RESEARCH ARTICLE

On- farm productivity response of rainfed grain Sorghum (*Sorghum bicolor L.)* to integrated nutrient supply system in Assosa Zone, Western Ethiopia, East Africa

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ABSTRACT

Sorghum is an important cereal crop and occupies third place in production after Maize and Tef in Ethiopia. Information on the response of Sorghum to organic and inorganic nutrient sources in the Assosa Zone is scanty. On farm experiments were they are conducted at two locations, for three years, to investigate the effect of eight treatments of inorganic and organic fertilizer integration (Recommended NP (check), Recommended FYM based on N equivalency, Recommended compost based on N, 50% Recommended FYM based on N equivalency + 50% Recommended NP, 50% Recommended compost based on N equivalency + 50% Recommended NP equivalency, 50% Recommended FYM + 50% Recommended compost both based on N equivalency and 33% Recommended compost, 33% Recommended FYM both based on N equivalency + 33% Recommended NP) and was laid out in a randomised complete block design (RCBD) with each farmer as a replication. Significant influence on the grain yield of sorghum due to fertilizer application was recorded. The maximum grain yield (4640.4 kg ha^{-1}) was obtained from application of 33.3% recommended compost + 33.3% recommended FYM both based on N equivalency + 33.4% recommended NP , which was 73.3 % higher than the control (1962.8 kg ha^{-1}). The partial budget analysis indicate greater economic benefit with this integrated system of nutrient management than either organic or in organic source alone. 50 % Recommended compost + 50% recommended NP (3455 kg ha^{-1}), Recommended compost (3452 kg ha^{-1}) and recommended FYM (3456 kg ha^{-1}) performed equally well and were superior to no fertilizer(2677 kg ha^{-1}) application.

Keywords: Sorghum, on- farm study, organic manure; inorganic fertilizers, yield, economics

INTRODUCTION

Grain sorghum [*sorghum bicolor* (L.) Moenich] is one of the leading traditional food crops of Ethiopia. The control of osmosis by the neuroendocrine complex in insect was pointed out for the first time. It ranks third in the country following maize and teff in total production. The crop is utilized in different forms where the grain is used for human consumption and homemade beverage, the leaves and stalks are commonly fed to animals (Habtu, 1995). Similarly, sorghum is the main food crop in the Benishangul-Gumuze region in general and in Assosa zone in particular. Sorghum production in the zone is found both in shifting and permanent farming systems, which are practiced among natives and settler farming communities, respectively. The productivity of sorghum crop was by far lower than the potential yields obtained on research stations and on farm verification trials that was 4-6 t/ha (Hailu *et al,*. 2002, Mosisa *et al.,* 2004, Desalegn *et al.,* 2006). Despite, the fact that the number of farmers' as well as area coverage are increasing with time, crop yields are generally in declining trend (CSA, 2009). The low yields are due to the current cropping systems of most parts of the country which are dominated by cereal mono cropping (McCann, 1995). Besides, majority of smallholder farmers' fields have been characterized by small size and fragmented, cropped with little or no external input, removal of crop residues, miss management of farm yard manure and over grazing in between cropping seasons. These crop management practices lead to environmental degradation, importantly soil nutrient depletion.

The advent of inorganic fertilizers alleviated the above adverse trends and increased per capita grain production has been deemed attained through the use of external inputs. Conversely, high cost of inorganic fertilizers and other agro-chemicals along with cost of transportation make their use on staple foods uneconomical for most smallholder farmers (Sanchez et al., 1977; Benson et al., 1997). To halt this persisting problem of smallholder farmers, an increasing interest in improving soil fertility through legume N-fixation and improved nutrient recycling through the use of organic inputs and retention of crop residues have gained popularity and drawn attention of researchers and policy makers (Sanchez et al., 1989). As a result, the resource poor farmers adopting cereals as a mere source of human food and cash would end up with imbalanced diet and low income. Moreover, most of the cereal based farming systems should be diversified to legumes and oil crops. There is also a desire to include forage legumes for their contribution in soil fertility enhancement and provision of quality feed for livestock (Tesfa et al., 2004). Hence, cereal, oil crops, pulses and forage legume production method must be designed for eco friendly crop production system in the zone. Therefore, crops that would fulfill the needs of resource poor farmers, including better resource utilization (soil and water), good diet source and increased cash source have to be integrated in to the current farming system of Assosa Zone.

Accordingly, combining organic and inorganic source sorghum for improving soil fertility was to minimize the tremendous loss of production and productivity. In view of this, the current investigation was initiated with the objective to determine the effect of combined use of organic and inorganic sources on for sorghum yield and economics on different soil types.

MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Assosa Zone, in two districts viz; Bambasi and Assosa, western Ethiopia in the main rainy seasons of 2010, 2011 and 2012. The research sites are located in the altitude ranging between 1300-1470 m.a.s.l., with the minimum and maximum temperatures of 14.5 and 28.8 ^{o}C, respectively and average annual rainfall of 1358mm , of which 1128.5mm was received between May and October .

2.2. Treatments and Design

The experiment consisted of eight treatments with combination of inorganic and organic sources. The treatments are Recommended NP (check), Recommended FYM based on N equivalency, Recommended compost based on N, 50% Recommended FYM based on N equivalency + 50% Recommended NP, 50% Recommended compost based on N equivalency + 50% Recommended NP equivalency, 50% Recommended FYM + 50% Recommended compost both based on N equivalency and 33% Recommended compost +33% Recommended FYM both based on N equivalency + 33% Recommended NP and was laid out in randomised complete block design (RCBD) using each farmer as a replication. Compost and FYM were prepared from locally available materials according the procedure of compost and FYM preparation in the area. The rate of recommended compost and FYM applied were calculated based on the N equivalency from 100kg urea (blanket recommendation). The blanket recommended rate of P (100kg TSP) was applied uniformly to all treatments. Urea and triple super phosphate was used as the source of N and P, respectively. Application of urea was in two splits, while the entire phosphorus and organics (compost and FYM) were applied at sowing in bands and by broadcast respectively. The recommended intra and inter row spacing 75X25cm was used in this trial. Size of each plot was 4.5 m x 5.1m.

2.3. Soil Sampling and analysis

Soil samples were randomly collected from 0-30cm depth of soil surface layer of the experimental field to form composite before sowing and analyzed for the soil texture, pH, available P, total N, and Organic Carbon. Besides, compost and Farm yard manure samples were analyzed for available P and total N. At harvest, soil samples were collected from each plot to determine the pH, total N, Organic carbon and available P. The soil samples were air-dried and ground to pass through 2 and 0.5 mm sieves (for total N). All samples were analyzed following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000). Organic carbon and total N content of the soil were determined following the wet combustion method of Walkley and Black, and wet digestion procedure of Kjeldahl method, respectively. The available P content of the soil was determined following Olsen method. Soil texture was analyzed by Bouyoucos hydrometer method. The pH (1:2.5 solid: liquid ratio) of the soil was measured in water using pH meter with glass-calomel combination electrode.

2.4. Crop Management

The experimental field was well prepared. Initially, seeds were planted by drilling methods and latter thinned to one plant per hill. The spacing was 0.75m and 0.25m between rows and plants, respectively. A total of six rows were kept in each plot. Each plot and block was separated by 0.75 m and 1.5m, respectively. A plot for inorganic treatment received a blanket dose of 46 kg N/ha (in the form of urea) and 18/46 kg N/P_2O5 in the form of DAP. DAP was applied at sowing time , while urea was applied in two splits half at planting and the remaining half at knee height stage 30 to 40 days after planting. Compost and Farm yard manure were applied a month before sowing by broad cast. Sorghum Assosa 1 variety was used for the experiment. Important agronomic practices like hoeing and weeding were uniformly applied to all experimental plots as and when required.

2.5. Data Collection and Analysis

The four central row plants were used for data collection. Growth parameters such as plant height, head weight per plant and grain yield were collected. The plant height (cm) was measured from the base of the plant to upper top most leaves of the plant. The data were taken from five randomly selected and tagged plants and the number of smut per plot was taken from a visual count of the plant head. The grain yield from the middle four rows was recorded and grain yield per hectare was calculated. Analysis of variance was carried out for the yield studied following statistical procedures appropriate for the experimental design using SAS computer software. Whenever treatment effects were significant, the means were separated using the least significant difference (LSD) procedures test at 5 % level of significance.

2.6. **Economic and analysis**

Economic analysis was performed to investigate the economic feasibility of the nutrient management treatments. A partial budget, dominance and marginal analysis were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers were expecting from the same treatment. The average open market price (Birr kg^{-1}) for Sorghum and the official prices of N and P fertilizers were used for analysis.

RESULTS

3.1. Initial Soil Physico-chemical Properties

The texture of the soil was sandy clay loam. Soil pH was moderately acidic (pH=5.52). According to Havlin et al. (1999), the pH was within the range satisfactory for most crops and suitable for deriving maximum benefit from applied phosphorous. The pH ranges of the soils were sufficient to minimize toxicity while maintaining adequate availability of micro-nutrients. The electrical conductivity (EC) of both study sites was zero which indicates that the soil has no salinity problem (Herrera, 2005).The available phosphorous (P) content was 3.2 mg kg^{-1}. The available P content the experimental field was low according to Pushparajah (1997). The organic carbon (OC) content was 2.37 % which was classified as low (Landon, 1991). The total N content was 0.175% and according to Landon (1991), the N content was low. The very low OC and low N content in the study area indicate low fertility status of the soil. This could be due to continuous cultivation and lack of incorporation of organic materials. (Table 1)

3.2. Chemical Composition of Compost and FYM

Compost and Farm yard manure analysis indicated that it contained 0.97 % and 0.44 % total nitrogen respectively. The implication is that application of compost has supplied the soil with 69 kg/ha total N. The applied compost and FYM supplied 150 % of the recommended N rate of sorghum (46 kg N/ha). However, not all nutrients are available immediately for the crop uptake; i.e. the unavailable nutrients are expected to be slowly available both during the current growing season to the crop to which it is applied as well as to subsequent crops through residual effect. (Table 1).

3.3. Head length (cm)

Panicle length was not significantly influenced by application of treatments. The data on panicle length have been presented in Table 2. The data indicated that highest panicle length (24.95 cm) recorded at physiological maturity with application of 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP. The lowest panicle length was recorded with application of recommended compost based on N equivalency (23 cm). Nutrients and nutrient management may result in high photosynthetic rate, net assimilation rate and continuous metabolic reactions up to physiological maturity stage which attributed to increase in the length of panicle. Similar results were reported by Hugar et al., (2010) in sweet sorghum.

Table 1. Chemical characteristics of soil ,compost and FYM samples analyzed before planting

	Soil	Compost	FYM
Available P(Bray II)(ppm)	3.2	0.195	0.49
Total N (%)	0.175	0.97	0.44
K(mg/kg)	0.36	26.25	21.0
CEC(cmol/kg)	26.34	62.52	36.78
Organic carbon (%)	2.37	19.0	12.6
pH	5.52	7.8	7.82

Table 2: Effect of organic and inorganic source fertilizers on head length, Stand count at harvest, No. of Covered smut and head weight of sorghum

Treatments	Head length (cm)	Stand count at harvest	No. of covered smut	Head weight (g)
Control (No input)	24.3	171.75	23.0	35.05^{c}
Recommended NP (check)	23.15	189.25	18.25	49.20^{ab}
Recommended FYM based on N equivalency	23.6	181.0	23.5	40.75^{bc}
Recommended compost based on N equivalency	23.0	174.0	29.0	39.20^{bc}
50% Recommended FYM based on N equivalency + 50% Recommended NP	24.5	186.25	24.25	43.35^{bc}
50% Recommended compost based on N equivalency + 50% Recommended NP	24.8	181.5	21.0	48.80^{ab}
50% Recommended FYM + 50% Recommended compost both based on N equivalency	24.90	175.75	33.5	52.50^{a}
33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP	24.95	184.5	19.25	58.01^{a}
LSD	2.5	20.34	12.15	13.34
CV	7.03	7.73	34.47	20.23
Significance	Ns	Ns	Ns	*

Note: * = P<0.05 and ** = P<0.01 and NS = Non significant

Table 3: Effect of organic and inorganic source fertilizers on plant height and grain yield of sorghum

Treatments	1000 seed weight	Plant height(cm)	Grain Yield (Kg ha^{-1})
Control (No input)	28.99	140.58^{b}	2677.6^{d}
Recommended NP (check)	30.77	155.45^{a}	4426.3^{ab}
Recommended FYM based on N equivalency	29.69	145.98^{ab}	3456.6^{c}
Recommended compost based on N equivalency	29.78	151.53^{ab}	3452.3^{c}
50% Recommended FYM based on N equivalency + 50% Recommended NP	30.2	156.53^{a}	4012.0^{b}
50% Recommended compost based on N equivalency + 50% Recommended NP	30.05	146.32^{ab}	3455.6^{c}
50% Recommended FYM + 50% Recommended compost both based on N equivalency	30.57	147.20^{ab}	3871.6^{bc}
33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP	30.99	158.42^{a}	4640.4^{a}
LSD	2.05	4.9	273.77
CV	12.5	7.59	18.5
Significance	Ns	*	**

Note: * = P<0.05, ** = P<0.01 and Ns = Non significant

3.4. Head grain weight (g)

Results of two years experimental data analysis pertaining to panicle grain weight (g) of have been presented in Table 2 significantly influenced by application of nutrients. The highest mean head weight (58.01 g/plant) of sorghum was obtained by application of 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP. However, this treatment was not significantly different with application of 50% recommended compost + 50% recommended NP, and 100% recommended NP treatments. Despite of the insignificant results, the highest grain yield was observed from 100% recommended NP treatments. This is might be due to the highest nutrient diffusion (supply) characteristics of the mineral fertilizer as compared to the compost and FYM. Sharma (1981) reported that application of FYM @ 12 t ha-1 in conjunction with NPK fertilizers increased the growth and yield components like panicle length, number of grains per panicle and test weight of paddy significantly over the treatment receiving only inorganic fertilizers.

3.5. Plant Height (cm)

Data on plant height showed that it was significantly influenced by fertilizer application. Application of 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP result in taller plants (158.42 cm) , followed by 50% Recommended FYM based on N equivalency + 50% Recommended NP (156.53 cm). Shortest plants were significant observed from unfertilized plots (140.5cm) followed by only FYM application (146cm). Similar results were reported by although variations in plant height due to treatments were noticed; the integrated nutrient application that gave taller plants was at par with the blanket application of inorganic fertilizer. The plant height is the main growth character that could be influenced to great extent by management practices. The finding in this experiment is in agreement with Ahmed *et al.* (2007); Meena and Mann (2007); Mishra *et al.* (2010) and Hugar *et al*. (2010) who reported same on sorghum. (Table 3)

3.6. Thousand Grain weight:

Thousand Grain weight was not significantly influenced by application of treatments. The data indicated that highest thousand grain weight (30.99 g) recorded with application of 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP. The lowest was recorded with application of Control (No input) (28.99 g). The grain weight gain could have been due to higher rates of photosynthesis and photo assimilate partitioning to the grains, or longer periods of grain filling or both (Turk *et al.,* 2002). The effect of fertilizer treatments weren't significant on 1000-grain weight, but application of organic fertility systems increased the 1000-grain weight (table 3). Grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling (Kausar *et al.,* 1993).

Table 4. Partial Budget Analysis of effect of organic and inorganic sources on sorghum yield.

Treatments	Total cost of production (ETB/ha)	Grain yield (kg/ha)	Gross return (ETB/ha)	Net return (ETB/ha)	Dom. analysis	Marginal rate of return (MRR %)
Control (No input)	2330	2677.6	21420.8	19090.8		-
Recommended NP (check)	5555	4426.3	35410.4	29855.4		202
Recommended FYM based on N equivalency	5330	3456.6	27652.8	22322.8	D	
Recommended compost based on N equivalency	5830	3452.3	27618.4	21788.4	D	
50% Recommended FYM based on N equivalency + 50% Recommended NP	5442.5	4012	32096	26653.5		240
50% Recommended compost based on N equivalency + 50% Recommended NP	5692.5	3455.6	27644.8	21952.3	D	
50% Recommended FYM + 50% Recommended compost both based on N equivalency	5580	3871.6	30972.8	25392.8	D	
33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP	5590	4640.4	37123.2	31533.2		330.8

Note: Total cost= Fixed cost + Variable cost (Inputs like FYM, Compost and inorganic Fertilizer), Net return= Gross return – Total cost, Price of FYM 60 ETB /1 sack, Compost 65 ETB /1sack , price of Urea =13.85 ETB/kg, TSP=18.75ETB/kg, DAP=14.35ETB/kg, Price of Sorghum =8 ETB/kg, Labor cost =25 birr/person /day of 8 hours

3.7. Grain Yield (kg ha^{-1})

Grain yield is the result of many complex morphological and physiological processes occurring during the growth and development of crop (Khan et al., 2008). Significant influence on the grain yield of sorghum due to fertilizer application was recorded at trial locations. The maximum grain yield (4640.4 kg ha^{-1}) was obtained with the application of 33.3% recommended compost + 33.3% recommended FYM both based on N equivalency + 33.4% recommended NP which was 73.3 % higher than the control (1962.8 kg ha^{-1}) (Table 3).

By and large, statistically similar performances have been observed between inorganic and integrated fertilizers. On the other hand, sole compost, sole FYM and control treatments produced significantly lowest grain compared with other fertilizer applications. The increase in grain yield was probably due to better growth and yield attributing factors, better nutrient use efficiency and better grain development. Ayoola and Makinde (2006), reported higher nutrient use efficiencies with the combined organic and inorganic fertilizer applications; and also they reported similar sorghum yield between inorganic N fertilizer and enriched organic fertilizer with inorganic nitrogen. The result in this experiment was also in agreement with Shah and Ahmad (2006), who reported higher grain of wheat in the treatments receiving an integration of inorganic and organic fertilizer. Similarly, Ahmad *et al.* (2006), on maize found similar grain yield between (enriched compost and 50% of recommended N fertilizer) and inorganic fertilizer. In addition, Rajesh wari *et al.* (2007) also noticed higher yield from the integrated fertilizer application. The partial budget analysis also indicated economic benefit for sorghum when sorghum is applied with 33% recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP when compared with other treatments(Table 3). Application 0f 50% recommended FYM + 50% recommended NP (4012 kgha^{-1}) gave comparable yield with 50% recommended FYM + 50% recomme-nded compost (3871 kgha^{-1}) showing that inorganic NP can be substituted with compost (Table 3).

3.8. Economics of nutrient management

The result of this study revealed that except eight treatments all the other treatments were dominated. Because these treatments have net benefits less than treatments with lower variable costs. Such dominated treatments were dropped from economic analysis. As a result only marginal rate of return (MRR) of the eight treatments were computed. (Table 3).

Economic analysis revealed that the gross return and net return were maximum with equal proportion application of compost + FYM + NP in 1:1:1 ratio followed by recommended NP and 1:1 ratio of FYM +NP. MRR of 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP was well above the 100% minimum (CIMMYT, 1988). But investing on additional fertilizer rate gave less MRR. According to CIMMYT (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50-100%. Therefore, the treatments that have highest Marginal rate of return (MRR %), w/c is 33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP for sorghum production is recommended.

CONCLUSION

From the foregoing discussion it could be inferred that the soil analysis before sowing indicated that the major nutrients (N, P) were found at low levels. Compost and FYM analysis showed that considerable amounts of N nutrient were supplied by compost and FYM. The field result indicated that integrated compost and FYM application showed a significant influence on yield components and yield of Sorghum which was comparable at par with inorganic fertilizer application. Sole compost, sole FYM application and unfertilized plots showed least influence on yield components and grain yield of Sorghum. Combined use of compost and FYM with inorganic fertilizer (33% Recommended compost + 33% Recommended FYM both based on N equivalency + 33% Recommended NP) has been suggested and can be used at Assosa zone to obtain higher yield of sorghum. Continuous uses of FYM & Compost with inorganic fertilizers not only increases the availability of nutrients but also benefit to the environment because with decrease use of chemical fertilizer and use of inputs organic can move to sustainable agriculture and ultimately enhances sorghum.

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