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Original Paper

Response of Sorghum (*Sorghum bicolor*) to Applied Phosphorous Fertilizer in the Lowland Area of Eastern Amhara

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Abstract— ***Chemical fertilizers in Ethiopia have made a contribution to crop yield growth to date, although there is potential for further improvement. Phosphorus (P) is an element a primary constituent of plant and animal life. This study was conducted in East Amhara National Regional State of Raya-Kobo and Dawa-Cheffa districts in the 2018 cropping season to verify crop responses to phosphorous fertilizer. The test crop was sorghum (var. Girana one) for both districts. The treatments were: Control, Recommended NP, 50 Kg ha^{-1}NPS, 100 Kg ha^{-1}NPS and 150 kg ha^{-1} NPS with uniform rate of nitrogen. The design was randomized complete design and treatments were replicated three times per site. Recommended nitrogen was used uniformly for all treatments. The collected data were subjected to analysis of variance using SAS version 9.0. The Result showed that there was no statistical significance yield difference (p > 0.05) between different rates P fertilizer. Therefore, applying high amount of phosphorous fertilizers for the study districts for the test crops not advisable. But for the maintenance soil phosphorus, 10 Kg ha^{-1} P is enough.***

Keywords— ***Fertilizer, Grain Yield, Nutrient, Phosphorous, Sorghum***

I. INTRODUCTION

One of the controlling factor for agricultural production in Ethiopia as well as in the world is the problems of soil fertility [1]. Natural fertilizers have contributed to rise yields in Ethiopia, in spite of the fact that there's still a room for assist improvements. Ethiopia's Growth and Transformation Plan (GTP) recognizes the basic role of fertilizers in preserving soil fertility and driving agricultural productivity in the country [2].

Phosphorus (P) is a nutrient that is a primary essential of plant and animal growth. Phosphorous containing fertilizer plays a series of roles in the plant uptake and is one of the vibrant nutrients required by plant. Phosphorous fertilizer significantly affects plant reproduction, photosynthesis, N-fixation and strength of straw (prevent lodging and improvement of quality) [3].

Phosphorus is fundamentally held through responses with iron (Fe) and aluminum (Al), forming insoluble compounds such as $AlPO_4$ and $FePO_4$ oxides. In alkaline conditions (pH above 7), phosphorus tends to accelerate with calcium (Ca) as calcium-phosphate (Ca-P) minerals [4]. Notably, phosphorus deficiency is severe (nearly 100%) in the soils of the region, including the study districts, as reported by Agricultural Transforming Agency (ATA) & Ministry of Agriculture and Natural Resource (MoANRC) [5].

The research conducted in the lowland areas of Eastern Amhara indicated that there was little response to phosphorus application. The kebeles level extension workers are forced by the governments to distribute P source fertilizer like DAP and NPS to all locations irrespective of the responses. The farmers are complaining application of P fertilizers. So, it is highly important to re-examine the soil P status and crop response to applied P fertilizer for yield in different location in the lowland areas of Eastern Amhara. Therefore, the research was conducted to verify the response of sorghum to phosphorous fertilizer.

II. MATERIALS AND METHODS

A. *Description of Experimental Sites*

The experiments were conducted during the main cropping season in 2018 at Raya-Kobo and Dawa-Cheffa districts in the Eastern Amhara Region (Fig 1). Raya-Kobo district has an altitude about 1468 m above sea level (masl). The district receives a mean annual rainfall, maximum and minimum temperature of 630 mm, 29^{0}C and 15^{0}C respectively with considerable year to year variation. The area is characterized by seasonal moisture stress and erratic rainfall. Dawa-Cheffa is located about 325 km away from Addis Ababa in the Northeastern direction. It has an altitude ranges from 1000 to 2500 meters above sea level (masl). The district receives maximum temperature 33°C and minimum temperature12°C. The mean annual rainfall of the area ranges from 600 to 900 mm with a long heavy rainy season from June to September and a short rainy season from March to May.

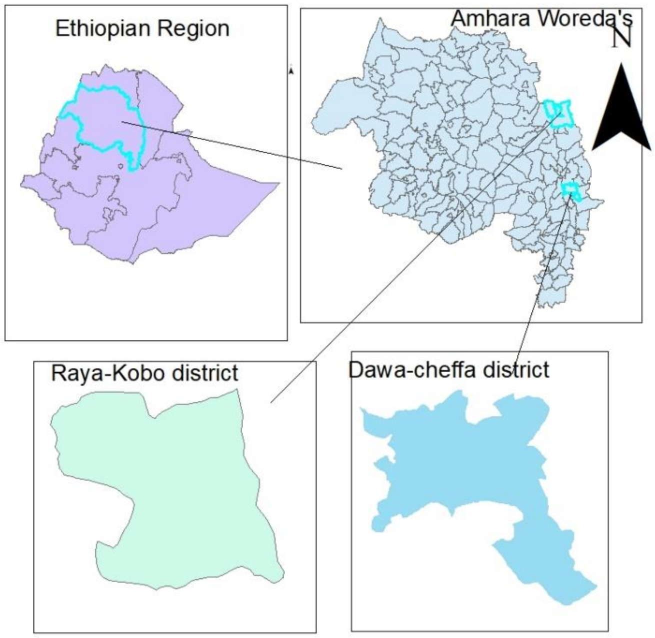

Fig. 1. Map of the Study districts

B. Experimental Set-up and Procedures

The experimental sites were prepared using standard cultivation practices before planting. Trial fields were plowed using oxen-drawn implements by farmer as usual. The experiment included five levels of phosphorous. Crop and site specific recommended nitrogen was applied for all treatments. The treatments used were:

1. Control (only recommended N without p fertilizer)
2. Recommended NP
3. 50 Kg ha-1 NPS (N was adjusted to the recommended rate)
4. 100 Kg ha-1 NPS (N was adjusted to the recommended rate) and
5. 150 Kg ha-1NPS (N was adjusted to the recommended rate).

The recommended rate 69 Kg ha^{-1}N and 69 Kg ha^{-1} P_2O_5 was applied for both districts. The rate of Nitrogen was equal for all treatments in the location. Treatments were randomized laid in a randomized complete block design (RCBD) with a plot size of 5m x 4.8m (24m2) with three replications for each site and four sites per each district. The spaces between plots and blocks were 0.5m and 1m respectively. Spacing between plants and rows were 15cm and 75 cm respectively. Girana one sorghum variety was used as a test crop. Sowing was done first week of July. Phosphorus was applied as triple super phosphate for recommended rate (treatment two) and NPS for the rest rates of phosphorous and also nitrogen was from NPS and Urea. Nitrogen was applied half at planting and half at knee height stage just after weeding with the presence of small rainfall. Karatin was sprayed for the protection of boll armyworm during the vegetative stage. The experiments were maintained to be free of weeding.

C. Soil Data Collection and Analysis

Surface soil samples (0-20 cm) were collected randomly in a zigzag pattern before sowing from the entire experimental field and composited. The soil samples were air-dried and passed through a 2 mm mesh sieve and analyzed in Sirinka Agricultural Research Center. Selected chemical and physical soil properties (texture, pH, OC, Total N and available P) were determined.

Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter (potentiometer). The texture of the soil was determined by the hydrometer method [6]. Organic carbon and total nitrogen were determined by the method of Walkely and Black [7] and Kjeldhal methods [8], respectively, while, available phosphorus was determined by the methods of Olsen [9].

D. Yield and Yield Components

Harvesting was done from the third week of November to last weeks of November. To measure total aboveground biomass and grain yields the central 4 rows of each plot were harvested as farmers' experience. Plant parameters data such as grain yield, plant height and aboveground biomass were collected as follows:

Grain yield: Grain yield was measured by harvesting the crop from the net middle plot area

to avoid border effects, after threshing seeds were cleaned and weighed and adjusted to a moisture content of 12.5% using grain moisture analysis result.

Biomass yield: At maturity, the whole plant parts, including leaves and stems, and seeds from

the net plot area was harvested and the biomass were measured (dry matter basis). Stalk sample was collected randomly at harvesting to adjust dry biomass based on moisture content using oven drying method.

E. Data Analysis

The collected data were subjected to analysis of variance using SAS version 9.3 [10]. The least significant difference (LSD) test at 5% level of significance was used to compare the means.

III. Results And Discussion

A. Physico-chemical Properties of the Soil

The results of soil analysis (Table 1) showed that the soil had moderate total nitrogen content in all experimental sites [11]. The soil organic matter ranges from 1.55-2.95% in Dawa-Cheffa and 1.63-2.48 % in Raya-Kobo which is categorized under low to moderate content of organic matter according to [12] in both districts. The laboratory results also indicated that the textural class of the experimental site was clay & clay loam based on USDA textural classification. The soil test result reveals that the available phosphorus content of the soil based on the rating of [9] categorized under high range for both districts. According to this result the soil data implies that available p is optimal for crop production & Phosphorous fertilizer application is not mandatory.

TABLE I. RESULT OF SOIL PARAMETERS TAKEN AT PLANTING.

Site	pH	OM (%)	TN(%)	Available P (ppm)	Textural class
Raya-Kobo	5.91-6.31	1.63-2.48	0.1-0.21	13.0-17.4	Clay, clay loam & loam
Dawa-Cheffa	6.13-6.66	1.55-2.95	0.2-0.27	21.4-24.7	Clay & clay loam

Note: pH=power of Hydrogen; OM=organic matter; TN= total nitrogen; P= available phosphorus;

B. *Sorghum Yield Response to Applied Phosphorous Fertilizer*

The statistical analysis indicated that grain yield of sorghum (Girana one) not significantly ($p>0.05$) responded (i.e. Yield increases compared to the control) to phosphorous application rates for districts (Table 2 & 3). But the highest Grain yield was observed from the application of 38 Kg ha^{-1} P_2O_5+69 Kg ha^{-1} N (Table 2) and 57 Kg ha^{-1} P_2O_5+69 Kg ha^{-1}N (Table 3) in Raya-Kobo and Dawa-Cheffa respectively without significance yield advantages over the control (without P).

TABLE II. EFFECT OF P FERTILIZER ON SORGHUM GRAIN YIELD ($KGHA^{-1}$) AT RAYA-KOBO

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Means
69 N only	4994	5282	3817	4130	4556
$19P_2O_5$+69N	5192	5195	3881	4312	4645
$38P_2O_5$+69N	5617	5026	3743	4799	4797
$57P_2O_5$+69N	5604	5013	3400	4592	4652
$69P_2O_5$+69N	5657	5121	3355	4770	4726
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	11.2	6.6	11	15.9	11.87

TABLE III. EFFECT OF P FERTILIZER ON SORGHUM GRAIN YIELD ($KGHA^{-1}$) AT DAWA- CHEFFA

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Means
69 N only	5660	3382	4672	3357	4268
$19P_2O_5$+69N	5965	3216	4590	3459	4307
$38P_2O_5$+69N	6090	3757	4506	3756	4527
$57P_2O_5$+69N	6076	3672	4388	4209	4586
$69P_2O_5$+69N	5591	3964	4454	3672	4420
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	7.6	22.6	9.6	12.6	12.3

In addition to grain yield, biomass yield response of sorghum to phosphorus fertilizer was not significant with respect to statistical point of view. But, with some irregularities, the result indicates an increasing trend with an increase in P rates (Table 4 and 5).

TABLE IV. BIOMASS YIELD ($KGHA^{-1}$) OF SORGHUM AT RAYA-KOBO

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Means
69 N only	15486	25870	12977	24850	19796
$19P_2O_5$+69N	15519	26999	13686	24486	20173
$38P_2O_5$+69N	17035	25343	14069	27202	20912
$57P_2O_5$+69N	16764	28625	12847	26260	21124
$69P_2O_5$+69N	19198	26477	11758	25030	20616
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	13.2	8.7	15.2	12	11.36

TABLE V. BIOMASS YIELD ($KGHA^{-1}$) OF SORGHUM AT DAWA-CHEFFA

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Means
69 N only	20482	13406	11906	12638	14608
$19P_2O_5$+69N	19157	12380	12687	12764	14247
$38P_2O_5$+69N	21653	12491	12295	14568	15252
$57P_2O_5$+69N	21805	14240	11624	15326	15749
$69P_2O_5$+69N	19038	14818	11496	13141	14623
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	12.6	13.5	7.2	14.4	12.75

An adequate supply of accessible phosphorous in the soil related with expanding root development, which suggests roots can investigate more soil for moisture and nutrients [13]. It is known that Phosphorus is a nutrient that is required in a large amount and acting a number of important roles in crop production. Plant reaction to applied phosphorous fertilizer relay on the quantity of plant-available P in the soil system and the capacity of a crop to utilized it. An acceptable supply of accessible P in the soil is related with expanding root development, which suggests roots can investigate more soil for nutrients and moisture. This result in contradict with, the work of [14] who found that application of 46 kg ha-1 P2O5 gave 134.82% biomass yield increment over the control. Reference [15] also, stated that application of 46 P2O5 fertilizers with N and moisture conservation increases the grain yield of sorghum up to 38% in the moisture stress areas of Eastern Ethiopia. In addition to this [16] also reported that nitrogen and phosphorus fertilizer increases the grain yield of sorghum. However, the response of sorghum biomass yield to the different phosphorus rates was not statistically significant in this research.

Soil pH affects the availability of phosphorous for plant in the soil. Phosphorous is considerably more obtainable in a pH range of 6.0 to 7.5 pH [17] which agrees with our study site soil pH values. This finding also in line with [18] who states that in areas with higher initial soil phosphorus level, applying phosphate fertilizer is not required.

Reference [17] states that soil dampness and temperature influences availability of phosphorous in the soil. Ideal soil moisture and temperature can offer accelerate microbe activity, subsequently discharging more Phosphorous from organic matter. Temperature is the foremost vital climatic variables controlling soil nitrogen and Phosphorous cycles. Increases in temperature mostly enable soil nutrient accumulation and organic matter decomposition [19]. Reference [20] also revealed that phosphorus nourishment might be influenced by root growth. Reference [21] stated that phosphorus sources have a significant effect on producing crops such as application of phosphorus from TSP (Triple Super Phosphate) increased the yield and yield components of maize. For this study TSP and NPS were the source of P fertilizer, but it doesn't give significant yield difference.

The outcome of this research contradicted with the soil ATLAS map which was produced by ministry of agriculture and natural resource and ATA [5]. The map indicates that nitrogen and phosphorous fertilizers are deficient in the region including the study district. In this research work the crop response result strengthens the soil results which indicate high available P in the study district as indicated in table 1 above. This research results contradicted with [22] who confirmed that combined application of nitrogen and phosphorous fertilizer significantly affect grain yield of sorghum. Farmers were forced to apply excess amount of phosphorous fertilizer in the study districts without additional yield increments, but this over-application can lead to the buildup of phosphorus in the soil.

CONCLUSION AND RECOMMENDATION

Phosphorus is the second most limiting soil nutrient in crop production. Application of the right amount of fertilizer is necessary to achieve maximum yield. Both grain and biomass yield didn't show statistically significant yield differences for different phosphorous fertilizer rate and source (TSP & NPS). So that for such area no need of applying high amounts of phosphorous fertilizer rather than applying small amounts for maintenance (10 P ha^{-1}), and also to save farmers from extra expenditure. Applying high amount of P fertilizer from different sources in such area is economically wasteful and can also damage the environment. Due to grain and crop residue removal available phosphorous may be deficient in the soil system as a result continuous follow up and checkup should be done for the future. additionally, Similar studies should be done for the future by assessing the soil phosphorous level.

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