

Research Article

On Farm Validation of Integrated Use of Vermicompost and Inorganic Fertilizer for Soybean Production at Mima Watershed, at Bambasi District

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Abstract

Crop yields are greatly influenced by soil fertility status, which can be improved with vermin compost and inorganic fertilizers. The effect of integrated soil fertility management (ISFM) on the yield of soybean was validated under on-farm conditions in the Mima watershed over three cropping years (2011/12 - 2013/14 E.C.). The trial consisted of three treatments (recommended rate of NP or site-specific fertilizer recommendation, which is 23 kg of N and 46 kg of P/ha, farmers' practice (negative control), and 50% recommended rate of NP + 50% vermin compost (23 ton/ha based on N equivalence)). The plot size was 10 m by 10 m. Results of the experiment showed that the highest grain yield of soybean (2453.9 kg ha⁻¹) was recoded for application of 50% recommended rate of NP + 50% of vermicompost, while the lowest mean yield was noted for the control plot. Application of 50% recommended rate of NP + 50% vermicompost increased yields of soybean by about 41.37% and 20.55% compared to the control and recommended NP treatment, respectively. Economic analysis also revealed that combined application of 50% recommended rate of NP and 50% vermicompost gave the highest net benefit (98165.43 ETB) with an acceptable marginal rate of return. Hence, this treatment is recommended for soybean production in Assosa area as well as in areas with similar agro-ecology.

Keywords

Economic Analysis, Inorganic Fertilizer, Soybean, Vermicompost, Yield

1. Introduction

Loss of soil fertility has emerged as the main cause of decreased soil nutrient availability to plants, particularly in smallholder farms around the world. Soil erosion by water exacerbates the issue [1, 2]. Due to the widespread adoption of strategies that combine intensive, continuous cropping with

poor soil management, the trend is growing increasingly severe [3]. Agronomic management measures must be made in order to boost agricultural output and sustain the existing natural resources in light of the exponential growth of world population, increasingly shrinking arable land, and ongoing

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soil fertility problems [4, 5].

It is known that organic and inorganic inputs cannot completely replace one another and are both necessary for sustainable production of crops, as using organic resources or fertilizers alone may not be adequate or appropriate to address some crop growth restrictions [6]. The potential for further advantages brought about by beneficial interactions between organic and mineral inputs in the short term, as well as the numerous functions that each of these inputs fill over a longer period of time. One important complementary relationship is that while mineral inputs can be directed at key limiting nutrients, organic resources improve the status of soil organic matter and the processes it supports, though a promising farming practice that benefits the human, ecological, and social environment is organic agriculture.

Currently, many research findings have shown the importance of integrating mineral fertilizers and organic resources in ways that are tailored to local conditions to achieve satisfactory crop yields, sustainable soil nutrient improvement and efficient fertilizer use [7]. The evidence from research reports suggested that combined application of half the recommended rate of nitrogen and phosphorus (NP) fertilizers with 50% of vermicompost based on N-equivalence can be the best alternative measure for integrated soil fertility management instead of applying inorganic fertilizers alone for sustainability [8]. In line with this, [9] have concluded that integration of organic fertilizer with inorganic fertilizer increases the potential of the applied fertilizer, thereby increasing crop productivity. Studies conducted at different research centers under EIAR have also shown that combined application of 50% inorganic fertilizer and 50% of vermicompost based on N-equivalence exhibited promising results for different crops. However, conclusive results were not yet validated by a greater number of farmers. Thus, the present work was done to validate the recommended findings in larger plots and demonstrate for the extension service and to end users in Assosa area, particularly in Mima Watershed.

2. Materials and Methods

2.1. Description of the Study Site

The validation activity was carried out for three consecutive years (2011/12 to 2013/14 E.C) in Mima watershed at Amba-16 kebele in the Benshangul-Gumuz Region on the farm lands of nine farmers. The Mima water shade covers an area of 1031 hactar and the Mima water shade is one of the main streams draining into Afa River. The water shade is found at the distance of 24 kms from Assosa town on the way to Addis Ababa through Bambasi District of Benishangul Gumuz Regional State. It is bordered by Amba 16 kebele to west and Jematsa kebele to east direction. Mima water shade is bounded by longitudes 34°39' east and latitudes 9°55' south. The central point of the water shade is transversely by Longitude 34°40' East and Latitude 9°56' N.

2.2. Treatments and Design

The trial comprised of three treatments, namely, farmers' practice (negative control), recommended rate of NP (23 kg N and 46 kg P/ha) from urea as N source and NPS for P source and application of 50% recommended rate of N from urea + 50% N from vermicompost (based on N equivalence) with recommended rate of P from NPS. It was laid down in a randomized complete block design (RCBD), where farmers who hosted the trial were used as replications, each with a plot size of 10 m by 10 m.

2.3. Vermicompost Preparation and Analysis

Vermicompost (VC) was prepared from chopped maize stock, soybean straw and dried animal manure following the standard procedure. Samples were collected from well decomposed vermicompost before being applied in the field. Total nitrogen content of the VC was analyzed at the soil analysis laboratory of Assosa agricultural research center before the onset of the trial to calculate the mineral fertilizer equivalence using the same analytical procedures that were used for soil samples.

2.4. Soil Sampling and Analysis

Soil samples were collected from the experimental plots in a diagonal pattern from 0-20 cm depth before planting and after harvesting. Then, soil samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2-mm sieve and analyzed for the selected soil physico-chemical properties, mainly for total nitrogen, soil pH, exchangeable acidity, available phosphorus, available potassium, cation exchange capacity and exchangeable bases using standard laboratory procedures. Soil pH was determined according to the procedure outlined by [10] using 1:2.5 (weight/volume) soil sample to water ratio and readings were taken using a glass electrode attached to a digital pH meter. Total nitrogen was analyzed by Micro-Kjeldhal digestion method using sulphuric acid [11]. Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc [12]. Available phosphorus was determined by the Bray II method [13]. Exchangeable acidity was measured after extracted using unbuffered 1M KCl. Basic cations (Ca, Mg, Na and K) were extracted using ammonium acetate at soil pH 7 and determined using atomic absorption spectrophotometry.

2.5. Treatment Application

Vermicompost was applied at a rate ofton/ha in broadcast a week before sowing and thoroughly mixed in the upper 0-20 cm soil depth. Nitrogen and phosphorus fertilizers were applied in the form of urea (23 kg/ha) and NPS (46 kg/ha), respectively, at planting. Soybean variety *Gishema*

was used as a test crop and planted at the recommended spacing (seed rate) and sowing dates. All recommended agronomic practices were applied during the crop growth period.

2.6. Evaluation of Field Performance

At the start of the activity, farmer research groups (FRGs) was formed for Amba - 16 kebele and farmers were trained about the use and application of organic fertilizers (vermicompost) integrated with inorganic fertilizers. There was timely and close follow up of field performance of the activity. Finally, field days were organized to assess the effectiveness of integrated use of vermicompost and inorganic fertilizers and feeling or perception of the farmers about the practice and share the lessons with other stakeholders. In addition to FRGs, neighboring farmers and respective stakeholders were invited for the field days.

2.7. Data Collection and Analysis

Grain yield of soybean was recorded after harvest at full physiological maturity stage. To estimate grain yield, an area of 8 m by 8 m (64 m²) was harvested from each plot and adjusted to 12.5% moisture content by air drying.

All data was subjected to analysis of variance (ANOVA) using SAS computer software version 9.1 [14] and the least significant difference between means (LSD) used to separate the treatment means at statistical significance level of $p \leq 0.05$.

2.8. Economic Analysis

Partial budget analysis [15] was employed to estimate the net benefit, dominance analysis and marginal rate of return that could be obtained from various alternative treatments. Since the vermicompost was prepared in As-sosa Agricultural Research Center (AsARC), its production house, cost of preparation and application, as well as the cost of inorganic inputs were considered as variable costs for partial budget analysis. The cost of inputs was estimated based on the current market price we used and labor cost also from the daily laborer cost in the area. The highest net benefits from the application of inputs for the production of the crop might not be sufficient for the farmers to accept as good practices. In most cases, farmers prefer the highest profit (with low cost and high income). For this purpose, it is necessary to conduct dominated treatment analysis. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. A dominated treatment is any treatment that has net benefits that are less than those treatments with lower costs that vary [16].

3. Result and Discussion

3.1. Selected Soil Chemical Properties Before Planting

Selected chemical properties of soil samples collected from two blocks prior to treatment application were presented in Table 1. Accordingly, based on the ratings outlined by [17], the soil was moderately acidic in reaction (5.36 and 5.44), high in total N (0.2% and 0.19%), moderate in organic carbon content (2.34% and 2.24%), very low in available phosphorous (4.65 and 5.23 mg kg⁻¹ soil).

Table 1. Selected soil chemical properties before planting.

code no.	Soil Parameters	Value	Remark
1st Block	Soil pH	5.36	Moderately acid
	OC (%)	2.34	Medium/moderate
	TN	0.2	High
	Av P	4.65	Very low
2nd Block	Soil pH	5.44	Moderately acid
	OC (%)	2.24	Medium/moderate
	OM (%)	3.86	Medium/moderate
	TN	0.19	High
	Av P	5.23	Very low

3.2. Selected Soil Chemical Properties After Harvest

According to the rating of [18], the treatment with vermicompost application showed medium/moderate soil organic carbon (OC) and high available N contents. The concentration of available P (Av. P) also showed some improvement but is still low. Similarly, cation exchange capacity somehow increased due to application of half dose of the recommended rate of NP and the remaining half dose from vermicompost (Figure 1).

The same results have been reported by [19], who found that addition of organic residues can increase microbial pool sizes and their activity, C and N mineralization rates and enzyme activities related to nutrient cycling process. Soil nutrient status showed a better response to integrated application of chemical fertilizers with vermicompost than did non-vermicompost applied treatments. These results confirm the fact that vermicompost application reduces the leaching of applied inorganic N fertilizer and promotes better use of applied nutrients. An increase in soil pH due to vermicompost application (Figure 1) might be due to the presence of exchangeable bases in vermicompost, which have been reported

to increase the pH level of acidic soils [20].

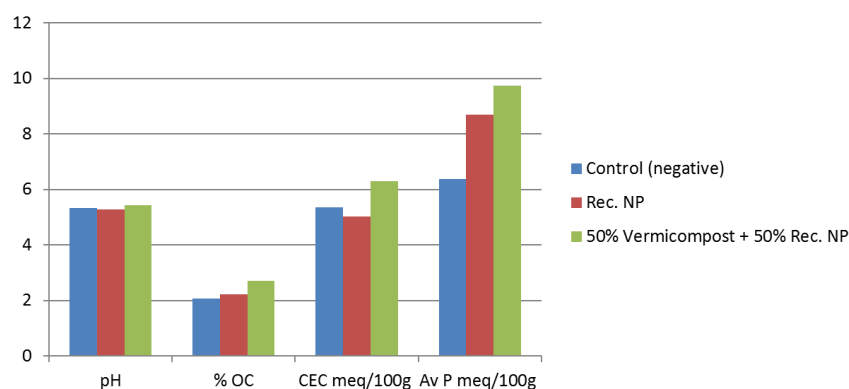


Figure 1. Selected soil chemical properties after harvest.

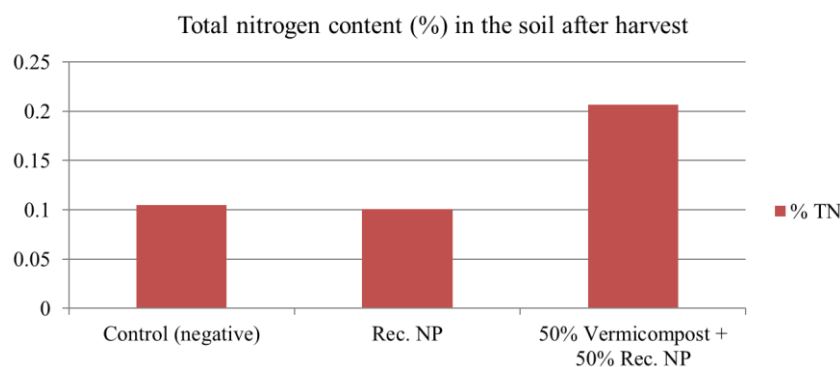


Figure 2. Total nitrogen content (%) of the soil after harvest.

3.3. Grain Yield of Soybean

As shown in Table 2, application of different treatments significantly affected grain yield of soybean. The highest grain yield (2454 kg/ha) was recorded for the plot that received combination of organic and inorganic fertilizers, followed by the recommended rate of inorganic fertilizer alone (1950 kg/ha). On the other hand, the least grain yield was recorded for the unfertilized control plot (1439 kg/ha). Application of 50% recommended rate of NP + 50% vermicompost based on N equivalency increased yields by about 52.148% and 22.89% over the control and recommended rate of NP, respectively. The corresponding increase in grain yield due to application of recommended inorganic fertilizer was

35.5% compared to the unfertilized control. Combined application of organic and inorganic fertilizers gives the highest yield because the organic fertilizer we used are source nutrients and additionally amend the soil reaction. In agreement with the present finding, [20] have also found that applying each half of the recommended amounts of N and P and manure and compost based on inorganic N equivalency led to yield advantages of roughly 129% and 68%, respectively, over the control and the lowest farmers' rate. Hence, the present work validated the importance of integrated soil fertility management (ISFM) in improving yields of soybean and demonstrated that combined application of inorganic fertilizers with organic sources might be taken into consideration as alternative to soil fertility management practice for sustainable soil and crop productivity in the study area.

Table 2. Over years combined analysis of soybean grain yield (kg/ha) as affected by application of inorganic NP fertilizer and vermicompost in Mima Watwrsheed.

Treatments	Yield (kg/ha)	Straw yield kg/ha
Control (negative)	1438.9 ^c	4437.50

Treatments	Yield (kg/ha)	Straw yield kg/ha
Rec. NP	1949.8 ^b	5229.20
50% Vermicompost + 50% Rec. NP	2453.9 ^a	6911.15
LSD	218.28	Ns
CV	19.41	10.9

LSD: Least significance difference, CV: Coefficient of variance. Figures followed by same letter are not significantly different at $P = 0.05$.

3.4. Straw Yield

Straw yield was non significantly influenced but relatively higher straw yield was recorded on the plots that was treated

by 50% recommended rate of NP + 50% vermicompost which was 6911.15 kg/ha. However, this result was not statistically different from the other two treated by negative control and conventional practice.

3.5. Economic Analysis

Table 3. Partial budget analysis (ETB).

Treatments	Adjusted grain yield [kg ha ⁻¹]	Adjusted straw yield [kg ha ⁻¹]	Gross field benefits [birr ha ⁻¹]	Total cost that vary [birr ha ⁻¹]	Net benefit [birr ha ⁻¹]	Marginal benefit	Marginal cost	Marginal rate of return%
Control (No input)	1295.01	2193.75	59811.10	0	59811.08			
Rec NP	1754.82	2906.30	81001.30	14080.73	66920.57	D	D	D
50% Vermicompost + 50% NP	2208.51	3520.04	101847	3681.55	98165.43	38354.35	3681.54	1042

The maximum net benefit was 98165.43 ETB for integrated application of 50% recommended rate of NP + 50% vermicompost (based on N equivalency). The lowest net benefit (59811.08 ETB) was obtained from the unfertilized control, followed by recommended rate of NP (23 kg of N and 46 kg of ha⁻¹) with a net benefit of 66920.57 ETB.

Application of 50% recommended rate of NP + 50% vermicompost also resulted in the highest (1042%) marginal rate of return (Table 3). Accordingly, it was found that the optimal recommendation for the study area is an integrated application of 50% of recommended rate of NP + 50% vermicompost (based on N equivalency).

3.6. Farmers' Perception During Field Days

Participants' perception on the integrated soil fertility management practice was assessed during the field days. Based on the existing physiological performance of the test crop and some yield indicator parameters, farmers evaluated the treatment with half dose of NP fertilizer plus half dose of vermicompost to the same level as or somewhat better than the performance of the positive control (Recommended rate

of NP). They also testified that this integrated soil fertility management practice could be used as the best alternative mineral source for improving soybean productivity in the study areas.

4. Conclusion and Recommendation

Agricultural yields are significantly impacted by depletion in soil fertility status, which can be improved through integrated use of vermicompost and inorganic fertilizers. Results of the present study showed that applying the recommended amount of inorganic NP fertilizer alone is insufficient for enhanced soybean production in Assosa area. But, integrated use of vermicompost as an additional organic fertilizer source is needed to increase the production.

Though application of recommended rate of inorganic fertilizer increased grain yield of soybean by 35.5% compared to the unfertilized counterpart, the increment was doubled with the integrated use of 50% inorganic fertilizer and 50% vermicompost (based on N equivalency). Moreover, combined application of 50% recommended rate of NP and 50%

vermicompost gave the highest net benefit (98165.43 ETB) with an acceptable marginal rate of return, and a relatively low overall cost of production. It also improved some selected soil chemical properties. Hence, this practice is recommended for use by soybean farmers in Assosa area and in areas with similar agroecology. However, it is advisable to carry out large-scale demonstrations on a cluster basis to reach more farmers and bring about significant improvement in production and productivity of the crop in those potential areas.

Abbreviations

RCBD	Randomized Complete Block Design
VC	Vermicompost
CALM	Climate Action Through Land Scape Management
DA	Developmental Agents

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix



Figure A1. Training for farmers and stakeholders on integrated use of vermicompost and inorganic sources.



Figure A2. Mini farmer's field day organized in order to share experiences each other.

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