 2003 respectively. For the 6 g fertilizer treatment, yield increase as kg of grain per kg of fertilizer was only 1.7 and 5.4 for the years 2001 and 2003.

In 2000, di-ammonium phosphate (DAP) was the fertilizer used, while in the other years NPK 15-15-15 was used. It appeared from observations in the year 2000 that, if there was a drought after sowing, DAP burned the plants when 6 g of fertilizer was applied. This effect was

Table 1. Effect of different fertilizer application rates on sorghum yield (kg/ha) in Bafaloubé.

Treatment	2000	2001
Control	832	538
0.3 g fertilizer per pocket	1,112	819
6 g fertilizer per pocket	1,531	938
Mean	1,158	765
Significance	P<0.001	P<0.01
Number of experiments	13	14

Table 2. Effect of different fertilizer application methods on pearl millet yield (kg/ha) in Macina and Koro.

	Macina, 2001	Koro, 2003
Control	210	228
0.3 g fertilizer per pocket	311	371
6 g fertilizer per pocket	469	556
Mean	330	385
Significance	P<0.01	P<0.001
Number of experiments	19	8

also visible to some degree in the 0.3 g fertilizer treatment. A much less pronounced burning effect was also observed when using NPK fertilizer.

Value-cost ratio (VCR) and time spent on fertilizer application

The VCR was calculated to assess the economic feasibility of the methods. The VCR should be above 2 and preferably above 4 under conditions of risk such as drought (Koning *et al.*, 1998). The VCR was below the threshold value in all the four sites in the 6 g fertilizer per pocket treatment (Table 3). However, the 0.3 g treatment became interesting to the farmers, as this method gave a VCR above 4 in three of the four cases.

Estimations of time spent on the different technologies were provided in meetings with groups of farmers in three villages (Table 4). Farmers' estimations varied, but the mean time to sow one hectare of land with the 0.3 g treatment was 5 man-hours, as compared with 14.6 man-hours for the 6 g fertilizer method. According to the farmers, sowing seeds and fertilizer in the mixed treatment (0.3 g) did not increase application time as compared with the traditional sowing method.

Farmers' constraints and assessment of microfertilizing technologies

At the end of the project, the farmers assessed the technologies from an agronomic, economic and social point of view. Table 5 summarizes these observations. The farmers concluded that the method in which 0.3 g of fertilizer was applied per pocket was of most interest because it was less labour-intensive than applying 6 g of fertilizer per pocket. One person can sow a maximum of about two

Table 3. Value-cost ratio for the treatments (compared with controls without fertilizer).

Species Site	Sorghum		Pearl millet	
	Bafal, 2000	Bafal, 2001	Macina, 2001	Koro, 2003
0.3 g fertilizer	9.33	9.37	3.4	11.9
6 g fertilizer	1.17	0.67	0.43	0.55

Table 4. Labour use (man-hours per hectare) for the different treatments and sites.

Site	0.3 g fertilizer pocket	6 g fertilizer pocket
Souley	4	10
Boungou Marka	3	18
Kationo	8	16
Mean	5	14.6

Table 5. Advantages and disadvantages of the two microfertilizing technologies.

0.3 g fertilizer per pocket (seeds and fertilizer 1:1)	6 g fertilizer per pocket
No effect on plants if drought after sowing	Burning effect on plants if drought after sowing
Lower yield than 6 g fertilizer	Highest yield
Lower labour demand than 6 g fertilizer	Higher labour demand than 0.3 g treatment
Sowing on time	Delayed sowing
Low financial risk in the case of crop failure	High financial risk in case of crop failure
Plant slightly exposed to drought	Plant exposed to drought
Increased straw availability	Much increase in straw availability
More resistant to <i>Striga</i>	More resistant to <i>Striga</i>
Less land needed to obtain the same production	Less land needed to obtain the same production
Can be mechanized	Mechanization difficult
Feasible for poor farmers	Not feasible for poor farmers

hectares per day using the 0.3 g treatment, but considerably less than one hectare using the 6 g treatment (Table 4). The low financial cost of the 0.3 g method is another reason why this method is preferred. Applying 6 g of fertilizer per pocket requires a financial outlay (at 2004 prices) of CFA39,000 per hectare (CFA500 = US\$1), while the 0.3 g treatment requires only CFA2,600 per hectare.

Farmers observed that the 6 g treatment made the plants more sensitive to drought both in the beginning and at the end of the growth cycle. There was a tendency for stunting of plants to occur when the 6 g of fertilizer

was applied if a drought occurred after sowing, but recovery was rapid and the plants receiving 6 g of fertilizer developed faster and grew more vigorously than those in the other treatments. However, farmers observed that the rapid development and more vigorous growth made the plants more susceptible to end-of-season droughts.

Farmers also observed that fertilizer application affected the tolerance of plants to *Striga* attack. In Koro, farmers stated that they were able to harvest from *Striga*-infected soils because they had used the 0.3 g fertilizer treatment.

Some farmers in Bafaloubé have been experimenting with mechanization of the microdose technology on their own initiative and without any support from the project. They have modified the disc in the sowing machine in order to sow seed and fertilizer simultaneously, and claimed that this modification was successful. This is particularly important in Bafaloubé, since mechanization is more widespread there than in the other sites of the project.

The microdose technology has generated interest among farmers in Macina, and in 2002, more than 120 hectares were sown using microdose technology. The majority of these fields were sown without any intervention or pressure from development organizations. At first, the project focused on seven villages where CARE extension agents were located. Farmers from neighbouring villages saw the results in the microdose demonstration sites, and then asked CARE if they could join the programme. In 2002, there were 23 'voluntary villages'. When the CARE project was phased out in 2003, the project committees that had monitored the work were still active in many of the villages.

Access to fertilizer in the project area has also been improved during the lifespan of the project. In 2004, there were four fertilizer outlets in Macina, whereas previously there had been none. It is worth noting that more farmers in Macina started to use and test the technology in 2004 even though there was no support available from CARE or any national organization.

Discussion

It is possible to increase yields of pearl millet and sorghum with application rates as low as 0.3 g of fertilizer per planting pocket. The year 2001 was a dry year, yet the results showed that microfertilization was applicable even in dry years. In Niger, using 4 g of single superphosphate per pocket gave a 45% increase in yield (Muehlig-Versen *et al*, 2003). In another series of experiments in Niger, yield increase over the control was 120% when 2.7 g of NPK 15-15-15 was applied per pocket (Buerkert *et al*, 2001).

Even though the yield increase was higher when 6 g of fertilizer was applied rather than 0.3 g per planting hole, the VCR was far better for the 0.3 g of fertilizer per pocket treatment. Applying 0.3 g of fertilizer per planting hole appealed to the farmers because the VCR using this method varied from 3.4 to 11.9. This result contradicts the previous conclusion that the use of mineral fertilizers was not profitable for pearl millet and sorghum crops (IER, 1996; Pieri, 1989) or in the drier areas of the Sahel in

general (Shapiro and Sanders, 1998). One important reason for the high value–cost ratio is that one kg of fertilizer increased the yield on average by 37 and 30.5 kg of grain per kg of fertilizer for sorghum and millet respectively. Previous studies in Mali with broadcast fertilizer showed that yield increase was 2 and 3 kg of grain per kg of fertilizer for pearl millet and sorghum respectively (Poulain, 1976). This shows that applying 0.3 g of fertilizer per pocket is much more efficient than broadcasting it. However, applying 6 g of fertilizer per planting did not seem to be more efficient than broadcasting it, since it gave the same result. Results from Niger and Burkina Faso also indicate the low profitability of applying fertilizer by broadcasting (Shapiro and Sanders, 1998).

Research on microfertilizing millet in Niger showed that 4 g of fertilizer in the form of SSP gave a VCR of 3 if the fertilizer price was double the price of grains (Muehlig-Versen *et al*, 2003). Applying 4 g of fertilizer in the form of SSP would not interest the farmer if the price ratio between fertilizer and grain was 4, as is the case in Mali. This result also indicates that 4 to 6 g of fertilizer per pocket is not economically feasible for farmers in Mali. The recommendation from ICRISAT to apply 6 g of fertilizer per pocket (ICRISAT, 1999, 2004) must therefore be questioned. The economic incentive to use fertilizer has not changed since the 1970s, as the ratio between the price of fertilizer and the price of grain in 2004 was about 4, the same as it was in the early 1970s (Pieri, 1989).

One reason for farmers' preference for the 0.3 g treatment is that one extra person is needed to apply 6 g of fertilizer per pocket, whereas the labour requirement for applying 0.3 g is no different from when no fertilizer is used. In addition, about 150 kg/ha of fertilizer will be applied to the field in the 6 g method, as compared with only about 7.5 kg/ha in the 0.3 g treatment. This increased quantity needs to be carried to the field, increasing the farmers' workload. Rainfall in the Sahel is erratic, and it is crucial to sow immediately after a rain shower because the soil will quickly dry out.

Applying 0.3 g of fertilizer per pocket increased yields by about 50% by supplying very low quantities of nutrients, but would make the nutrient balance more negative than cultivating without any use of fertilizer. This microfertilizing method should therefore be combined in the long term with complementary methods for maintenance of soil fertility, such as increased recycling of crop residues. It must also be expected that increasing amounts of mineral fertilizer will have to be added over the years in order to ensure the same yield benefits. The method of applying 0.3 g of fertilizer must be considered as a first step towards developing more sustainable cropping systems.

Organic matter management needs to be given due consideration in the future. Retention of crop residues is important for maintaining soil organic matter, reducing surface temperature, reducing crusting, and infiltration of more water and trapping dust that is rich in nutrients during sandstorms (Buerkert *et al*, 2000).

Users of fertilizer will need to develop a market-oriented approach. In many cases, farmers cannot operate as individuals because that will make the purchase of fertilizer too expensive. Each village will have to operate

as a group, identify how much fertilizer the village needs, collect the money, establish contact with fertilizer dealers, transport the fertilizer to the village, store it and distribute it in the village. All this requires organizational skills that will take time to build.

Conclusions

This study makes it necessary to reconsider soil fertility management in the Sahel. The study shows that it is possible to intensify millet and sorghum production in the Sahel using only minor investments in fertilizer. Current recommendations from ICRISAT do not seem to be economically profitable for farmers. The method of mixing seed and fertilizer in a ratio of 1:1 (0.3 g per fertilizer pocket) has proved to be very interesting to farmers, and the risks involved are only moderate due to the low quantities of fertilizer used. It appears that this small quantity is profitable even in dry years. This methodology should be scaled up in the Sahelian environment. However, scaling-up may not take place without backing from national development agencies, NGOs, the commercial sector and research institutions. Access to fertilizer in the rural areas is also a major factor limiting further expansion.

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