Improving cereal productivity and farmers' income using a strategic application of fertilizers in West Africa

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Abstract

In the past two years, ICRISAT, in collaboration with other International Agricultural Research Centres, National Agricultural Research and Extension Systems, has been evaluating and promoting point or hill application of fertilizer along with "Warrantage" in three West African countries, namely, Burkina Faso, Mali and Niger. The hill application of fertilizers consists of applying small doses of fertilizer in the planting hills of millet and sorghum. The combination of strategic hill application of fertilizer with complementary institutional and market linkages, through an inventory credit system (known as "Warrantage") offers a good opportunity to improve crop productivity and farmers' incomes. Results from the two year on-farm trials showed that, on average, in all the three countries, grain yields of millet and sorghum were greater by 44 to 120% while incomes of farmers increased by 52 to 134% when using hill application of fertilizer than with the earlier recommended fertilizer broadcasting methods and farmers' practice. Substantial net profits were obtained by farmers using "Warrantage". Farmers' access to credit and inputs was improved substantially through the "Warrantage" system. The technology has reached up to 12650 farm households in the three countries and efforts are in progress to further scale-up and out the technology to wider geographical areas.

Key words: Collaboration, millet, sorghum, poor soil fertility, strategic application of fertilizers, "Warrantage"/inventory credit system, net profits

Introduction

The Semi-Arid Sudano–Sahelan zone of West Africa remains one of the poorest regions of the world due to several constraints to agricultural development. The major constraints to arable agriculture are crop growth on the predominantly sandy soils that are of poor soil fertility; particularly in phosphorus (P) and nitrogen (N) (Bationo et al., 1992; 1993; 1998a;b); It has, however, been reported that phosphorus tends to be more limiting to crop productivity than nitrogen. Crop response to nitrogen was found to be minimal until crop phosphorous requirements had been satisfied (Traore, 1974).

The little arable land in these zones is being gradually reduced due to the southward creep of the 400 mm isohyet (Sivakumar, 1992). Furthermore, due to the high population growth rate (3.4% per annum) and the increasing population density, considerable pressure is being put on the available cultivated lands. As a consequence of this, the length of fallow periods has significantly decreased and in most cases fallow

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periods have completely disappeared; this has forced farmers to cultivate marginal and degraded lands, which result in low yields and further land degradation. Stoorvogel and Smaling (1990) reported that because of these problems, increases in crop production have resulted more from the expansion of cultivated areas than from improved productivity.

Van Keulen and Breman (1990, pp. 177–197) and Breman (1990, pp. 124–134) stated that the only real cure against land hunger in the West African Sahel lay in increased productivity of the arable land through the use of external inputs, mainly chemical fertilizers. Although soil fertility enhancement technologies have been developed over the years for the main staple food crops in West Africa, such as sorghum and millet, these technologies have not been adopted by farmers due to the high costs and unavailability of the inputs as well as the inappropriateness of the fertilizer recommendations made. Yields per hectare (ha) of sorghum and millet have therefore continued to decrease.

In the past years, a collaborative research effort between various national and international research institutions operating in the Sahel, led to the development of an effective technique to increase fertilizer use efficiency, reduce investment costs for resource-poor small scale farmers, thereby increasing crop growth and productivity (Bationo et al., 1998a;b; Buerkert and Hiernaux, 1998). The strategic application of fertilizer, also known as fertilizer "micro-dosing", is based on applying small doses of fertilizer in the hill of the target grain crop.

Linking farmers to input or product markets, and the vertical integration between these are also becoming prerequisites to uptake of agricultural technologies. Efforts to develop institutional arrangements likely to improve the linkages of rural households to major markets are often major development challenges. The combination of the strategic application of fertilizer (fertilizer "micro-dosing") with the complementary institutional and market linkages, through an inventory credit system (known as "Warrantage") appears to be a promising strategy for improving crop productivity and increasing farmers' incomes in the Semi-Arid Sudano-Sahelan zone of West Africa.. The "Warrantage" credit facility was initiated in Niger in the late 1990s to remove barriers to the adoption of soil fertility restoration inputs. Through this system, farmers have access to cash credit to enable them purchase external inputs such as fertilizers, and can store their surplus harvested grains to take advantage of the higher prices offered during the period when market supply of grains begins to decline.

Through a United States Agency for International Development (USAID) grant, ICRISAT in collaboration with its national and international research and development partners have extended the fertilizer "micro-dosing" technology and "Warrantage" system to three countries in West Africa, namely, Burkina Faso, Mali and Niger. This paper highlights the major results obtained from the evaluation of these technologies in the three selected countries.

Materials and methods

Demonstrations/On-farm field trials

Demonstrations and field tests of the strategic application of fertilizers (fertilizer "micro-dosing") were established in farmers' fields in the three participating countries in West Africa, namely Burkina Faso, Mali and Niger, during the 2002 and 2003 rainy seasons. The demonstration tests consisted of three plots per farmer, each plot measuring approximately 300 square metres (m^2). Three treatments were applied comprising of the farmers' practice, the earlier recommended broadcasting system of fertilizer application (about 100 kg NPK (15:15:15) per ha, and the fertilizer "micro-dosing" at 4–6 grams per hill of compound fertilizer (NPK) [40 to 60 kg NPK per ha) or two grams of Diammonium Phosphate (DAP) per hill (20 kg DAP per ha)]. The test crops used were millet and sorghum. Plant densities under farmer conditions varied between 5,000 and 6,000 hills per ha while the recommended densities in the "micro-dosing" plots are about 10,000 hills per ha.

These demonstrations were managed by the farmers themselves together with technical backstopping from the resident extension workers. Farmers planted when they felt the soil was moist enough for germination of seeds. They used their own densities in the control plots, but had to follow the recommended densities in the 'micro-dosing' plots. They also weeded when it is time to do, in some cases, on the advice of field technicians. Harvesting is done by farmers under the supervision of field technicians. Data collection was done by the field extension agents and Non-Governmental Organization (NGO) staff. Regular visits and monitoring tours were undertaken by all the partners including ICRISAT, and other International Agricultural Research Centres (IARCs) and National Agricultural Research Centres (NARES) staff.

In addition to the field demonstrations, a socio-economic evaluation was carried out in order to assess the economic performance of the fertilizer "micro-dosing" technology. Net gain was calculated as the difference between the total revenues from the grain and the total cost of the main input , in this case the cost of fertilizer, as:

$$NG = R - C$$

Where, NG = Net gain; R = revenue from grains; and C = cost of fertilizer

Net gain was expressed in FCFA per ha. The cost of labour was not used as the data were collected from plots that are not large enough and the data were not reliable.

Burkina Faso

In Burkina Faso, INERA (Institut National de l' Environnement et de Recherches Agronomiques) coordinated the local project activities. Its NGO partners were: FNGN (Fédération Nationale des Groupements NAAM); ADRK (Association pour le Développement de la Région de Kaya); and Hunger Project.

FNGN operates in the northern zone of Burkina Faso. In the first year, demonstration plots were established in the three villages of Kain, Oula and Pobe Mengao. Ten farmers per village participated in the trials giving a total of 30 farmers in the northern zone. ADRK covered the Central North Zone. The demonstration fields were sited in the villages of Tallé, Nionko and Kassirin in the department of Pissila. There were ten farmers per village. Field trials were established by Hunger Project in the villages of Malgretenga, Sarago and Nagrengo. Ten farmers per village also participated in these demonstrations. The total number of villages and farmers involved in the demonstrations in Burkina Faso increased from 9 villages in 2002 to 30 villages in 2003 and from 90 farmers in 2002 to 210 farmers in 2003.

Mali

Three NGO partners: Winrock International, Sasakawa Global 2000 (SG 2000), and ADAF-Gallé; the Institut d' Economie Rurale (IER), the Malian National Research Institute that coordinates the local project in Mali were involved in the demonstration trials.

Demonstration plots were also set up during the 2002 and 2003 cropping seasons. In 2002, rainfall was below the long term annual average and there were also dry spells immediately following sowing and at the flowering stage, which adversely affected crop growth. In contrast, rainfall amount and distribution were adequate during the 2003 cropping season.

Demonstration plots of fertilizer micro-dosing were established in villages in the Mopti and in the Segou regions, which are covered by Winrock International. SG 2000 established the demonstration fields in villages in the Koulikoro and the Segou regions. Two zones were covered by ADAF-Gallé: The Mande and the Bélédougou zones. Sasakawa 2000 (SG 2000) conducted the demonstrations in Segou and Beledougou. Overall, 22 villages were involved in the field tests in 2002 and this increased to 44 villages in 2003. The number of participating farmers increased from 108 in 2002 to 321 in 2003

Niger

About 1,536 demonstrations were established by Projet Intrants of FAO in 254 villages in five departments in southern Niger, namely, Tillabery, Dosso, Tahoua, Maradi and Zinder. Projet Intrants of FAO collaborates with various structures including farmers' organizations, NGOs, projects and federations. The USAID TARGET project complemented the on-going work on fertilizer "micro-dosing" by expanding the work to more villages, increasing the frequency of joint visits to the demonstration fields by the Niger NARES, INRAN, Projet Intrants of FAO and ICRISAT, and, by enabling the project team to collect additional data which will be very useful for up-scaling the fertilizer "micro-dosing" technology. Sowing was done early in June 2002, but drought in June and July 2002 adversely affected crop establishment. Several farmers had to re-sow their fields. As the rains became more regular in August and September 2002, crop performance improved. In 2003, the rainfall conditions were good.

Training

Field agents and farmers

Before the start of the cropping seasons targeted for the 2002 and 2003 rainy seasons, extension agents and farmers in all the three selected West African countries

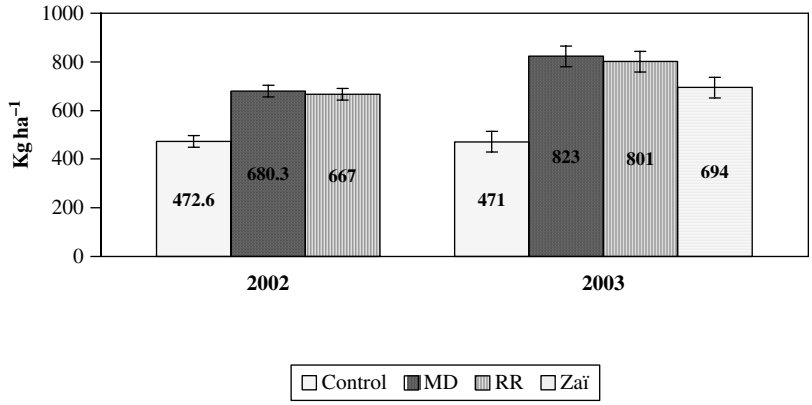

Figure 1. Millet Grain Yields (kg ha^{-1}) for Demonstration Trials (Control, Micro-Dose, Recommended Rates (RR), and Zai) in Burkina Faso, 2002 and 2003.

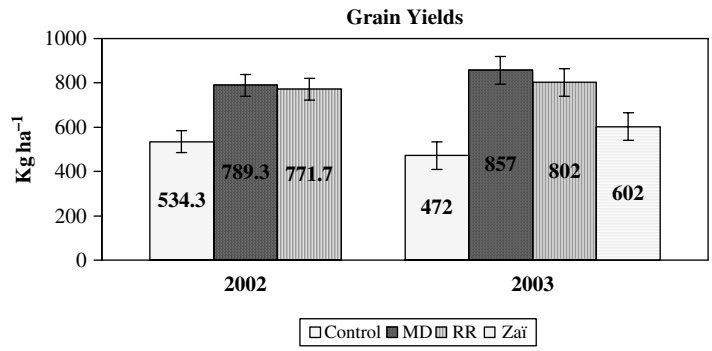

Figure 2. Sorghum Grain Yields (kg ha^{-1}) for Demonstration Trials (Control, Micro-Dose, Recommended Rates (RR), and Zai) in Burkina Faso, 2002 and 2003.

were trained in the correct application of the fertilizer "micro-dosing" technology. These training sessions consisted of demonstrating to them in the field how to measure the recommended rate of fertilizer (micro-dose), how to apply it correctly and how to manage the field after sowing. Emphasis was also put on the best way of collecting agronomic as well as socio-economic data from the trials set up.

Results

Burkina Faso

Grain yields

Overall, during both the 2002 and 2003 cropping seasons, grain and fodder yields from the micro-dosing treatments were higher than yields from the control treatments. In 2002 and 2003 millet grain yields from the micro-dose were, on average, 43% and 75% higher, respectively, than yields from the control (Fig. 1). In 2003, the Zai treatment yielded 47% more than the control. During both 2002 and 2003 there was no significant difference between the grain yields from the micro-dose and the recommended rates of fertilizer broadcasting. Sorghum grain yields from the micro-dosing were 48% higher than those from the control plots in 2002 while in 2003 the micro-dosing treatments produced 82% more grain yield than the control treatments

(Fig. 2). There was no significant difference between yields from the micro-dosing and the recommended practice of fertilizer broadcasting.

Net returns

The revenue that was obtained with millet from the micro-dose treatment was approximately three times the revenue from the recommended practice (12575

FCFA ha^{-1} as compared to 5175 FCFA ha^{-1}). For sorghum, it was about 2.5 times (22780 FCFA ha^{-1} vs 9255 FCFA ha^{-1})

Mali

Grain yields

In Mali, overall grain yields of both sorghum and millet obtained from the fertilizer micro-dosing plots were greater than those from the control treatments. In 2002, millet grain yields from the micro-dose treatments were about 61% greater than those from the control plots while the micro-dose treatment gave a 107% higher sorghum grain yields than the control plots (Fig. 3 and 4). In 2003, millet and sorghum grain yields from the micro-dosing plots were 90% and 69% higher than the control, respectively.

In Segou, sorghum grain yields from the micro-dosing treatments were significantly higher than those from the control plots (1069 kg ha^{-1} vs 728 kg ha^{-1}). Millet grain yields increased from 687 kg ha^{-1} under no-fertilizer treatment to 1212 kg ha^{-1} with fertilizer micro-dosing, a 100% increase. In Beledougou, sorghum grain yields were also significantly greater than the yields from the control plots (1050 kg ha^{-1} vs 738 kg ha^{-1}). Millet yields from fertilizer micro-dosing were three times the yields from the control plots (688 kg ha^{-1} vs 205 kg ha^{-1}).

ADAF-Gallé covered the zones of Beledougou and Mande. In Beledougou, sorghum grain yields from fertilizer micro-dosing plots were twice as much as those from the control plots (670 kg ha^{-1} vs 300 kg ha^{-1}). This trend was also observed in the Mande region where sorghum grain yields from the fertilizer micro-dosing treatment were twice as much as the yields from the control plots (1300 kg ha^{-1} vs 600 kg ha^{-1}). Yields were generally higher in the Mande than in Beledougou due to the relatively higher rainfall in Mande.

The zones where Winrock International established the tests included villages in Mopti and Segou. Sorghum grain yields increased from 500 kg ha^{-1} to 800 kg ha^{-1} when fertilizer was applied in small quantities in plant hills. In the Segou region yields have

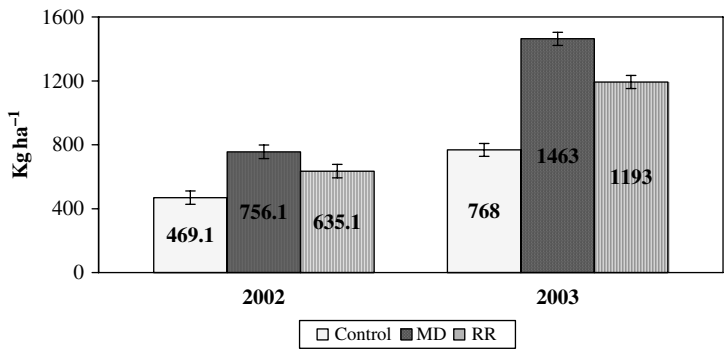

Figure 3. Millet Grain Yields (kg ha^{-1}) for Demonstration Trials (Control, Micro-Dose, and Recommended Rates (RR)) in Mali, 2002 and 2003.

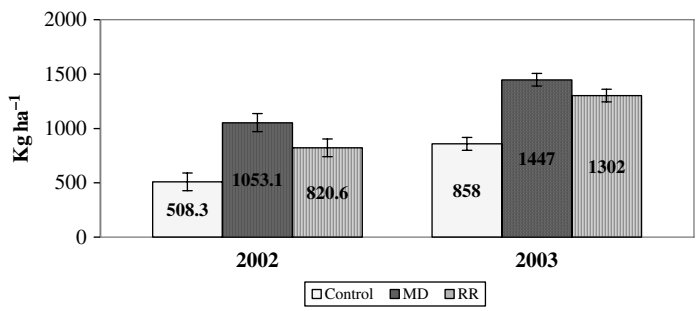

Figure 4. Sorghum Grain Yields (kg ha^{-1}) for Demonstration Trials (Control, Micro-Dose, and Recommended Rates (RR)) in Mali, 2002 and 2003.

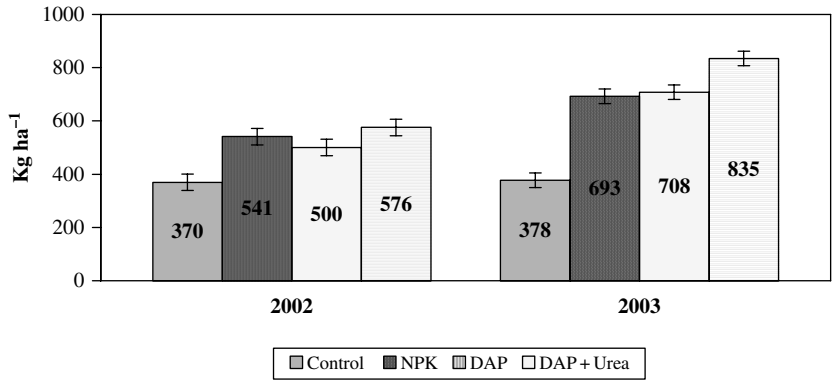

Figure 5. Millet Grain Yields (kg ha^{-1}) for Demonstration Trials (Control and Micro-Dose) in Niger, 2002 and 2003.

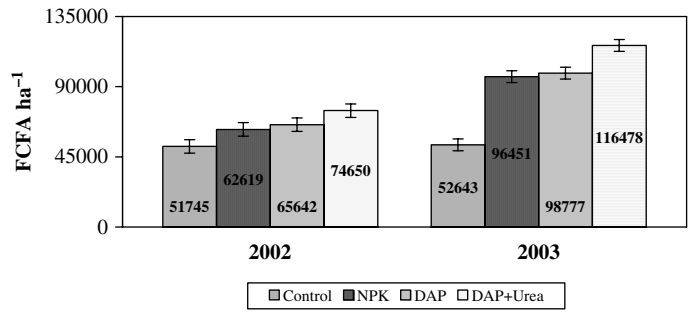

Figure 6. Net Profits (FCFA ha^{-1}) from Millet Grown Under Fertilizer Micro-Dosing Technology and Farmers' Practice, Niger, 2002 and 2003.

doubled under the fertilizer micro-dosing (1000 kg ha^{-1} vs 500 kg ha^{-1}).

Net returns

Net monetary gains obtained from millet from the micro-dosing plots were 119690 FCFA ha^{-1}which were 68% higher than the net profits from the control (71167 FCFA ha $^{-1}$and 33% greater that the net gain from the earlier recommended rates (89959 FCFA ha^{-1})

Niger

Overall, fertilizer micro-dosing treatments yielded higher than the controls. In 2002, average grain yields of millet were 576 kg ha^{-1} for DAP+Urea, 500 kg ha^{-1} for DAP, 541 kg ha^{-1} for NPK and 370 kg ha^{-1} for the control treatment (Fig. 5). In 2003, the micro-dose treatments produced up to 120% more grain yields than the control treatment (Fig. 5).

Net returns

In 2002, net gains were 74650 FCFA for DAP + Urea, 65642 FCFA for DAP, 62619 FCFA for NPK and 51745 FCFA for the control (Fig. 6). Net profits from the micro-dose were 44% higher than the control plots in 2002 and 121% higher in 2003. (Fig. 6)

'Warrantage' or Inventory Credit System

This scheme enables the establishment of a link between credit and cereal grain markets. This credit facility removes the barriers to the adoption of soil fertility restoration technologies. Farmers can have access to credit to enable them purchase external inputs such as fertilizers and invest in income generating activities like fattening of small ruminants, horticulture, trading, etc.., while using the stored grains to get higher prices at a time when the market supply begins to decline. In order to make inputs accessible to farmers, sustainable farmer-based enterprises and cooperative organizations

Table 1. Results from "Warrantage" in Mali, 2002/2003.

NGO Partner	Villages	Crops	Quantity of grain stored (kg)	Credit received under "Warrantage" (FCFA)	Management fees (FCFA)	Net benefits (FCFA)
SG 2000	Kondogola	Millet	4,000	360,000	4,000	236,000
	Niamabougou	Millet/ Sorghum	28,500	4,246,500	1,320,000	922,500
	Sélinkégny		2,000	580,000	79,000	Consumed
	Tioribougou	Paddy rice	3,800	482,000	–	29,400 +
			4,200	420,000	100,000	Consumed
		Maize/millet	4,130	619,500	10,500	196,000
		Paddy rice				
		Sorghum				
ADAF/ Gallé	Kénioroba	Millet/ Sorghum	6,885	1,141,000	–	91,415
Winrock International	Tissa laSofara	Millet/ Sorghum	6,200	620,000	46,500	35,.000
			13,107	638,375	–	215,547
		Paddy rice	902	126,280	49,925	Consumed
		Sorghum				

are developed, storage facilities and inputs shops (boutique d' intrants) are built, credit and savings schemes are also developed. These facilities are managed by members of these cooperatives.

Significant net benefits were achieved by farmers who practiced the "Warrantage" system in Mali in 2002/2003 (Table 1).

Training

Discussion

Results obtained from the demonstration trials in all the three participating countries confirmed the potential of this strategic application of fertilizer in the hill of plants (fertilizer "micro-dosing"). In general, grain yield increases under the fertilizer "micro-dosing" technology were more than twice as much as those from the control treatments. Net gain was also achieved by farmers using this technology. Earlier studies with fertilizer "micro-dosing" had been conducted mainly on millet grown in the sandy soils of Niger. The USAID TARGET project made it possible to evaluate this technology in higher rainfall areas with heavier soils in Burkina Faso and Mali. As was the case with millet in Niger, significant yield increases were also achieved with sorghum and millet at higher planting densities and in wetter environments.

The main concern of the project development partners relates to the socio-economic aspect of the technology in wetter areas where planting densities of sorghum and millet are usually higher than in drier areas thereby leading to larger quantities of fertilizer use per ha if the same rate of 6 grams of the compound fertilizer NPK or two grams of DAP fertilizer is applied. This shows that further studies are needed to come up with lower fertilizer application rates per hill in these cases. These studies are already in progress on research stations.

Another issue that requires further investigation is the possibility of soil mining arising from using the fertilizer "micro-dosing" technology. As grain yields increase per unit area and very little organic matter (OM), including crop residues, are put back into the soil there is the risk that nutrient imbalances will inevitably develop with time. There is therefore a need to ensure that OM is added and incorporated into these soils to improve their structure so that their capacity to store adequate moisture and nutrients even after crops are harvested is enhanced.

Labor could also be a major constraint to the wide adoption of the fertilizer "micro-dosing" technology. To further reduce the cost–benefit ratio, efforts should be made to develop labor-reducing equipment to complement the farmers efforts. The precise application of the fertilizer micro-dose in the hill of the plant requires that appropriate technology be developed and used.

The "Warrantage" or inventory credit system offers an excellent opportunity to farmers to get better prices for their grain products like sorghum and millet, to have access to cash credit and to purchase the needed inputs for increasing their agricultural productivity. The example from Mali given in this paper showed clearly that farmers can obtain great benefits from practicing the "Warrantage" system. There is, however, a need to strengthen farmers' organizations and assist them to establish effective linkages with financial stakeholders (commercial banks etc.) for additional funding.

Conclusions

In all the project study sites in the three West African countries (Burkina Faso, Mali and Niger), grain yields of millet and sorghum were greater by 43 to 120% when using fertilizer "micro-dosing" than with the earlier recommended fertilizer broadcasting rates and farmers' practices. The incomes of farmers using fertilizer "micro-dosing" and inventory credit system or "Warrantage" increased by 52 to 134%. Farmers associations were strengthened through training, technical back-stopping and exchange visits arranged among producers/farmers together with NGO staff from the three selected countries.

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