Diagnostic trial on sorghum (Girana one) for developing site-specific nutrient management practices in low lands of Eastern Amhara

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Abstract

A field experiment was conducted for the identification of yield-limiting nutrients through crop response in Kobo with test crop sorghum (Girana one variety). The experimental design was a randomized complete block design (RCBD) using farmer field as replication. Biological yield data were collected and subjected to analysis of variance (ANOVA). Whenever there was a significant difference between treatments, the means were separated using the least significant difference (LSD) individual nutrients (N, P, K and S) alone or in combination with farmyard manure (FYM) of these nutrients from fertilizer application resulted in a significant sorghum grain yield reduction. The highest grain yield was observed with the treatment receiving NPS+FYM whereas the lowest with omission of all nutrients (control). There was no significant difference in biomass yield between treatments for both years. Application of FYM in combination with inorganic fertilizer (NPS) and NP contained treatments (NPS, NPSK and NPSKZN) could be used as nutrient sources and can meet nutrient requirements for sorghum. The grain yield under different nutrient omitted plots followed the order NPS+FYM, NPS, NPSK and NPSKZN > NP, NS and PS > N, S and P. Application of farmyard manure is essential and the most yield-limiting factor followed by Nitrogen, Sulfur and Phosphorous fertilizer.

Keywords: Crop response, FYM, Omission, Nutrient, Yield

Introduction

Soil fertility heterogeneity in smallholder farming systems is a major factor that affects productivity and the suitability of crop and nutrient management recommendations for different locations at various spatial scales. The Nutrient Expert for sorghum (NE) supports the development and dissemination of site-specific nutrient management (SSNM) options for Sorghum production systems (Ren *et al.*, 2015). NE provides a systematic framework for applying the site-specific nutrient management concept (SSNM) to develop strategies to optimize the management of fertilizer N, P, K, S secondary and micronutrients in heterogeneous production systems. SSNM integrates soil, agronomic and climate information to provide location-specific guidelines on nutrient requirements (Oyinbo, 2019). It aims to (a) account for indigenous nutrient sources, including crop residues and farmyard manure; and (b) apply balanced fertilizer at optimal rates and at critical growth stages to meet the deficit between the nutrients needs of a high-yielding crop and the indigenous nutrient supply.

The optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely determines the ultimate yield. Soil fertility refers to the nutrient supplying capacity of soil for crop growth. It describes the available nutrients status of the soil and its ability to provide nutrients for optimum plant growth (Dev., 1997). When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, the application of supplemental nutrients is required. Fertilizer is one of the most important sources to meet this requirement. Indiscriminate use of fertilizers, however, may cause adverse effects on soils and crops both regarding nutrient toxicity and deficiency either by overuse or inadequate use (Ray *et al*. 2000). Diagnostic techniques including identification of deficiency symptoms, soil and plant analysis and biological tests are important in determining specific nutrient stresses and quantity of nutrients needed to optimize the yield (Havlin *et al*. 2007). Soil fertility evaluation, thus, is the key to adequate and balanced fertilization in crop production.

To increase the productivity of crops of smallholder farms and therefore improve food security in the study sites, there is a need to identify the soil factors that constrain crop growth. In addition to this one or two types of fertilizer recommendation applies to the whole districts or a wide region. In order to increase the use efficiency of applied nutrients and the cost-effectiveness of resource input, there is a need to target interventions whether related to soil amendments to improve the condition of the soil or to fertilizer application to address nutrient requirements. Knowing the limiting soil factors would inform about the right inputs needed. Therefore, this research was conducted to find out the yield-limiting nutrients and or factors (FYM) based on sorghum-response using nutrient omission technique and to develop Site-Specific Nutrient Management practices under variable soil fertility and climatic conditions.

Material and methods

Site description

The experiment was conducted at kobo which is located 54 km from woldia town in the direction of north. Its altitude ranges from 1000-2800 m.a.s.l. It has an agro-ecology of hot to warm sub moist valley and escarpment. The study district is located at a geographical coordinate point of 12^{o} 09’N latitude and 39^{o} 38’E longitude. Annual rainfall, minimum, and maximum temperature of the study area are 649 mm, 29^{o}c and 15^{o}c respectively. The dominant soil type of the area is euritic fluvisol lying on low plain on valley floor enclosed by low but steep sidehill and drains to rift valley river basin. The soils are deep to very deep mostly alluvial origin and have moderately to imperfectly draining properties. The infiltration rate and permeability are low with high runoff generation potential. But due to flat topography, it is less susceptible to erosion. The major crops grown in the area are sorghum, teff and maize (Getachew, 1993) and currently most of the irrigable area shifts to cash crop production. The livelihood of the population is depending on mixed farming (crop production and livestock production), with about 96% of its population engaged in agriculture.

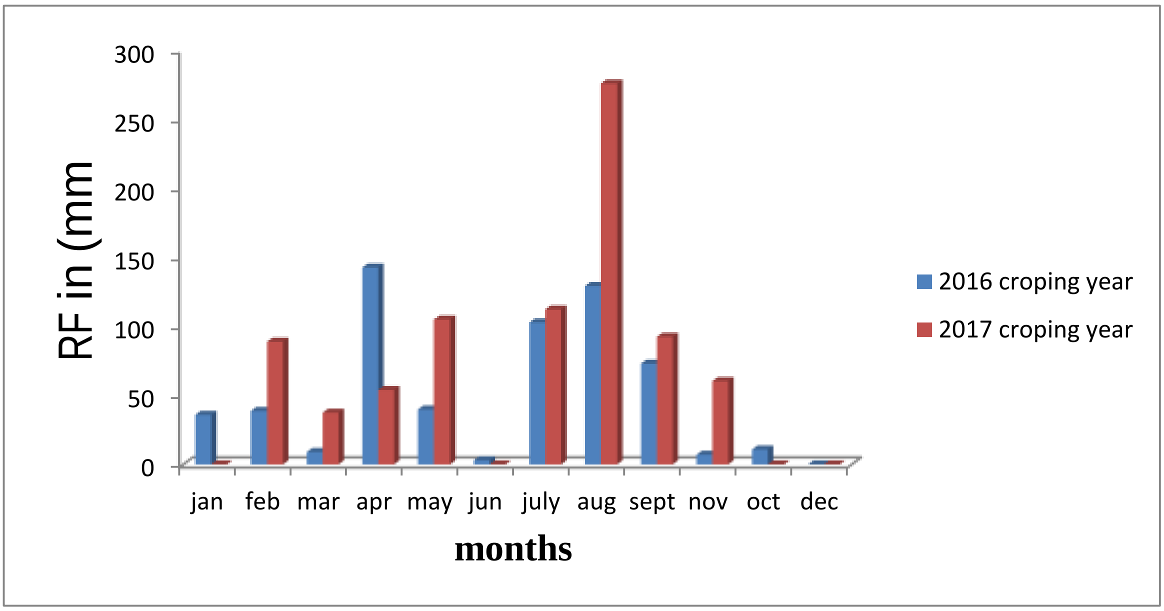

Figure 1. Monthly rainfall distribution of the study area during the two cropping years.

Experimental treatments and design

The experiment was conducted for two years in 2016 and 2017 main cropping seasons at Abuare, Aradom, and Ayub kebeles of the district. The experimental design was randomized complete blocks design (RCBD) with farmer's field as replication. Twelve treatments with 3 m by 4.5 m net plot size were used. Sites were selected carefully to ensure a good representation of the district.

Table 1. Treatments description

Plot	Description
Control	No fertilizer application. Used to measure grain yield as an indicator of the effective indigenous NPS supply from soil, rainwater, crop residue and atmosphere.
N	Provide sufficient N only, other nutrients are assumed to come from the soil
P	Provide sufficient P only, other nutrients are assumed to come from the soil
S	Provide sufficient S only, other nutrients are assumed to come from the soil
PS	N omission plot with sufficient P and S amounts applied. Used to measure grain yield as an indicator of the effective indigenous N supply from soil, rainwater, crop residue and atmosphere.
NS	P omission plot with sufficient N and S amounts applied. Used to measure grain yield as an indicator of the effective indigenous P supply from soil, rainwater, crop residue and atmosphere.
NP	S omission plot with sufficient N and P amounts applied. Used to measure grain yield as an indicator of the effective indigenous S supply from soil, rainwater, crop residue and atmosphere.
NPS	Full NPS input to estimate the nutrient-limited yield gap and evaluate agronomic use efficiencies of N, P, and S. Fertilizer N is applied in two splits :)
NPSK	This treatment will be used to assess the contribution of K with primary nutrients.
NPKSZN	This treatment will be used to assess the contribution of secondary and micronutrients to Sorghum productivity. The secondary nutrients rates already determined from existing work
NPS+FYM	This treatment will be used to assess the contribution of farmyard manure to Sorghum and Teff productivity through its multiple effects including organic matter addition and regulation of nutrient supply and water and air circulation.

Nutrient application rates

Nutrients (NPSK) were applied at rates required to achieve the expected attainable yield without nutrient limitation in each location. Nutrient application rates depend on the maximum attainable yield as determined based on rainfall and agro-ecological potential. The following guidelines were used to determine nutrient application rates:

Table 2. Amount of Nutrients applied

Treatment	Nutrient application rates (kg/ha)								
	N	P	P_2O_5	K	K_2O	S	Zn	**$ZnSo_4$	FYM
Control	0	0	0	0	0	0	0	0	0
N	150	0	0	0	0	0	0	0	0
P	0	55	125	0	0	0	0	0	0
S	0	0	0	0	0	20	0	0	0
PS	0	55	125	0	0	20	0	0	0
NS	150	0	0	0	0	20	0	0	0
NP	150	55	125	0	0	0	0	0	0
NPS	150	55	125	0	0	20	0	0	0
NPSK	150	55	125	60	72	20	0	0	0
NPSKZn	150	55	125	60	72	20	5	25	0
NPS+FYM	150	55	125	0	0	20	0	0	12t/ha
R.NP	69	30	69	0	0	0	0	0	0

Note. *R.NP=Recommended Nitrogen and Phosphorous*

- *The source of S&K was $CaSO_4$ & KCL respectively.*
- *FYM: Recommended rate of 12t/ha in micro-dosing (spot application method).*

Data collected

Grain and biomass yields

Grain yield was measured from the harvested innermost rows and was adjusted to 12.5 moisture content. Fresh biomass weight was measured by weighing the fresh total above-ground biomass and the head of the harvestable rows. Plant height was measured from ground level to the tip of the head at maturity from randomly taken five plant samples of the harvestable rows..

Soil sampling analysis

Composite soil samples were taken before sowing /planting at 0-20cm depth for soil analysis (Total N, available P, OC, texture and pH). The collected soil sample were analyzed according to the following methods; soil pH was determined using a glass electrode of pH meter in 1:2.5

soil water suspension after string for 30 minutes as described by Piper (1966); organic carbon was estimated by wet digestion method of Walkley and Black (1934)'; available P in soil was extracted by Olsen *et al.* (1954) and P in the extract was determined by the ascorbic acid method; total nitrogen in soil was determined by (wet digestion) procedure of Kjeldahl method and soil texture was determined by hydrometer method.

Data Analysis

The data obtained were subjected to analysis of variance using General Linear Model (Proc GLM) with statistix 10 software and treatment effects were compared using the Fisher's Least Significant Differences test at 5% level of significance.

Results and Discussion

Physico-chemical properties of the soil

The first-year soil analysis results (Table 3) showed that the soil had total nitrogen content in the ranges of 0.11-0.32 (%). According to Tekalign et al.(1991) the soil total N was moderate to high. This is because Tekalign and his coauthors defined that soils contain total N of less than 0.05% was considered as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and more than 0.25% as high. Based on this assumption the experimental site showed moderate to high content of total nitrogen. The soil organic matter ranges from 1.26-2.75% which is categorized under low to medium content of organic matter (Berhanu, 1980). According to Berhanu, soil organic matter content of less than 0.7% is considered as very low, 0.7-2.6 as low, 2.6-5.2% as medium and more than 5.2% as high. The soil analysis results also indicated that the textural class of the experimental site was clay according to USDA textural classification. Thus, the textural class of the experimental soil is ideal for sorghum production. The soil reaction (pH) of the experimental site ranges from 6.4-6.9 which shows a neutral range (Tekalign, 1991), but it is within the optimum range for sorghum production, i.e., 5.5 - 7.0.

The second year results of soil analysis (Table 3) showed that the soil had total nitrogen content in the ranges of 0.1-0.25 (%) which is categorized under poor to moderate total nitrogen. The soil has organic matter which ranges from 0.88-2.2% which was considered as low content of organic matter (Berhanu, 1980). The soil test result revealed that the available phosphorus content of the soil, as per Olsen et al. (1954) rating is in the high range. The existing available soil phosphorus content in the area is adequate for the optimal crop production and thus phosphorus fertilizer application is not praiseworthy. This phosphorus content is accounted for the neutral pH of the soil in which there is no fixation of phosphorus and is therefore conducive for the availability of phosphorus. Similar results were recorded for soil pH and textural class for the second year.

Table 3. value of some parameters of soil samples taken at planting at Kobo in the year 2016&2017

Year	pH	% OM	%T.N	Avail. P (ppm)	Textural class
2016	6.4-6.9	1.26-2.75	0.11-0.32	30.8-34.4	Clay
2017	6.5-6.8	0.88-2.2	0.1-0.25	33.85-44.45	Clay

Grain yield and biomass of sorghum

The application of different inorganic fertilizers provides a significant difference in sorghum grain yield ($P<0.05$) (Table 4). This significant difference was found in combination or alone of the inorganic fertilizers and farmyard manure (FYM). Compared to the control treatment, the highest sorghum yield was obtained from NPS plus FYM application without significant difference from NPS, NPSK and NPSKZN treatments (Table 4). The combination of NPS with FYM gave 2.1ton ha^{-1} yield advantage over the control treatments in the first year. Lower grain yield was found using higher rate of NP than the recommended NP rates implying that the recommended NP rate is enough for that site and adding additional NP gives yield penalty either due to logging effect. This could be justified by the higher biomass yield in higher rate of Np than the recommended NP (Table 4).

Table 4. Effect of different nutrients on sorghum grain and biomass yield at kobo in 2016

Treatments	Grain yield(kg/ha)	Biomass(kg/ha)
Control	3366.8c	9949
N	3816.7bc	9854
P	3453.3bc	10051
S	3548.7bc	9122
NP	3825.4bc	9736
NS	3619bc	8915
PS	4076.7abc	9198
NPS	4302.7abc	11118
NPSK	4979ab	11780
NPSKZn	4932.9abc	12861
NPS +FYM	5538.1a	12441
Rec NP	4503abc	9069
CV(%)	31.56	34.4
LSD(0.05)	1688.4	4138.9

Like the first year result the second year result showed that sorghum grain yield was affected by the application of different inorganic fertilizer which is presented in table 5. As indicated in Table 5 grain yield was significantly affected by the application of the inorganic fertilizers in combination with FYM or alone at ($P<0.05$). Compared to the control treatment, the highest sorghum yield was also obtained from NPS plus FYM application without significance difference from NPS, NPSK and NPSKZN treatments (Table 5). The treatment NPS +FYM provided 2.1ton ha^{-1}yield advantage over the control treatments. Unlike first year, the second year indicates that addition of higher rate of NP gave higher grain yield than recommended NP rate this indicates the recommended rate is lower than the crop requirement.

Table 5. Effect of different nutrients on sorghum grain and biomass yield at kobo in 2017

Treatment	yield(kg/ha)	biomass(kg/ha)
Control	3266.2[c]	11034
N	4888.9[abc]	11665
P	4192[abc]	8390
S	4337.6[abc]	12068
NP	5092[ab]	12830
NS	4654.6[abc]	11317
PS	4144.2[abc]	8271
NPS	4674.9[abc]	10290
NPSK	4613.9[abc]	13002
NPSKZn	4673.4[abc]	13089
NPS +FYM	5448.6[a]	12779
Rec NP	3440[bc]	8565
CV (%)	22.34	36.53
LSD (0.05)	1684.2	6871.3

The two year combined analysis of the result indicated that sorghum grain yield was affected by the application of different inorganic fertilizer alone or incombination with FYM ($P<0.05$) (Table 6). Compared to the control treatment, the highest sorghum yield were obtained from NPS plus FYM application without significance difference from NPS, NPSK and NPSKZN treatments (Table 6). This combination also provided 2.2 ton ha^{-1} yield advantage over the control treatments. This result indicated that omission of the individual nutrients of N, P and S or all together significantly reduced the grain and straw yields of sorghum than the treatment receiving all nutrients. This could be justified by the lower yield of control (no fertilizer; 3316.7 kg ha^{-1}) and higher yield of NPS + FYM (5490.3 kg ha^{-1}). Grain yields with addition of N, P and S were increased by 857, 401 and 495 $kgha^{-1}$ respectively and were significantly higher than the control (no fertilizer) treatment.

The total biomass yields of sorghum were not significantly affected by the application of different fertilizers treatments at ($P< 0.05$) in the year 2016, 2017 and also the combined data over years.

Table 6. Effect of different nutrients on sorghum yield (kg/ha) Combined over years at Kobo in 2016&2017

Treatments	Grain yield	biomass
Control	3316.7[c]	10311
N	4174.1[bc]	10458
P	3717.9[bc]	9805
S	3811.7[bc]	9081
NP	4294[bc]	10767
NS	4001[bc]	8887
PS	4099.2[bc]	8889
NPS	4426.8[abc]	11666
NPSK	4857.3[ab]	11578
NPSKZn	4829.2[ab]	11920
NPS +FYM	5490.3[a]	12531
Rec NP	4148.6[bc]	9476
CV (%)	28.02	33.63
LSD (0.05)	1196.3	3574.4

A nutrients omission trial aims to find out the most limiting nutrients to the growth of a crop . If any element is omitted while other elements are applied at suitable rates and plants growth was affected, then the tested element is a limiting factor for crop growth. Conversely, if any element is omitted but plants are healthy and are not affected, then that element is not a limiting factor for crop production. When a nutrient is deficient in the soil then the growth of a crop and ultimately the yield is affected.

High crop yields can only be achieved when high yielding crop varieties got an important nutrition in a correct amount and proper ratios. In addition to this limitation, low fertilizer efficiency, inadequacy of current fertilizer recommendations and the ignorance of nutrients other than N and P may limit crop production. Accordingly, the yield obtained from the control treatment was significantly lower ($P \leq 0.05$) than the yields obtained due to the application of all of the different fertilizers. This implies that the grain yield was low without application of either of the soil fertility amendments mechanisms. In this aspect, the result of this work is in lined with the work of Kanchikerimath and Singh (2001) who reported that soil organic matter content and soil microbial activities are vital for the nutrient turn over and long term productivity of the soil that nutrient availability is enhanced by balanced application of nutrients and manure. Similarly, Shrotriya (1998) reported that balanced application of N-P caused up to 122% increase in sorghum yield in India. Bumb and Bannante (1996) also confirmed that increased plant growth with optimal N, and P application provides good vegetative cover which resulted in high grain yield of sorghum plant. Large reductions in the grain and straw yield of rice were observed with the omission of Nitrogen and phosphorus as compared to the other nutrient omission treatments. Singh et al. (2018) reported that Omission of N reduced the yield by 47.64 %; P omission by 40.82 % and S omission caused yield reduction of 19.51 %.

Conclusion and Recommendation

The above studies showed that both inorganic fertilizers and farm yard manures have their own roles to play in soil fertility management but none can solely supply all the nutrients for optimum sorghum production. The results revealed that among the different combinations of inorganic and farmyard manure treatments, sorghum responded well to the application of NPS +FYM. Increased in grain and biomass yield in this study may be associated with the supply of essential nutrients. Overall conclusion is that organic sources i.e. FYM applied in combination with inorganic fertilizer (NPS) could be used as nutrient sources and can meet nutrient requirement for sorghum. The grain yield under different nutrient omitted plot followed the order NPS+FYM, NPS, NPSK and NPSKZN > NP, NS and PS > N, S and P. This implies that application of farm yard manure is essential.

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