Effect of phosphorous on Sorghum (*Sorghum bicolor*) Yield in the lowland areas of Eastern Amhara

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Abstract

Chemical fertilizers in Ethiopia have contributed 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 a uniform rate of nitrogen. The design was RCBD 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 of P fertilizer. Therefore, applying high amount of phosphorous fertilizers for the study districts for the test crops not advisable. Nonetheless, application of 10 Kg P ha^{-1} for the maintenance of soil phosphorus is advised.

Keywords: *Fertilizer, Nutrient, Phosphorous, Sorghum*

Introduction

Chemical fertilizers in Ethiopia have contributed to crop yield growth to date, although there

recognizes the importance of fertilizer for maintaining soil fertility and maximizing agricultural growth in the country. Phosphorus (P) is an element that is a primary constituent of plant and animal life. P plays a series of functions in the plant metabolism and is one of the essential nutrients required for plant growth and development (Marschner, H., 2011). Among the most significant functions of plants on which P has an important effect are reproduction, photosynthesis, N-fixation, crop maturity (flowering and fruiting including seed formation), root development (particularly of the lateral and fibrous rootlets), the strength of straw in cereal crops, thus helping to prevent lodging and finally, quality and quantity of products (Brady and Weil, 2002).

Phosphorus availability in most soils is at a maximum in the pH range of 5.5 to 6.5. At low pH values, the retention results largely from the reaction with Fe and Al and precipitation as $AlPO_4$ and $FePO_4$ oxides. Above pH 7, Ca precipitate with P as Ca-P minerals (Tisdale et al., 2002). Phosphorous is highly deficient (almost 100%) in the soils of the region including the study sites and districts (MoANRC and ATA, 2016).

Researches were conducted in Srinka agricultural Research center 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 locations in the lowland areas of Eastern Amhara. Therefore, the research was conducted to verify the response of sorghum to phosphorous fertilizer.

Materials and Methods

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. Raya-Kobo district has an altitude of about 1468 m above sea level (masl). The district receives a mean annual rainfall, maximum and minimum temperature of 630 mm, 29 ^{O}C, and 15 ^{O}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 a maximum temperature of 33°C and a 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.

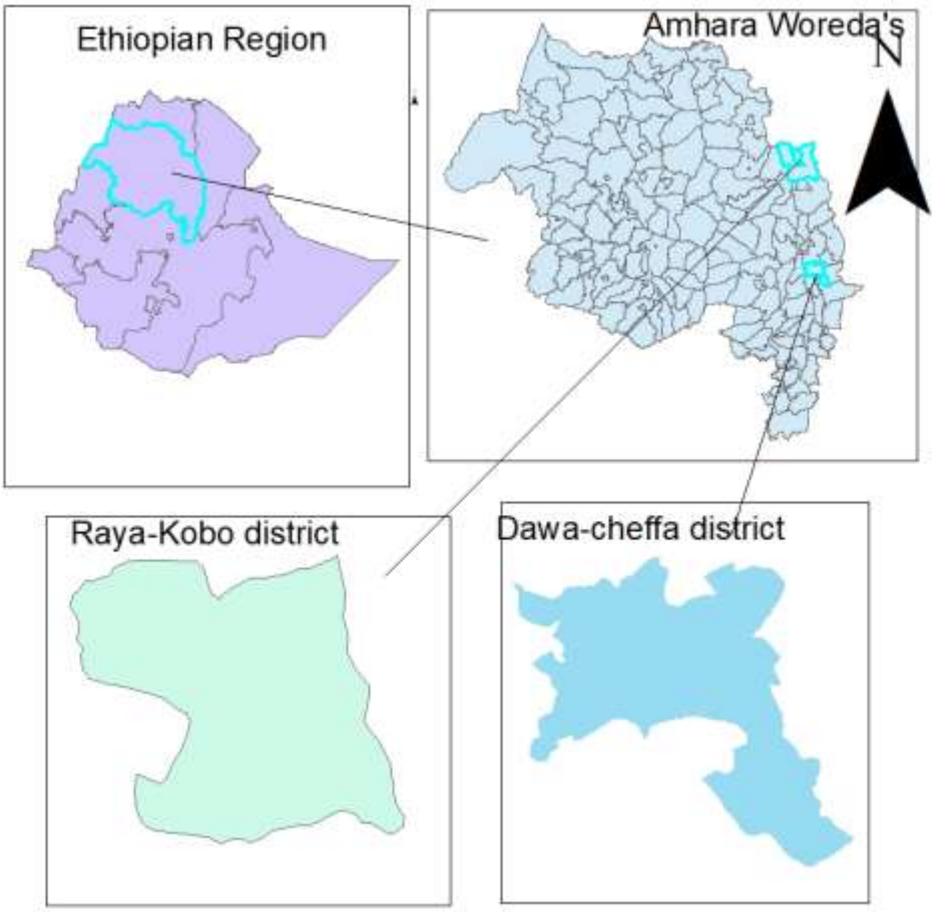

Figure 1. Map of the study districts

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 a farmer as usual. The experiment included five levels of phosphorous. Crop and site-specific recommended nitrogen rate was applied for all treatments.

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^{-1}NPS (N was adjusted to the recommended rate).

The recommended rate of 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 ($24m^2$) with three replications for each site and four sites per 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 the 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.

Sampling and data collection

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 soil 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. Organic carbon and total nitrogen were determined by the method of Walkely and Black (1934) and Kjeldahl methods, respectively, while, available phosphorus was determined by the methods of Olsen (1954).

Yield and Yield components

Harvesting was done from the third week of November to the last weeks of November. To measure total aboveground biomass and grain yields the central 4 rows of each plot were parameters 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 was measured (dry matter basis). Stalk sample was collected randomly at harvesting to adjust dry biomass based on moisture content using the oven drying method.

Data analysis

Collected data were subjected to analysis of variance using SAS version 9.0. The least significant difference (LSD) test at a 5% level of significance was used to compare the means.

Results and Discussions

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 (Tekalign, 1991). 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 Berhanu (1980) 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 is based on the rating of Olsen (1954) 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 1. Result of soil parameters taken at planting.

Site	pH	OM (%)	TN (%)	Available P (ppm)	Textural class
-	-	-	-	-	
-	-	-	-	-	

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

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 - - 57 - P_2O_5+69 - N (Table 3) - -

Table 2 - -

LSD (5%)	NS	NS	NS	NS	NS

Table 3. 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 from a 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 4. 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
CV (%)	13.2	8.7	15.2	12	11.36

Table 5. 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

It is known that Phosphorus is a macronutrient that plays several important roles in plants. Crop response to applied P fertilizer depends on the quantity of plant-available P already in the soil and the ability of a crop to take up it. An adequate supply of available P in soil is associated with increased root growth, which means roots can explore more soil for nutrients and moisture. This result disagreed with the work of Alemu *et al*., (2016) who found that the application of 46 kg ha^{-1} P_2O_5 gave 134.82% biomass yield increment over the control. Gebrekidan (2003) stated that the application of 46 P_2O_5 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 Masebo and Menamo, (2016) 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.

Plant availability of P can be also affected by soil pH. Soil P is slightly more available in a pH range of 6.0 to 7.5 pH (McKenzie, 2013) which agrees with our study site soil pH values. This finding also in line with Bereket *et al*, (2014) which states in fields with higher initial soil phosphorus levels, there is no need of applying phosphate fertilizer. McKenzie, (2013) states that soil moisture and temperature affect P availability. Optimal soil moisture and temperature can help accelerate microbe activity, thereby releasing more P from organic matter. Temperature is the most important climatic factor controlling soil N and P cycles. Temperature increases generally facilitate the decomposition of soil organic matter and accelerate the accumulation of soil available nutrients (Conant, *et al*. 2011).

Beegle and Durst (2002) revealed that phosphorus nutrition could be affected by root growth. Factors affecting root growth will affect the ability of plants to get adequate phosphorus. Young seedlings have limited root growth. Due to this, it may be affected by phosphorous deficiency even if the soil has a high available phosphorous level. But the test crop for this research was deep-rooted which could be exploring adequate phosphorous in the soil solution and also during seedling stage deficiency symptom of phosphorous was not observed. The ability of a plant to take up phosphorus is largely due to its root distribution relative to phosphorus location in soil. Because phosphorus is very immobile in the soil, it does not move very far in the soil to get to the roots. Kamran (2018) 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 sources of P fertil a significant yield difference. Grain yield of sorghum significantly affected by combination of NP fertilizer rate (Workat and Merse, 2018).

Farmers were forced to apply an 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. The source of phosphorous fertilizer was DAP and NPS in the districts. The amounts required vary from field to field because of heterogeneity in the inherent P fertility of agricultural soils due to parent material, soil types, and agricultural practices. In this research work, the crop response result strengthens the soil results which indicate high available P in the study districts. In the study, district farmers are selective in applying nutrients to crops and commonly prioritize crops that have a higher and immediate benefit in terms of income and food security than perennial crops with long-term benefits. Not only crops but also, they select appropriate fertilizer type which gives high grain and biomass yields relatively. Most of the time the farmers apply urea fertilizers during the vegetative stage of the crop and when the crop stand is poor.

Conclusion and Recommendation

Phosphorus is the second most limiting soil nutrient in crop production. The application of the right amount of fertilizer is necessary to achieve maximum yield. As indicated in the differences for different phosphorous fertilizer rates and sources (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 the extra expenditure. Applying a high amount of P fertilizer from different sources in such areas is economically wasteful and can also damage the environment.

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