Chapter 15
Economic Efficiency of Sorghum Microfertilizing in Smallholder Farms in the North-Sudanian Zone of Burkina Faso

A. Traoré, B. Ouattara, H. Sigué, F. Lompo, and Andre Bationo

Abstract The mineral fertilizer microdosing (MD) technique was disseminated in the North-Sudanian zone of Burkina Faso for 3 years, using various extension tools. This study aimed to analyze the economic efficiency as well as farmers' perception of the use of MD technique. Quantitative and qualitative data were collected from 60 demonstration plots conducted by innovative farmers and from 300 households, using an interview guide during the focus groups. The results of the demonstration trials showed that this innovation significantly increased ($P<0.05$) sorghum productivity compared to farmer's practice. It even tripled sorghum yields when combined with soil and water conservation (SWC) techniques, and the use of improved seed varieties. It also led to the efficient use of production capital with cost-benefit ratios ranging from 1.3 to 6.9 depending on the sorghum germplasm and its combined use with SWC techniques. Farmers acknowledged the positive effects of MD technique on their socio-economic well-being through higher incomes from sorghum production and improved food availability. These results challenged policy makers to trigger actions aiming at promoting large-scale adoption of MD technique for sustainable local development.

Keywords Soil fertility • Demonstration trial • Effectiveness • Efficiency • Farmers' perception

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Contents

15.1 Introduction

Continuing soil degradation and soil fertility decline hamper the development of agriculture (Sawadogo 2006), the main economic sector in West African countries (Gafsi and M'Bétid-Bessane 2007). These soils, mainly sandy, and characterized by general nitrogen and phosphorus deficiencies, are subjected to a mining-type of agriculture, which contributes to accelerate the rate of their degradation (Compaoré et al. 2001; Ouattara et al. 2006; Lompo et al. 2007). Moreover, the prevailing climate, especially in the Sahelian part, characterized by strong rainfall variability, hinders the development of farming systems (Paturel et al. 2002; Zoundi et al. 2007; Ouédraogo et al. 2010). In Burkina Faso, to improve production conditions and increase agricultural productivity, the government has been supporting farmers, since the 1980s, in the implementation of soil and water conservation techniques (SWC), and the use of improved seeds varieties, mineral and organic fertilizers (Ouédraogo 2005; Ouédraogo et al. 2010). These different intensification practices have a potential role in restoring degraded land and improving crop yields (Barro et al. 2005; Sawadogo et al. 2008).

However, the use of mineral fertilizers remains low due to financial constraints, climatic and economic risks, lack of appropriate incentive policies, etc. (Tabo et al. 2006; Zoundi et al. 2007). Yet, in the current context of low local availability of organic matter (around 1%) and very low soil fertility levels, it would be difficult to achieve high yields without the use of mineral fertilizers (Ouédraogo 2005; Ouattara et al. 2006). Thus, mineral fertilization through the microdose technique was developed by research in the Sahel to address these economic and edaphic constraints (Palé et al. 2009; Bakayogo et al. 2011). This low cost fertilization consists in applying small amounts of mineral fertilizers into seed holes or after plant emergence. The fertilization rates vary from 2 g for sorghum to 3 g for maize (that to say 62.5–94 kg.ha^{-1}, respectively) (Tabo et al. 2006; Palé et al. 2009). Combined with SWC techniques and organic fertilization, it has optimized crop yields (Zougmoré et al. 2004) in the Sahelian zone. Therefore, its widespread adoption by Burkinabè smallholder farmers could foster food security in the country. With this in view, activities aimed at disseminating the technology of combined use of microdose and SWC techniques with improved varieties of sorghum have been initiated since 2011 by research and development partners through demonstration trials in Burkina Faso. These trials aimed to assess and promote the agronomic and economic potential of the combined use of these technologies.

Several studies have shown the positive agronomic effects of MD technique. However, most authors have either assessed the effects of this innovation alone (Tabo et al. 2006; Aune et al. 2007; Bakayogo et al. 2011) or its application alone on improved seed varieties (Palé et al. 2009). Thus, there is a lack of information on the effects of the combined use of MD with SWC techniques on improved sorghum seed varieties. An analysis of the effects of these combined intensification practices would support the generalization of the results on the importance of MD technique and the promotion of technological options that are economically effective and efficient. Moreover, the analysis of farmers' perceptions of this innovation would reinforce the major conclusions on its effects and would guide not only policy makers in making decisions supporting large-scale dissemination but also researchers in perfecting this innovation. The purpose of this paper is to highlight the agronomic and economic effects of the combined use of MD and SWC techniques on the performance of an improved sorghum germplasm compared to the local variety. It specifically aims to demonstrate whether investment in this technology is economically profitable, technically efficient and socially necessary.

15.2 Materials and Methods

15.2.1 Study Sites

The study was conducted on two sites located at the northern (Zondoma Province) and central (Kourittenga) boundaries of the north Sudanian zone of Burkina Faso.

The province of Zondoma is located between 12° 38′ and 14° 18′ north latitude and 1° 33′ and 2° 55′ west longitude. The area is between isohyetes 600 and 845 mm per year. Soils are poorly developed and can be classified into three main types: (i) undeveloped erosional mineral soils and leached ferruginous soils; (ii) slope and deep valley soils consisting of slightly leached tropical ferruginous soils and hydromorphic soils; (iii) tropical ferruginous soils slightly leached on sand or on birrimian clay (Ganou 2005). Degraded vegetation is composed of tree strata, shrub strata, bushy strata, herbaceous strata and glacis. In general, agro-ecological conditions are precarious.

The province of Kourittenga, lies between 11° 48′ and 12° 34′ north latitude and meridians 0° 20′ and 0° 38′ west longitude. Annual rainfall is between 600 and 900 mm. These soils are shallow and low in fertility. The dominant types are the highly leached ferruginous tropical soils and the low erosional soil resulting from the dismantling of ferruginous crust (48%), vertisols and eutrophic brown soils (25%) and hydromorphic soils (27%). The vegetation is wooded, with the presence of clear forests and gallery forests along permanent or temporary streams. Generally, these soils are low in phosphorus and nitrogen and have degraded structures (Ouattara et al. 2006; Sermé et al. 2015).

Table 15.1 Technology packages implemented

Technologypackages	Factors combined
P1	SWC + MO + MD + IV
P2	SWC + MO + No MD + IV
P3	SWC + MO + MD + LV
P4	SWC + MO + No MD + LV
P5	NoSWC + MO + MD + IV
P6	NoSWC + MO + No MD + IV
P7	NoSWC + MO + MD + LV
P8	NoSWC + MO + No MD + LV

SWC Soil and Water Conservation technique; *NoSWC* Without Soil and Water Conservation technique; *MD* Fertilizer microdosing; *NoMD* Without Fertilizer microdosing; *OM* Organic Matter; *IV* Improved seed Variety; *LV* Local seed Variety

15.2.2 Demonstration Trials

Demonstration trials were carried out from 2011 to 2013 in five villages in the provinces of Zondoma and Kourittenga. Each of thirty farmers (men and women) identified in each province; freely choose a pair of technology packages proposed by the research team. These packages combine SWC and MD techniques, organic matter (OM) input, the use of local seed variety (LV) and/or improved seed variety (IV) of sorghum (Table 15.1). The SWC technique was either stone lines or grass strips; associated with zaï.

Zaï holes were dug during the dry season; with spacing of 0.80 m between sowing lines and 0.40 m between zaï holes on the sowing line; i.e. a density of 31,250 sowing holes per hectare. The zaï holes received uniformly a handful of organic matter (OM) at a rate of about 2.5 tons per hectare.

The amount of fertilizer applied in microdose per zaï hole was 2 g, i.e. 62.5 kg.ha^{-1} of NPK (14-23-14) and 1 g of urea; i.e. 31.2 kg ha^{-1} of urea. NPK and urea were supplied respectively 10 days and 45 days after sowing.

The target crop was either a local seed variety (Kansiagui; Belko; Kapelga) or the improved seed variety (Sariaso 11) of sorghum. Sorghum cropping cycle varied between 75 and 110 days for the local varieties against 90 and 100 days for the improved variety.

The size of the elementary test plot was 500 m^2. The experimental design was the Fisher-type with scattered blocks in which each farmer was considered as a replicate and was testing two technology packages.

15.2.3 Data Collection on Demonstration Plots

Sorghum panicles were collected on the elementary plot, after removing two lines and two edge seed holes on both sides. They were air dried until constant weight. The panicles were then threshed. The grains obtained were weighed.

15.2.4 Analysis of the Economic Efficiency of MD Technique

This analysis highlights the contribution of MD technique to the achievement of households' objectives, which typically, in the African countries, are to meet family food needs through improved yields and increased incomes (Roesch 2007). The indicators used for this analysis were: income or gross margin (*GM*) in CFA francs per hectare and grain yield in kilograms per hectare (*Yield*). To this end, in addition to data relating to grain production on the demonstration plots, input price information was collected from farmers and input suppliers. Yield per hectare and gross margin are obtained by the following formulas:

$$Yield_i = \frac{\mathrm{Pr}\ od_\mathrm{i}}{area} \tag{15.1}$$

With i = (1 ... 8), the number of treatments; *Prod* is the total production of sorghum in kilograms of an elementary plot, *area* is the area of an elementary plot expressed in hectare.

$$GM_i = Yield_i{}^* P_i - TVC_i \tag{15.2}$$

With P_i, the unit price in CFA francs of the kilogram of sorghum; and CVT_i, the total variable costs in CFA francs per hectare of treatment i.

In this paper, MD technique is considered efficient if the yield and gross margin generated by it are significantly higher than on the control. The data used to estimate the various indicators result from 3 years of experimentation in farmers' fields. The descriptive statistics using the SPSS version 20 software produced the average values of the various indicators on the basis of the 3 year data.

15.2.5 Analysis of the Efficiency of Fertilizer Use in Microdose

The relative efficiency of fertilizer use in microdose is measured by productivity in fertilizer value. According to (Gafsi and M'Bétid-Bessane 2007), productivity is a true indicator of the relative technical efficiency of the use of inputs. In terms of value for a given production factor, it corresponds to the increase in the value of the factor, divided by the cost of this factor (Brossier 2007). In the context of this study, the productivity of the MD technique corresponds to the cost/benefit ratio obtained by the ratio between the gross margin of yield increase per hectare due to mineral fertilizers and the cost of these fertilizers. This ratio reflects the gain obtained when the producer invests 1 FCFA in the purchase of mineral fertilizers. This means that labor costs for fertilizer application are not taken into account. The different cost/benefit ratios (CBR) are obtained by the following formula:

$$CBR = \frac{GM_m - GM_t}{TVC_m - TVC_t}$$

Where, GM_m and TVC_m respectively represent the gross margins and the variable costs of the treatments with microdose; GM_t and TVC_t, the gross margin and variable costs of the control treatment.

15.2.6 Analysis of Farmer's Perception of MD Technique

To carry out this analysis, focus group exercises were conducted with 300 farmers. The diagnosis allowed to collect information on the general appreciation of these technologies at the village level. The focus groups were conducted with women and heads of households. This allowed to gather assessments specific to each group. In terms of effects, the focus was on changes in production, income and product availability. Depending on the points of interest, the information collected was summarized in terms of relative frequencies.

15.3 Results

15.3.1 Efficiency of Mineral Fertilizers Microdose Combined with SWC Techniques

The efficiency of mineral fertilizers by microdose in association with SWC techniques was assessed through the evaluation of yields and incomes from the different treatments on the demonstration plots.

Microdose fertilization resulted in significant ($P < 0.05$) increases in sorghum grain yields of 100% and 186% with the local seed variety and the improved seed variety respectively, compared to the control (Fig. 15.1). Its effects are even greater when combined with SWC techniques. This combined use of techniques on the local and improved varieties yielded increases of 158% and 300%, respectively, compared to the absolute control. The yields obtained with the SWC techniques alone were higher than those of the control, but lower compared to those with the microdose alone.

In economic terms, the application of MD technique to sorghum significantly improves the financial situation of farmers (Fig. 15.2). This generates incomes of 100, 385 and 184, 625 CFAF.ha^{-1} respectively with local and improved seeds of sorghum varieties, resulting in increases of 57% and 160%. These effects are further enhanced when combined with SWC techniques: income increases by 118% with the local variety and 284% with the improved variety.

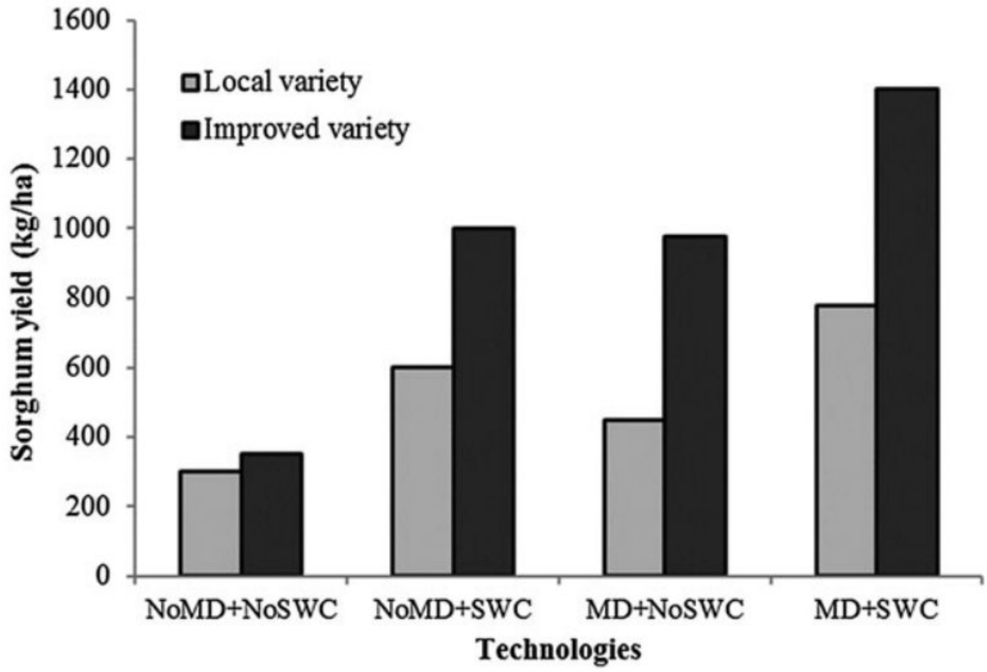

Fig. 15.1 Response of sorghum to MD combined with SWC techniques. NoMD + NoSWC = without Microdose and without SWC techniques; NoMD + SWC = without Microdose with SWC techniques; MD + NoSWC = Microdose without SWC techniques; MD + SWC = Microdose with SWC techniques

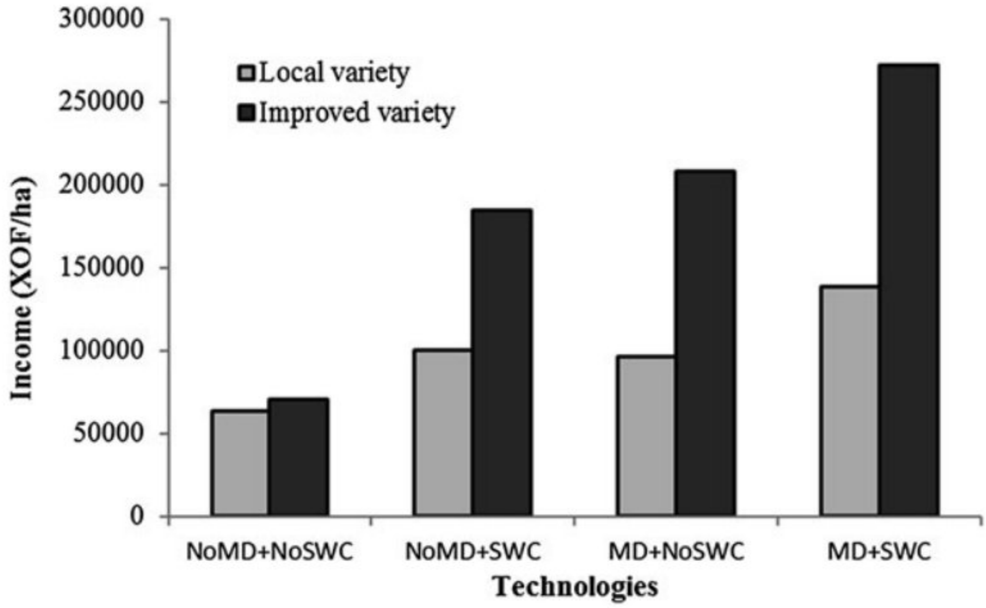

Fig. 15.2 Effect of fertilizer microdosing on income from sorghum crop. NoMD + NoSWC = without Microdose and without SWC techniques; NoMD + SWC = without Microdose with SWC techniques; MD + NoSWC = Microdose without SWC techniques; MD + SWC = Microdose with SWC techniques

15.3.2 *Analysis of Mineral Fertilizer Microdosing Technique Efficiency*

Mineral fertilization by microdose has made profitable farmers' investments in mineral fertilizers. Indeed, for 1 CFAF invested in the purchase of mineral fertilizer in microdose, the farmer had a profit of CFAF 1.6 when growing the local seed variety and 3.8 CFAF when growing the improved seed variety of sorghum. When combined with SWC techniques, microdose further increased capital productivity with respective profits of 2.6 and 6.9 CFAF for local seed variety and the improved seed variety for each Franc invested.

According to more than half of the farmers who participated in discussions within the focus groups, MD technique has induced considerable change in sorghum intensification practice in the study areas. It has increased the number of users of mineral fertilizers by reducing the level of risk associated with investment in fertilizers. Farmers believe that, with small doses, they incur very few financial risks besides the fact that climatic risks are also reduced by the SWC techniques combined with microdose. They also mentioned that this fertilization technique is much more applied on sorghum and cowpea, which are the major crops respectively for heads of households and women of the study sites.

The results of the focus groups also showed that farmers are convinced of the positive effects of microdose on yields. Indeed, 80% of those who adopted this innovation, carried out demonstration trials, or participated in guided visits reported that in plots where yields did not exceed 300 kg/ha, microdose fertilization enabled to achieve more than 700 kg and more than 1000 kg/ha when combined with SWC techniques. According to them, this yield increase helped to improve the food situation in households and increase the quantities of cereals stored in warrantage warehouses. Moreover, they stressed that this innovation has improved the availability of fodder for animals, all things favorable to the development of agro-pastoralism.

As for the economic aspect, on the whole, farmers are convinced of the economic impact of the MD technique. According to its adopters, this type of fertilization helped to improve their financial situation directly and indirectly. Directly through increased production which generates higher incomes and indirectly through greater food availability of food to the extent that the money intended for the purchase of food supplement is saved. According to women producing cowpea, increased income generated through MD technique has enabled most of them to carry out secondary activities, including trade, which also provides additional incomes.

15.4 Discussion

The results of the study show that microdose is a technique economically effective and efficient. This can be explained by the low production costs due to the use of low fertilizers rates, and its high agronomic potential. This fertilization practice has improved mineral fertilizer use efficiency by limiting losses through leaching and reducing competitiveness between weeds and crops. This generates higher yields which, coupled with low production costs, makes investment in mineral fertilizers more profitable for farmers. (Bationo et al. 1998) held the view that nutrient storage in the proximity of the plant root system through microdose ensures more efficient use and therefore proper plant growth and higher yields.

These results are consistent with those of Aune et al. (2007) on sorghum and millet, of (Hayashi et al. 2007) on millet, of (Tabo et al. 2007; Bakayogo et al. 2011) on sorghum, millet and maize) in different countries of West Africa. Farmers of the study sites are well convinced of the positive effects of MD technique on their socio-economic indicators. These results are in line with those obtained in a study on farmers' perception of SWC techniques in northern Burkina Faso (Ouédraogo et al. 2010). Since meeting food needs and securing a minimum income to cover family spending priorities are considered to be the priority objectives of African farmers (Roesch 2007), farmers' positive perception of the microdose effects on these vital issues should facilitate its widespread adoption.

Moreover, the combination of MD with SWC techniques further increases its agronomic potential. This result confirms those of (Zougomré et al. 2000; Zougmoré et al. 2003a, b, 2004; Sawadogo et al. 2008) indicating that the efficiency of soil fertility management techniques depends on their combination. These authors found in various agroclimatic zones of Burkina Faso that the combination of SWC techniques with organo-mineral fertilization optimized crop yields compared to individual techniques. SWC techniques, thanks to soil moisture retention by the slowdown in water speed and rainwater harvesting, enable optimal use of mineral fertilizers by the crops (Barro et al. 2005; Sawadogo et al. 2008). These techniques limit losses of organic and mineral fertilizers by runoff waters and reduce the degradation of soil surface layer. As a result, microdose combined with SWC improves both the structure and the chemical parameters of the soil.

Moreover, the effects of microdose are enhanced with the use of improved seed varieties due to their very high agronomic potential which allowed obtaining productions even on marginal lands. The effects of microdose on improved varieties are considerably greater than on local varieties. This result is consistent with the theory relating to the important role of improved seed varieties in increasing the agronomic and economic efficiency of MD technique as shown by the studies of (Palé et al. 2009, Twomlow et al. 2010). The positive effects of microdose combined with SWC techniques and improved seed varieties on yields and incomes support the agronomic and economic potential of the combination of the three technological options. The combination of microdose with SWC techniques on improved varieties leads to highest yields and incomes, which ensures better profitability from fertilizer investments.

In light of this discussion, combining fertilization technologies is a good strategy to significantly increase crop yields while protecting the environment in the arid and semi-arid areas of the Sahel.

15.5 Conclusion

This study has shown that mineral fertilizer microdosing (MD) technique is economically efficient and socially necessary. Combined with soil and water conservation (SWC) techniques on improved seed varieties, it has significantly increased sorghum yields and consequently food availability and farmers' incomes in the study areas. Analysis of farmers' perception of the microdose technology indicates that they clearly perceive the beneficial effects of this innovation through improved yields, higher incomes, food availability in households and positive change in their production system.

Thus, promoting a massive adoption of MD combined with SWC techniques for the cultivation of improved seed varieties of sorghum would be a good alternative for sustainable soil management. This innovation should enable to substantially improve food security and farmers' incomes while breaking the vicious circle of rural poverty in West Africa.

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