Original Research Article

Fertilizer Micro-dosing: Evaluating the Yield Response of Sorghum to Different Levels of Fertilizers Applied on the Planting Pit at Mereb-Lekhe District

ABSTRACT

Next to drought, poor soil fertility is the single major cause of crops nutrient starvation in Tigray specifically at Mereb-lekhe district. Farmers of the study area use different organic and inorganic fertilizers separately and in combination to overcome soil fertility problems for sorghum production. However, the pace of sorghum production stays constant and occasionally decreases with time. Fertilizer efficiency; the type, rate and method of fertilizer application they use were thought to be the reasons for the steady or declining sorghum production. Hence, this study was initiated to determine the yield response of sorghum to microdose fertilizer application. The experiment was set in a randomized complete block design with three replications. The treatments were; farmers' practice or blanket recommended nitrogen (N) and phosphorous (P) (50kg ha^{-1} Urea & 100 kg ha^{-1} DAP), recommended compost at a rate of 7 ton ha^{-1}, 75% of recommended NP, 50% of recommended NP, 25% of recommended NP, 75% recommended NP+25% recommended compost, 50% recommended NP+50% recommended compost and 25% recommended NP+75% recommended compost. All treatments were applied with microdosing method except the recommended N and P is broadcasting method. The highest sorghum grain yield (4201 kg ha^{-1}) and straw yield (19107 kg ha^{-1}) were obtained from treatment recommended compost at a rate of 7 ton/ha and 50% recommended NP+50% recommended compost, respectively. This study showed that combined application of organic and inorganic fertilizer gave a better economic advantage for sorghum crop. Hence, it could be concluded that use of compost at a rate of 7 ton ha^{-1} and the 75% recommended N and P could increase production and productivity of sorghum by the application of micro dosing than broadcasting method.

Key words: *Fertilizer, micro-dosing, sorghum, Grain yield*

INTRODUCTION

The main production system in Mereb-lekhe district is traditional dry-land farming and it is the main source of livelihood income. The major food crops grown are sorghum, finger millet and groundnut. Sorghum is a staple cereal crop grown in Ethiopia next to teff and maize. Its overall national average grain yield is about 2700 kg ha^{-1}[1].by over 500 thousand households, occupying more than 200,000 hectares of land in Tigray region . This indicates that sorghum is very important in the overall food security of the region.

Due to large quantities of nutrients removal from soil through crop harvest without sufficient supply of fertilizers and/or manure causing low input agriculture, crop productivity have been low and increase food insecurity. The majority of farm lands in Tigray and particularly in the study area produce reduced yields due to nutrient deficiency, poor farming techniques and lack of water. Poor soil fertility is the root cause of declining sorghum productivity and food insecurity in household level especially the low income farmers in Mereb-lekhe district.

"Nitrogen and phosphorus are believed to be the most limiting nutrients for sorghum production in Ethiopia, and particularly in Tigray due to crop mining and low input. Very high rate of annual depletion for 22 kg nitrogen (N), 2.5 kg phosphorus (P), and 15 kg potassium (K) per hectare of cultivated land or an annual loss equivalent to 4 billion U.S. dollar in fertilizer in 37 African countries over three decades" [2]. "Traditional application of inorganic fertilizers or use of organic fertilizing materials such as plant residues, green manure, and animal manure uses of crop management system such as cover crops, legumes, mulching, fallow and agroforestry and continuous application of inorganic fertilizers have been used to restore soil fertility" [3-4].

"The need for sustainable intensification of agriculture in sub-Saharan Africa (SSA) has gained support, in part because of the growing recognition that farm productivity is a major entry point to break the vicious cycle underlying rural poverty" [5]. "Climate Smart Agriculture (CSA) which is defined as agricultural practices, approaches and systems that sustainably increase food production and ability of farmers to earn a living, while protecting and restoring the environment" [6]. "CSA consists of sustainable intensification practices such as conservation agriculture, microdosing, agroforestry, residue management and others" [7, 8]. "A precision-farming technique called 'Microdosing' has developed by scientists at ICRISAT to address the problem of soil fertility, across much of sub-Saharan Africa" [9, 10] . "Microdosing refers to the application of tiny amount of fertilizer with the seed at planting time or as top dressing three to four weeks after emergence" [9, 11]. "Microdosing provides sufficient nutrients especially on poor soils or degraded lands in amounts that are not too costly and are not damaging to the environment" [9]. This technology is also effective on conserving the soil and water especially at drought prone areas which help plants to use nutrients and water properly.

In the study area farmers use different organic and inorganic fertilizers separately and in combination for sorghum production. However, there existed a constant and occasionally decreasing sorghum production along with time. Fertilizer efficiency; the type, rate and method of fertilizer application they use were thought to be the reasons for the steady or declining sorghum production. The local farmers apply fertilizer by broadcasting all over the field. Less can be more if the appropriate fertilizer is applied at the right time, in the right quantity and in the right place.

Therefore, the study was conducted to determine the yield response of sorghum to microdose fertilizer application; to introduce the fertilizer microdosing technology which helps farmers to better manage the natural resource base and increase production and household incomes.

Materials and Methods

Description of the Study Area

Field experiments were conducted during the 2013 and 2014 main cropping seasons under rain fed conditions on six selected farmer's fields at Mereb-lekhe district (located at a latitude of $14^0$409'38''N and longitude of $38^0$735'45''E with an altitude of 1390 m.s.l), central zone of Tigray Regional, northern Ethiopia. The area predominantly lies under semi-arid tropical belt of Ethiopia with a hot to warm 'kola' agro climatic zone with a mono-modal, erratic and torrential rainfall pattern. The mean minimum and maximum monthly temperature ranges from 12.13^0c to 27.88^0c, respectively. Soil of the study area is classified primarily under sandy loam.

Experimental design, Treatments and Procedures

Treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Eight treatments; recommended NP (50 kg ha^{-1} urea and 100 kg ha^{-1} DAP) and practice, 75%, 50%, 25% of recommended NP and recommended compost at a rate of 7 ton ha^{-1}; and an integrated rate of 75% + 25%, 50% + 50% and 25% + 75% of recommended NP and recommended compost, respectively were tested. The plot size was 4m by 3.75 m (15 m^2). The Spacing between plants, rows, plots and replications were 40 cm, 75 cm, 1 m and 1.5 m respectively. All recommended cultural practices for the test crop was done as per the recommendation of the area.

Soil Sampling and Analysis

"Before planting, physical and chemical properties of the soil were analyzed for the surface composite soils (0-20cm) taken from the experimental areas. Auger was used for collecting soil samples. The collected samples was properly labeled, packed and transported to Shire soil research center. Particle size distribution was determined using the Bouyoucos hydrometer method" [12]. "The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter" [13]. "Electrical conductivity (EC) (1:5 soils to water suspension) was measured according to the method described by Jakson" [14]. "Organic carbon was determined by the Walkely and Black" [15]. "The organic carbon is then converted to organic matter by multiplying a constant conversion (1.72) factor assuming that 50% of the organic matter is organic carbon" [16]. "Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney" [17]. Moreover, Available P was determined following the Olsen method[18] using ascorbic acid as reducing agent.

Data Analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS statistical software program. Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability [19].

RESULT and DISCUSSIONS

Soil Physico-chemical properties of the study area

Experiments done on fertilizer trials consider status of nutrient availability in the soil. Hence, it is initial activity to take soil samples as per the interest of the trial. The soil samples collected from the farmers' fields were analyzed at Shire Soil Research Centre /Laboratory/. According to the analyzed result all the soils of the sites are classified under sandy loam textural class. The average soil bulk density of the study sites was

Table 1: Soil physical properties of the experimental sites before sowing

No	**Farmers name**	**Bd**	**Soil texture**			**Texture Class**
			Clay (%)	**Silt (%)**	**Sand (%)**	Sandy loam (SL)
1	Farmer1	1.33	15	75	25	Sandy loam (SL)
2	Farmer2	1.30	18	72	28	Sandy clay loam (SCL)
3	Farmer3	1.41	22	87	13	Sandy loam (SL)
4	Farmer4	1.35	15	85	15	Sandy loam (SL)
5	Farmer5	1.40	19	86	14	Sandy loam (SL)
Mean		1.36	63.2	17.8	19	

Where Bd= Bulk density

Similarly, the soil of the study sites has neutral with an average pH value of 6.22 (Table 2). It is also supported by [20] who indicated that the soil pH is classified as slightly acidic. In addition, the experimental soil had an EC value of 0.22 dS m^{-1}. Hence, the soil is suitable for crop production being mostly medium in available phosphorus with a mean value of 5.69 ppm [18]. On the other hand, organic matter content of the soil was very low (0.85%) which was below the recommendations [21].

Table 2: Soil chemical properties of the experimental sites before sowing

No	**Farmers name**	**Soil result microdosing on sorghum**					
		P (ppm)	**pHwater (1:2.5)**	**EC (dS m^{-1})**	**OC (%)**	**OM (%)**	**CEC (cmol(+) kg^{-1})**
1	Farmer1	4.94	6.24	0.24	0.28	0.48	10.20
2	Farmer2	3.37	6.04	0.18	0.34	0.58	5.60
3	Farmer3	6.20	6.29	0.25	1.33	2.29	10.00
4	Farmer4	6.12	6.16	0.22	0.30	0.51	8.80
5	Farmer5	7.84	6.37	0.22	0.23	0.41	7.80
Mean		**5.69**	**6.22**	**0.22**	**0.49**	**0.85**	**8.48**

After harvest the result of mechanical analysis revealed that there was no change on textural class of the surface soil. The soil of the study sites classified as sandy loam with average particle size distribution of 61% sand, 28% silt and 11% clay. The average bulk density value was also 1.30 after harvest. This reduced soil bulk density of the study sites might be due to the applied organic fertilizers at sowing. Soil chemical properties of the experimental sites also showed that pH ranges from 6.04 to 7.43 with an average value of 6.8; available phosphorus at the range of 4.9 to 8.53 ppm soil, CEC of ranges from 5.6 to 18.83 with an average value of 11.51 cmol(+) kg^{-1} soil, 0.2 to 1.33%, and 0.108% for organic carbon and total nitrogen respectively. According to Tekalign [21] OC of the soil categorized under medium level, TN under low; and low to medium available P [18]) nutrient supply.

Effect of fertilizer microdosing on growth parameters of Sorghum

Plant height and panicle length: Plant height was measured at 90% physiological maturity. According to the analyzed results plant height and head length of sorghum were statistically significantly ($P<0.01$) influenced by the different organic and in organic fertilizer rates under microdose application (Table 3). Addition of organic and inorganic fertilizers increased plant height consistently.

Table 3: Mean plant height and head length of sorghum as affected by microdosing

Treatments	**Plant height (cm)**	**Panicle length (cm)**
1. Rec.NP	173.3b	22.13ab
2. Rec. Compost	179.7ab	23.00a
3. 75% Rec.NP	193.8a	22.67ab
4. 50% Rec.NP	190.3a	22.53ab
5. 25% Rec.NP	189.6ab	21.53ab
6. 75% Rec.NP + 25% Rec. Com	187.5ab	21.07b
7. 50% Rec.NP + 50% Rec. Com	190.7a	23.07a
8. 25% Rec.NP + 75% Rec. Com	187.5ab	22.00ab
Mean	186.56	22.25
LSD	15.029	1.463
CV (%)	4.6	3.8

Where; LSD= Least significant Difference, CV= Coefficient of Variance, Rec.NP= recommended nitrogen and phosphorus, Rec.Com= recommended Compost and means having the same letter are not statistically significantly different

The highest sorghum plant height (193.8 cm) and head length (23.07 cm) shows 11% and 4% increment over the check treatment or recommended N and P fertilizers respectively. This increment in plant height and head length is thought to be due to fertilizer microdosing. Though it is in statistical parity with all treatments except with the control, highest plant height (193.8 cm) was obtained from plots received 75% of recommended NP under microdose application. Highest head length (23.07 cm) was also obtained from 50% of recommended NP and 50% recommended compost under microdose application.

Effect of fertilizer microdosing on Yield and yield components

Grain and straw yield: According to the result of this experiment, the yield and yield components of sorghum (grain, straw and harvest index) were statistically significantly ($P \geq 0.05$) affected by the different rates of fertilizers under microdosing fertilizer application (Table 4). Although statistically in par with the other fertilizer rates except the 25% of Rec.NP, highest grain yield (**4201** kg ha^{-1}) was obtained in response to the application of compost at a rate of 7 ton ha^{-1}.

Table 4: Mean straw yield, grain yield and harvest index as affected by microdosing

Treatments	**Straw yield (kg ha^{-1})**	**Grain yield (kg ha^{-1})**	**Harvest index (%)**
1. Rec.NP	12366c	2967ab	19ab
2. Rec. Compost (7 ton *ha^{-1}*)	14799abc	4201a	22a
3. 75% Rec.NP	18175ab	3992a	18ab
4. 50% Rec.NP	15525abc	3364ab	18ab
5. 25% Rec.NP	12747c	2253b	15b
6. 75% Rec.NP + 25% Rec. Com	19107a	3560ab	15b
7. 50% Rec.NP + 50% Rec. Com	16504abc	3607ab	18ab
8. 25% Rec.NP + 75% Rec. Com	13410bc	3146ab	19ab
Mean	15329.13	3386.25	18
LSD	4447.204	1331.826	0.51
CV (%)	14.6	16.5	15.9

Where; LSD= Least significant Difference, CV= Coefficient of Variance, Rec. NP= recommended nitrogen and phosphorus, Rec.Com= recommended Compost and means having the same letter are not statistically significantly different

Sorghum yield response to fertilizer microdose application is by far good with yield increment of 1234 kg ha^{-1} as compared to the farmers practice. The lowest sorghum grain yield (2253 kg ha^{-1}) obtained from plots received 25% of Rec.NP shows a yield reduction of 1958 kg ha^{-1} off the highest yield.

Straw yield was highest (19107 kg) for plots treated with 75% Rec. NP + 25% Rec. compost. This highest straw yield showed a yield increment of 6741 kg ha^{-1} over the rate and practice that the local farmers use.

Harvest Index: As indicated in Table 1, the highest harvest index was obtained in response to application of Compost at a rate of 7 ton/ha. However, there was no consistent trend of increase or decrease in harvest index related to source and fertilizers microdosing. The highest harvest index was recorded from the organic fertilizer (Compost) at rates of 7 ton/ha and the lowest harvest index were recorded recommended NP at of 25% rate and 75% Rec. NP+25% Rec. compost.

Conclusion and Recommendations

Sorghum productivity can possibly be increased by the traditional way of applying integrated fertilizers in the rain fed agriculture. In the study area farmers use different organic and inorganic fertilizers separately and in combination for sorghum production. However, crop productivity is relatively lower than that of the intended optimum yield. This might be due to the efficiency of sorghum crops to use the applied fertilizers. A precision-farming technique called 'Microdosing'; the application of tiny amount of fertilizers around the plant conserves the soil and water especially at drought prone areas, provides sufficient nutrients in amounts that are not too costly and are not damaging to the environment and help plants to use nutrients and water properly. Hence, this study was initiated to determine the yield response of sorghum to Microdose fertilizer application and introduce this technology to help farmers to increase production and household incomes while better managing their natural resource base.

According to this study it is possible to increase sorghum productivity in Mereblekhe district at a relatively low cost. The trials on farmers' fields and on site verified the biological and economic benefits of fertilizer microdosing in improving crop establishment and improving yields.

Fertilizer microdosing has the potential to greatly influence yields across a range of fields in the study area. Overall, sorghum grain yields were 41.6% higher with the use of fertilizer microdose application than with the earlier recommended fertilizer rates under the broadcasting method or that of farmers practice. This simple technology is affordable to resource poor small scale farmers in the dry areas of Tigray as it enables them to reduce the risk nutrient loss and increase crop yields. Therefore, based on the results of the study and the above summary, it can be recommended that;

- Application of organic and inorganic fertilizers under fertilizer microdosing is crucial to improve the productivity of sorghum at the study area.
- Application of organic fertilizer (Compost) at a rate of 7 ton/ha was best to enhance the grain yield of sorghum and microdosing application of 75% of Recommended NP was the next yielder.

Disclaimar

Authors declare that No generative AI technologise has been used during writng of this manuscripts.

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