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Evaluation of Soil Test Based Phosphorus Fertilizer Recommendations Under Balanced Nutrient Formulations for Teff and Wheat in Southern Ethiopia

Mulugeta Habte Shiferaw Boke
Department of Natural Resources Research
Hawassa Agricultural Research Center, Southern Agricultural Research Institute, Hawassa, Ethiopia

Abstract
Nutrient depletion through erosion and removal by crops over many years and limited capacity of farmers to invest in fertilizers or soil conservation measures has resulted in very low productivity. A trial was conducted to evaluate soil test based fertilizer recommendation under balanced fertilization for teff (Eragrostis tef) and wheat production in the Southern Nations, Nationalities and Peoples' Region of Ethiopia during the main cropping season of 2015. The treatments were based on soil test based phosphorus (P) fertilizer recommendation of teff (30 kg P ha^{-1}) and wheat (40 kg P ha^{-1}). Treatments were arranged in a randomized complete block design and replicated across five farms, including 100% P (30 kg ha^{-1}) plus recommend N (64 kg ha^{-1}), 100% P plus balanced fertilizers (NKSZnB), 66 % of P plus balanced fertilizers (NKSZnB), 133 % of P plus balanced fertilizers (NKSZnB) and the agronomic recommendation of N and P fertilizers (64N + 20P kg ha^{-1}). The proportion of NKSZnB was 63, 17.5, 7.6, 2.23, 0.37 and 69, 25, 11.2, 3.44, 0.5 kg ha^{-1} for teff and whest, respectively. Except number of tillers, grain yield and biomass of teff not showed statistically significant differences ($P < 0.05$). Significantly higher number of tillers was recorded when the critical P-value combined with balanced fertilizers (NKSZnB) in both locations at Bensa and Halaba. Similarly, statistical difference ($P < 0.05$) was observed between treatments on plant height and spike length of wheat. Although grain and biomass yields of both crops were not showed statistical difference, but in all cases the trend indicated that high results were obtained from plots treated by the soil test based P recommendation plus the balanced fertilizers. The current study indicated that reconsidering the previous soil test based phosphorus fertilizer recommendation under balanced fertilization is required in order to determine P which can be apposite with the new soil fertility maps of the region (SNNPRS) and nutrient combinations recommended for each woreda.
Keywords: Phosphorus, teff, wheat, use of balanced fertilizers, low productivity

1. Introduction

Ethiopia is among the most populous in Sub-Saharan Africa (SSA). Agriculture sector is of great economic importance to Ethiopia, however, it is characterized by low productivity and the prevalence of a fragmented smallholder/subsistence farmer population that is relegated to highly degraded/marginal lands (World Bank, 2010).

Low productivity can be attributed to limited access by small farmers to agricultural inputs, financial services, improved production technologies, irrigation and agricultural output markets and, more importantly, to poor land management practices that have led to severe land degradation in some areas (PIF, 2010). Moreover, although many parts of East Africa have inherently rich soils, nutrient depletion through erosion and removal by crops over many years has resulted in very low productivity (Ngome *et al*., 2013; Thorne *et al*., 2002)

Ethiopia has one of the highest rates of nutrient depletion in SSA. The estimated annual nationwide loss of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer use (PIF, 2010. Land degradation and nutrient depletion are further aggravated by overgrazing, deforestation, population pressure and the poor land use planning and tenure system (PIF, 2010).

According to Tilahun (2004), soil fertility decline is the major constraint to agricultural production and food security in the Ethiopian highland farming systems. Farmers have very limited capacity to invest in fertilizers or soil conservation measures. As a result, yields are low and many farmers are forced to put fallow and marginal lands into production to meet their food needs (Tilahun, 2004). Although most subsistence farmers appreciate the value of fertilizers, they rarely apply them at the recommended rate or time or every year (Duflo *et al*., 2008; Marenya and Barrett, 2009).

Almost three-quarters of total cultivated area is dominated by cereal crops, grown by 12.7 million farmers, most of whom are smallholders. These farmers and land area produced about 17.8 million mt of cereals, representing 68 percent of total crop production and 32 percent of A-GDP (or 14 percent of total GDP) (PIF, 2010). Among cereal crops, teff, corn, wheat, barley and sorghum represent 95 percent of total cereal planted area and 96 percent of total cereal production. Although the cereal cultivated area has been increasing since the early 2000s, yields are still low and production is susceptible to weather shocks, especially droughts (Taffesse et al., 2011).

To avert these problems different efforts have been made at national and regional level mainly focused on inorganic fertilizers. Among the pronounced efforts, phosphorus calibration studies have been conducted on major crops and soil types for about four seasons in federal and regional research centers. Accordingly, critical P concentrations (Pc) and P requirement factors (Pf) have been determined for major crops and soil types of various agro-ecologies of the country.

Unfortunately, these soil testing results were not complete, or they were focused on two major essential nutrients while ignoring the others (Farina, 2011). Balanced fertilization must consider all essential plant nutrients because if any nutrient is deficient, it will affect both, crop yield and quality, as well as nutrient use efficiency of other applied plant nutrients. Therefore, it is imperative to examine the previous soil test based P fertilizer recommendation developed for its general validity under balanced fertilization program. The present work, therefore, focused on validating the previous soil test based P fertilizer recommendation under balanced fertilization at different agro ecology for teff and wheat production.

2. Materials and Methods

Evaluation trials were conducted in three districts (woredas) of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping season of 2015. For teff trial, the sites were located between 06.48611N latitude and 038.77166E longitude at an altitude of 1992 meter above sea level at Bensa district; and between 07.34483N latitude and 038.05778E longitude at an altitude of 1813 at Halaba special district. For wheat trial, the site was situated between 06.28545N latitude and 038.34060E longitude at an altitude of 2734 meter above sea level at Hula district. Halaba special district received an average annual rainfall of 78.9 mm. The mean maximum and minimum annual air temperatures were 28.4 and 14.2 $^{\circ}$C, respectively. Bensa district received an average annual rainfall of 109.3 mm with 25.4 mean maximum and 12.3 minimum annual air temperatures. Hula district received long-term average annual rainfall of 114.7 mm and the mean maximum and minimum annual air temperatures were 19.0 and 6.42 $^{\circ}$C, respectively.

Previously identified phosphorus critical values for teff and wheat were compared with agronomic recommendation of nitrogen and phosphorus fertilizers as well as under and above critical P recommendation with balanced fertilization. The balanced fertilizers were NKSZnB with different composition for both test crops. For teff NKSZnB fertilizer was applied at the rate of 63, 17.5, 7.6, 2.23, 0.37 kg ha^{-1} and for wheat 69, 25, 11.2, 3.44, 0.5 kg ha^{-1}, respectively. Both teff and wheat experiments consist of five treatments.

Treatments arranged for teff trial were (1) 100% critical P value (30 kg ha^{-1}) plus recommend N (64 kg ha^{-1}), (2) 100% critical P value (30 kg ha^{-1}) plus balanced fertilizers (NKSZnB), (3) 66 % of critical P value (19.8 kg ha^{-1}) plus balanced fertilizers (NKSZnB), (4) 133 % of critical P value (39.9 kg ha^{-1}) plus balanced fertilizers (NKSZnB) and (5) the agronomic recommendation of nitrogen and phosphorus fertilizers (64N + 20P kg ha^{-1}). Similarly, the treatment arrangements for wheat were (1) 100% critical P value (40 kg ha^{-1}) plus recommend N (69 kg ha^{-1}), (2) 100% critical P value (40 kg ha^{-1}) plus balanced fertilizers (NKSZnB), (3) 66 % of critical P value (26.4 kg ha^{-1}) plus balanced fertilizers (NKSZnB), (4) 133 % of critical P value (53.2 kg ha^{-1}) plus balanced fertilizers (NKSZnB) and (5) the agronomic recommendation of nitrogen and phosphorus fertilizers (69N + 20P kg ha^{-1}).

The sources of N and P were urea and triple supper-phosphate (TSP). Phosphorus (P) was drilled along seed line at planting while N was applied in split at planting and 45 days after planting. The experiment was laid out in RCB design using 4 m by 4 m plot size and replicated across five farms. The test crops were planted in row and other crop management practices were applied as per the recommendation developed for each crop.

Agronomic data for teff, including tiller number, straw yield, total biomass and grain yield, were collected. For wheat, plant height, spike length, total biomass and grain yield were collected. To estimate the biological yield and the grain yield of both test crops, the whole plot (16 m^2) was harvested and threshed manually. Analysis of variance for all data was done using SAS statistical package program version 9.0 (SAS institute Inc., 2002). The least significant difference (LSD) at 5% probability level was used to establish the significance of differences between the means.

3. Result and Discussion

Phosphorus (P) calibration study was conducted in different parts of the Southern Nations Nationalities and People Regional State (SNNPRS) for some major crops for about three years. And P required for teff and wheat production was determined and the critical values were evaluated under balanced fertlization. Based on the current experiment, there was no significant difference among all treatments except number of tillers at Bensa soil condition (Table 1). Significantly higher number of tillers was recorded when the critical P-value combined with balanced fertilizers (NKSZnB). Although statistical difference was not observed, the trend indicated that high grain and biomass yield was obtained from treatment 4 when 133% of the critical-P value combined with NKSZnB (Table 1).

Similarly, at Halaba there was no statistical difference between treatments except number of tiller. Even though there was no statistical evidence, the trend of grain and biomass yield increment was also obtained from the plots treated by 133% critical P plus NKSZnB (Table 2).

Table 1 Yield and biomass components of teff influenced by critical P plus balanced fertilizers at Bensa.

Treatments	No of tiller	Straw yield (t/ha)	Biomass (t/ha)	Grain yield (kg/ha)
1. 100% critical P and recommend N	5.36b	2.42	3.35	921.5
2. 100% critical P and NKSZnB	5.68ab	2.96	3.94	973.6
3. 66% critical P and NKSZnB	6.56a	3.22	4.23	1021.9
4. 133% critical P and NKSZnB	6.44a	3.34	4.68	1329.8
5. Recommended NP (agronomic recommendation)	5.40b	2.54	3.47	907.7
Least Significant Difference	1.03	NS	NS	NS
Coefficient of Variance	12.84	27.59	28.36	22.91

Note: Values followed by the same letter are not significantly different at P < 0.05.

Table 2 Yield and biomass components of teff influenced by critical P plus balanced fertilizers at Halaba

Treatments	No of tiller	Straw yield t/ha	Biomass t/ha	Grain yield kg/ha
1. 100% critical P and recommend N	6.32c	4.30	6.02	1709.2
2. 100% critical P and NKSZnB	6.96bc	5.02	6.80	1783.4
3. 66% critical P and NKSZnB	7.56abc	4.50	6.38	1863.6
4. 133% critical P and NKSZnB	8.04ab	4.96	6.88	1899.0
5. Recommended NP (agronomic recommendation)	8.72a	4.12	5.74	1598.8
Least Significant Difference	1.55	NS	NS	NS
Coefficient of Variance	15.61	24.94	21.58	24.03

Note: Values followed by the same letter are not significantly different at P < 0.05.

The experiment was also conducted at Hulla district using wheat as test crop. Based on the result presented in table 3, statistical difference was observed between treatments on plant height and spike length of wheat. Significantly high result was recorded when the critical P value combined with balanced fertilizers (NKSZnB) compared to 100% critical P plus recommended nitrogen and the recommended NP. This can be an indication that the previous soil test based P recommendation is required to evaluate under balanced fertilization. Similarly, although grain yield was not significantly differing between treatments the trend showed grain yield increment obtained when the critical combined with balanced fertilizers.

Table 3 Yield and biomass components of wheat influenced by critical P plus balanced fertilizers at Hulla.

Treatments	Plant Height (cm)	Spike length (cm)	Biomass (t/ha)	Grain yield (kg/ha)
1. 100% critical P and recommend N	108.2b	9.44b	11.34	2882.4
2. 100% critical P and NKSZnB	115.2a	9.64ab	14.62	4143.0
3. 66% critical P and NKSZnB	115.2a	10.40a	13.30	4006.1
4. 133% critical P and NKSZnB	113.0ab	10.40a	13.42	4045.9
5. Recommended NP (agronomic recommendation)	107.0b	9.24b	11.26	3117.2
Least Significant Difference	6.95	0.77	NS	NS
Coefficient of Variance	7.44	8.35	13.31	12.31

Note: Values followed by the same letter are not significantly different at P < 0.05.

5. Conclusion

Balanced fertilization is indispensible to increase nutrient uptake by crops and thereby improve productivity. The current study indicated that reconsidering the previous soil test based phosphorus fertilizer recommendation under balanced fertilization is required.

Moreover, the calibrated phosphorus should be apposite with the new soil fertility maps of the region (SNNPRS) and nutrient combinations recommended for each woreda. Therefore, a thorough future investigation is suggested to calibrate phosphorus under balanced fertilizers and toidentify critical P which can be used with the blended fertilizers recommended for each woreda.

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