Verification of phosphorus on teff (*Eragrostis teff*) and bread wheat (*Triticum aestivum)* yields in Vertisols of Eastern Amhara

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Abstract

Plants utilize nutrients in different ways, and each plant has a different set of nutrient requirements. The biological activity contributes to P solubilization through mineralization, weathering, and other physicochemical reactions, so that the plow layer is the major source of soil available p for crops. This study was conducted in East Amhara National, Regional State of Jamma district in the 2018 cropping season to verify the yield of teff and bread wheat due to phosphorus fertilizer application. Teff (variety, Dega teff) and bread wheat (variety,

50 Kg ha^{-1}NPS, 100 Kg ha^{-1}NPS, and 150 kg ha^{-1}NPS. The design was RCBD and treatments were replicated three times per site. Recommended nitrogen was used uniformly for all treatments. Collected data were subjected to analysis of variance using SAS version 9.0. Results indicated that applications of P fertilizer significantly improved the grain yield of wheat and teff. The result showed that there was a statistical significance yield difference ($p < 0.05$) between different rates of P fertilizer. So, the application of P fertilizer is essential for the study district.

Keywords: *Mineralization, Nutrient, phosphorous, Teff, Wheat, yield*

Introduction

Sustaining soil fertility and enhancing crop production on smallholder farms is a critical challenge in Ethiopian agriculture. Fertilizer recommendation in Ethiopia was mainly based on very general crop-specific guidelines or more often, a single blanket recommendation for most crops (100 kg urea ha^{-1} and 100 kg DAP ha^{-1}). This blanket application can lead to excesses or deficiency in relation to plant nutrient requirements. Increasing climate erraticism, declining soil fertility status of the soil, inadequate land size, and low crop and livestock productivity is the major challenges of the Ethiopian agricultural sector (Agegnehu and Amede 2017).

Plants utilize nutrients in different ways, and each plant has a different set of nutrient requirements. How, where, and when plants utilize nutrients can greatly affect the overall yield and plant production. For a farmer seeking to maximize crop yields and lower input costs, it can be critical to understanding Phosphorus is the second most important nutrient after nitrogen in Ethiopia, which is a particularly most limiting nutrient in areas where the soil is acidity or alkalinity problem. Phosphorus is critical in the early developmental stages of growth, and in energy transfer within the plant throughout the growing season (Hodges, S.C., 2010) as well as for maturity. Availability of phosphorus from fertilizers may be affected by the soil reaction, the degree of soil phosphorus deficiency, rate, and method of application.

The biological activity contributes to P solubilization through mineralization, weathering, and other physicochemical reactions, so that the plow layer is the major source of soil available p for crops. In regions of developed countries where intensive livestock production occurs, disposal of animal manure on relatively small land base has led to a massive accumulation of soil available p, as well as more soil organic matter and buildup of organic P compound (Ziadi et al., 2013). According to ATA and the Ministry of Agriculture and Natural Resource (2016), phosphorous fertilizer is recommended for entire of the district. So, it is highly important to re-examine the soil P status and crop response to applied P fertilizer for yield in the Jamma district of Eastern Amhara. Therefore, the current research was designed to verify the response of teff and wheat crops to phosphorous fertilizer application.

Materials and Methods

Description of experimental sites

The experiments were conducted during the main cropping season of 2018 in Jamma district. Jamma district lies between the geographical coordinates of 10^{o} ^{o} 39^{o} ^{o} an altitude of 2630 meters above sea level (masl) (Figure 1) and the rainfall patterns of the district are indicated in Figure 2. The dominant soil type of the study district is Vertisols. The major crops widely grown in the study areas include wheat, teff, and faba bean.

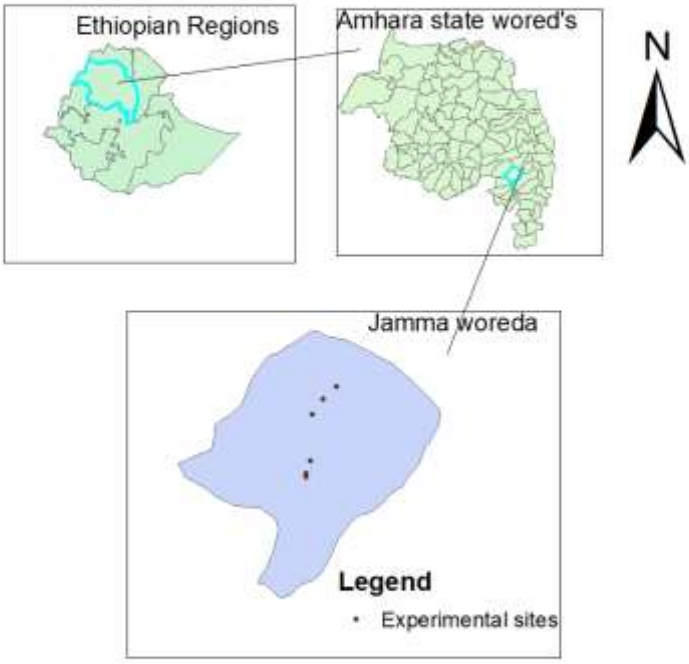

Figure 1. Location of Jamma district and experimental sites

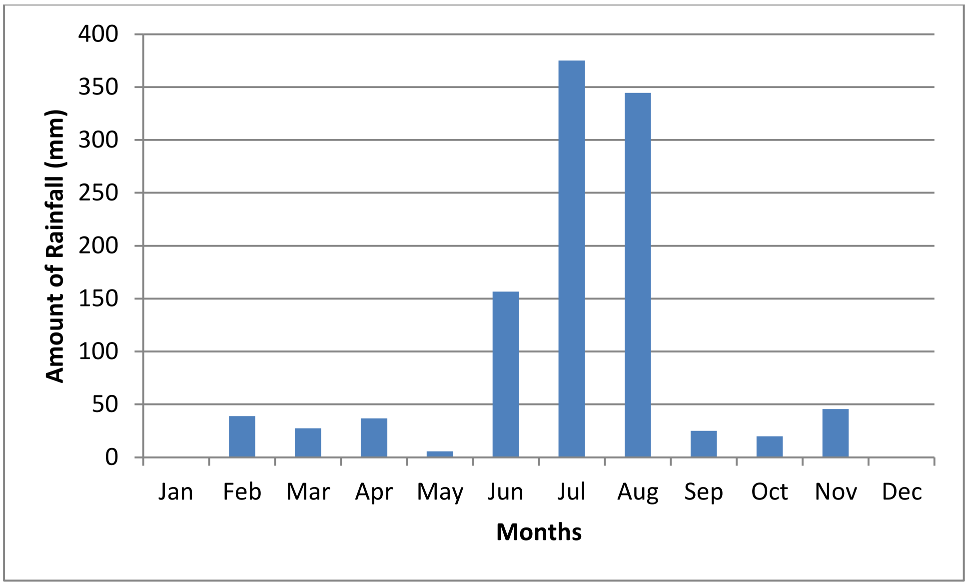

Figure 2. Monthly Rainfall of Jamma District in 2018

Experimental set-up and procedure

The experimental sites were prepared using standard cultivation practices before planting. Trial fields were plowed using oxen-drawn implements by a farmer as usual. After plowing broad bed furrow (BBF) was prepared manually, in order to drain excess water in the experimental sites. The experiment comprised of five levels of phosphorous (0, 19, 38, 57 and recommended P_2O_5kg ha^{-1}). The full recommended nitrogen rate was applied for all treatments uniformly and clearly indicated below.

Treatments:

1. Crop and location-specific recommended N only
2. Recommended (crop and location-specific) NP
3. 50 kg ha^{-1} NPS (N was adjusted to recommended)
4. 100kg ha^{-1} NPS (N was adjusted to recommended) and
5. 150kg ha^{-1} NPS (N was adjusted to recommended).

The recommended N & P rates were: 115 kg ha^{-1} N & 69 kg ha^{-1} P_2O_5 for wheat. While for teff 92 kg ha^{-1}N & 46 kg ha^{-1}P_2O_5.Recommended nitrogen rate was uniformly applied for all the treatments. Treatments were arranged in a randomized complete block design (RCBD). Plot sizes were: 5m by 5m (25 m^2) for teff and 5m by 4.8m (22m^2) for wheat. Treatments were replicated three times for each site. Three sites for teff and five sites for wheat were addressed. BBF (80cm *40 cm) was used for wheat production. The spaces between treatments and blocks were 0.5 m and 1 m, respectively for both crops. Spacing between rows was 20 cm for wheat and teff was planted as broadcast. Sowing was done in the second week of July for teff and wheat trials. Phosphorus was applied as triple super-phosphate for recommended rate of NP (for treatment two only) and NPS for the rest rates of phosphorous and also nitrogen was from NPS and Urea. Nitrogen was applied half at planting and the other half at tillering stage for teff and wheat with the presence of small rainfall.

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 for the analysis of texture, pH, OC, TN, and available P. Soil sample were air-dried and passed through a 2 mm mesh sieve and analyzed at Sirinka Agricultural Research Center. 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. Organic carbon and total nitrogen were determined by the method of Walkely and Black (1934) and Kjeldahl methods, respectively. Available phosphorus was determined by the methods of Olsen (1954).

Yield data

Harvesting was done in the second week of December for wheat and in the first week of January for teff. To measure total above-ground biomass and grain yields the central BBF was harvested for wheat and the teff above-ground biomass was harvested using quadrant (4m*4m). At maturity, the whole plant parts, including leaves, stems, and seeds from the net plot area were harvested. Then the biomass was measured (dry matter basis). Grain yield was measured by harvesting the crop from the net middle plot area to avoid border effects after threshing seeds were cleaned, weighed, and adjusted to a moisture content of 12.5% using grain moisture analysis result (only for wheat crop).

Data analysis

Analysis of variance was carried out for the yield using SAS Version 9.0. Whenever treatment effects were significant, the means were separated using the least significant difference (LSD) procedures test at a 5% level of significance.

Result and discussion

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 has organic matter (Table 1) which ranges from 0.86%-1.61% which is categorized under the low range (Berhanu, 1980). The textural class of the experimental site is clay-based on USDA textural classification (Hillel, 1998). The soil test result (Table 1) reveals that the available phosphorus content of the soil was moderate to high level based on the rating of Cottenie (1980).

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=Phosphorus

Yield and yield-related data

Teff yield response to applied phosphorous fertilizer

The combined analysis indicated that grain yield of teff was not significantly (p 0.05) responded (i.e., yield not increased relative to the control) to different phosphorus rates. As observed in the result (Table 2) among the three sites in two sites, there was no statistically significant yield variation among different P rates and without P treatments while for one site there was a significant yield difference among different phosphorus rates. The highest grain yield (1532 Kg ha^{-1}) of teff was recorded with the application of recommended rate of nitrogen and phosphorus fertilizer (- - without statistical significance difference with the application of different rate of phosphorous. According to the combined statistical analysis above ground biomass yield of teff was not statistically significant ($p > 0.05$) between the different rates of phosphorus and control (without P treatments). The highest biomass yield was obtained from the application of 46 Kg ha^{-1} P_2O_5 (Table 4).

Table 2. Effect of P fertilizer on teff grain yield (kg ha^{-1})

Wheat yield response to applied phosphorous fertilizer

Applications of different rates of phosphorus were significantly affecting (*P*

biomass yield of wheat (Table 3). Except, Farm 3 (Table 3) and Farm 2 (Table 5) in all sites application of different rate of P fertilizer increase yield of wheat in comparison with control (without P fertilizer application). This result implies that the application of phosphorus with nitrogen fertilizer increases the yield of wheat in Vertisols of Jamma district. The highest grain yield (2646 $Kgha^{-1}$) and biomass yield (6087 $Kgha^{-1}$) were obtained from the application of 57 kg ha^{-1} P_2O_5 with 115 kg ha^{-1} N. Application of 57 kg ha^{-1} P_2O_5 with 115 kg ha^{-1} nitrogen resulted in 22% and 26% grain yield and biomass yield advantage over the control (without P treatment) respectively (Table 3 and 5).

Table 3

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm5	combined
92 N only	2140	2095	3165	1921	1477	2160
19p_2o_5+115N	2817	2243	3362	2276	1616	2463
38p_2o_5+115N	2774	2379	3513	2154	1794	2523
57p_2o_5+115N	2498	2546	3597	2370	2218	2646
69p_2o_5+115N	2305	2742	3397	2138	1852	2487
CV (%)	11.0	12.6	8.9	10.8	17.2	11.8
LSD (0.05)	520	569	575	445	580	213

Treatment	Farm 1	Farm 2	Farm 3	Combined
92 N only	5889	6903	7768	6853
19p_2o_5+92N	6396	7275	7692	7121
38p_2o_5+92N	6322	6728	7225	6759
46p_2o_5+92N	6089	8347	7440	7292
57p_2o_5+92N	6750	7618	7365	7244
CV (%)	5.5	6.3	8.5	11.3
LSD (0.05)	647	867	1198	376.5

The results of this study showed that the use of chemical phosphorus fertilizer in combination with nitrogen consistently enhanced the grain yield of wheat and teff compared to inorganic nitrogen fertilizer applied alone. But the result of pre-planting soil shows high available phosphorus in the study sites. The result obtained disprove the thought that there is no increase in yield or benefit to crop quality when; applying phosphorus to soil having sufficient readily-plant-available P. The result of this research disagreed with the findings of Bereket *et al.*, (2014) who stated that for areas with higher initial soil phosphorus application of phosphate fertilizer is wastage for wheat production. On the other hand, continuous application of phosphate fertilizers in time tends to increase the level of this nutrient in the soil and in particular its level in the labile forms which can release phosphorus to the soil solution (Brady and Weil.,2002). As indicated in Table 1, the pre-planting soil analysis result shows the high level of available P. Even if the soil data revealed the high range of available P; both crops responded to applied P fertilizers.

Table 5

	4533	4533	7167	1921	3767	4800
	6233	4733	7900	2276	3867	5560
	6567	5333	9033	2154	4233	5953
	5667	5567	8700	2370	5167	6087

there was no significant difference between and among treatments. To say there is crop response to applied phosphorus there must be a visible difference between treatments that received the targeted nutrient and without. Plants showed normal growth with the application of phosphorus and resulted in improved agronomic traits which lead toward improved grain yield.

Conclusions and Recommendations

Application of phosphorus fertilizer significantly affected wheat but not for teff grain yield over the control. The combined analysis over sites indicates that there was a significant yield response of wheat grain yield to the application of phosphorus fertilizer. In addition to grain yield, biomass yield of wheat was significantly affected by different rates of phosphorus fertilizer but biomass yield of teff was not affected by phosphorus fertilizer. In this result, there was no significant yield difference between different rates of applied phosphorus for grain and biomass yield of teff. This implies that a small amount of P fertilizer could be sufficient to increase the yield of both crops. Therefore; appropriate phosphorus fertilizer rate determination should be needed with different rates of nitrogen fertilizer in the districts for both crops.

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