



Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat (*Triticum Aestivum* L.) Production in Horo District, Oromia Regional State, Ethiopia

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Abstract: On-farm verification trial of soil test based crop response phosphorous calibration study for bread wheat production was conducted in 2019/20 main cropping season in the Horo District of the Horo Guduru Wollega Zone. The trial was initiated to verify phosphorus critical level and requirement factor for bread wheat production in Horo District. The treatments were the control (without phosphorus fertilizer), farmers practice (blanket recommendation) and soil test based recommended phosphorus fertilizer rate (RR). The trial was conducted on six farmers' field across the district. Plot size was 10m * 10m. Soil data before planting and yield data were collected throughout the trial. Soil reaction pH (H₂O) of all the sites ranged from 4.73 to 5.42 and available P ranges from 1.4 to 12.6ppm. Soil acidity of the experimental sites were amended with lime. Bread wheat grain and biomass yield (kg/ha) were high and significantly ($p < 0.01$) affected by different fertilizer rates used as treatments. The highest grain yield (2875 kg/ha) was resulted with soil test based phosphorus fertilizer rate recommendation. Economically optimum N (46 kg/ha), critical level phosphorus (10 ppm) and phosphorus requirement factor (11.03 kg/ha) for bread wheat production in the district were gained and recommended during the calibration study. It was significantly higher than the grain yield gained from the farmers' practice (2119.4 kg/ha) and control/without phosphorus fertilizer (1647.2 kg/ha). Similarly, soil test based phosphorus fertilizer rate recommendation was economically optimum and feasible for bread wheat production in the district.

Keywords: Bread Wheat, Horo, Phosphorus Fertilizer, Recommendation

1. Introduction

Wheat with production area of about 1.66 million hectares is one of the most important cereal food crops cultivated in Ethiopia, ranking fourth after teff (*Eragrostis tef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area coverage [4]. Traditionally, wheat grains are used to prepare household bread, beverage and pancake. It is also processed in factories to produce flour for commercial production of bread for consumers in cities and towns. Despite, the population of Ethiopia is currently growing at a faster rate and demands also proportional for agricultural products.

On the other hand, growth in food production is not in equal footings with population pressure. Strengthening food

production capability of the country by wisely exploiting its existing human and natural resources is critical option to avert the existing situation. However, soil fertility depletion and soil quality decline are the main constraints affecting the yield and sustainability of crop production in Ethiopia. The annual per-hectare net loss of nutrients is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K [14]. The identification of the proper fertilizer mix is beneficial at the macro-economic level by improving the efficiency of fertilizer procurement and resource allocation. It is generally understood that crop response to fertilizer inevitably declines, if nutrient applications are continually unbalanced. But, if harvested nutrients are replaced, intensive agricultural systems can be sustained indefinitely, provided that measures

are taken to halt soil erosion and to minimize detrimental changes in soil pH.

In Ethiopia, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation [1]. Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture (David and David, 2012). Studies have demonstrated that Nitisol areas in Ethiopia are marginally to severely deficient in P [3 and 12]. In Ethiopia, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production systems [18]. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences.

Soil tests are designed to help farmers predict the available nutrient status of their soils. Once the existing nutrient levels are established, producers can use the data to best manage what nutrients are applied, decide the application rate and make decisions concerning the profitability of their operations [2]. However, local assessments for the soil P critical levels and soil P requirement factors even for the major crops of the country are negligible. Currently, soil

fertility research improvement is agreed with respect to site specific fertilizer recommendation in the country [8].

Previously, soil test crop response based phosphorus calibration on bread wheat study was carried out in Horro district and the critical phosphorus value has to be verified to approve the acceptance of the technology at farmers' level. Therefore, this project must address the need for reliable soil nutrient calibration/ correlation data and verify the economic profitability of the technology comparing with farmers practice and verify the critical levels of P calibrated previously.

2. Materials and Methods

2.1. Description of the Study Area

Horo is situated at latitude: 1,042,726N to 1,091,814N; Longitude 270,000E to 316,199E and an altitude ranging from 1449-3147 m above sea level; in Horo-Guduru Wollega Zone of the Oromia regional state, Ethiopia (Figure 1.). The terrain is generally undulating to rolling plains. The area is characterized by a mono-modal rainfall pattern. The mean monthly rainfall ranges from 12.8 to 343.8 mm, and mean monthly temperature is 17.23-to 22.9°C. The major soil types are generally described as Nitisols [9].

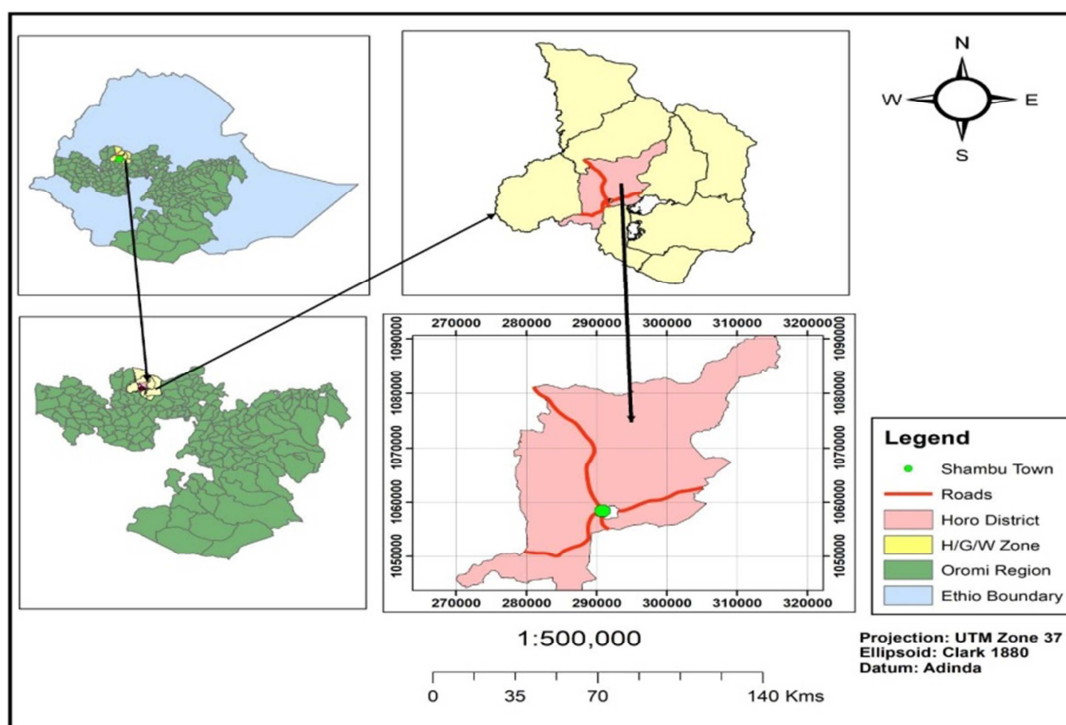


Figure 1. Location map of Horo District, Oromia, Ethiopia.

2.2. Experimental Design and Procedures

The study was conducted on farmers' fields across the District. Six farmers were selected purposively based on their willing, wealthy and initial soil P-value. Improved wheat variety Dendea was used at 150 kg/ha seeds rate with 20 cm inter row spacing were sown. Phosphorus fertilization rate

was given according to the formula developed, $P \text{ (kg/ha)} = (P \text{ critical-P initial}) \times Prf$. This recommendation was compared with *farmers practice (blanket recommendation) and control*. Urea and DAP were used as the source of N and P, respectively. For verification purpose the experiment was laid out in randomized complete block design that was replicated

over farmers. The treatment considered were calculated P (Rate of P fertilizer to be applied = (Critical P conc.-initial P values)*P requirement factor whereas $P_c = 10$ ppm, and $P_f = 11.02$) with determined optimum N (46 kg), Farmer practice/blanket recommendation (100 kg DAP and 100 kg Urea) and control (without fertilizer). Nitrogen was applied in the form of urea in two splits (1/2 at planting and 1/2 at mid-stage). Plot size was 10 m x 10 m and there was 1m between blocks and 0.5m between plots. Composite soil samples were collected at a depth of 20 cm from each selected farmers' field to determine pH (H_2O) and available P (Olsen method). The grain data and biomass yield of the crops were collected. Grain yield and biomass yield recorded on the plot bases were converted to $kg\ ha^{-1}$ for statistical analysis.

2.3. Economic Analysis

Partial budget analysis was done to determine economic feasibility of recommended fertilizer P for bread wheat production around the study areas following procedures described as [5]. The mean grain and biomass yield data of wheat were employed in the analyses. Furthermore, the grain and biomass yield obtained from each treatment were adjusted down by 10% in order to narrow down the possible yield gap that may happen due to difference in field management. The average prices of relevant inputs required to do the partial budget analyses were collected from different sources.

2.4. Data Management and Analysis

Data were subject to analysis of variance (General Linear Model (GLM) procedure) using SAS software [15] to test treatments effect on crop growth and yield parameters. Means of treatment effects were separated using the Duncan's Multiple Range Test (DMRT) comparison at $p \leq 0.05$.

3. Result and Discussion

3.1. Soil pH and Available Phosphorus

The soil reaction of the experimental sites before planting ranged from 4.73-5.42 (table 1). Accordingly, the soils were strongly to extremely acidic in reaction [17]. According to [13], the suitable pH range for wheat crop is between 5.5 and 7.0. Continuous cultivation and long-term application of inorganic fertilizers led to low soil pH and aggravated the losses of basic cations from highly weathered soils. Moreover, the acidic nature with low soil pH obtained from the whole sites may be attributed to the fact that the soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil [10].

The maximum and minimum values of available P were 37.88 and 2.31 ppm, respectively (table 1). Available phosphorus of most samples fall under low category according to the critical level set by EthioSIS [11]. Generally, the available P status of the soils in the study area are low, even below the critical level indicating that soil P infertility is

among the factors that are highly limiting the productivity of the soils. This shows the need for external application of phosphorus fertilizer sources for good crop growth and yield.

Table 1. Initial available soil phosphorus and soil pH.

Sites	Soil pH (H_2O)	Available P (ppm)
Site 1	4.73	7.04
Site 2	5.31	2.31
Site 3	5.42	7.29
Site 4	5.09	37.88
Site 5	5.4	19.25
Site 6	5.27	6.98

3.2. Biomass and Grain Yield of Bread Wheat

The analysis of variance showed that the recorded biomass yield of bread was significantly affected ($p < 0.001$) only by the application of soil test crop response-based phosphorus fertilizer application. The highest mean grain yield (2875 kg/ha) was recorded with the soil test crop response-based fertilizer recommendation treatment (table 1) which was significantly higher than the farmer practice (2119.4 kg/ha). The results of this study are consistent with findings of [7] who reported that the highest grain yield was recorded under application of soil p calibration.

Table 2. Mean grain and biomass yield (kg/ha) of bread wheat as influenced by different fertilizer application at Horo district.

Treatments	Grain Yield (kg/ha)	Biomass (kg/ha)
RR	2875.0 ^a	8330.6 ^a
FP	2119.4 ^b	6625.0 ^b
C	1647.2 ^b	6036.1 ^b
Significance	***	***
LSD (5%)	536.03	1543.4
CV	12.12	1.04

RR: Recommended rate; FP: Farmers practice/blanket recommendation; C: Control

3.3. Economic Analysis

The results of partial budget analyses data of S fertilizers across two soils are summarized in table 3. Accordingly, all treatments produced higher and positive net benefit (NB) relative to the control treatment in both sites, indicating that feasibility of fertilizer application for wheat production in the study area.

The marginal rate of return of the non dominated treatments in table 3 shows that 149 kg/ha of soil test crop response-based P fertilizer (RR) treatments provided a positive marginal rate of return of 3501.6. According to [5], on the farm-economic analysis of major cereals training reported that MRR that range from 50% to 100% was the minimum recommended rate in most agricultural production and it is better when the MRR was $>100\%$. Treatments that receive recommended rate of fertilizer was received 3501.6 which indicates that by investing one birr on these treatments, there was high rate of returns which was 35.02 birr benefit without including costs that not vary among treatments.

The marginal rate of return (MRR) was found to be

3501.6% for soil test-based fertilizer rate and 1970.7% for farmer practice (table 3). The economic analysis showed that the highest net income (27649.3ETB) was obtained from soil test based recommended treatments. So, those

treatments that receive recommended fertilizer record the highest MRR acceptance range and so, farmers use this soil test crop response-based fertilizer application than other treatments which is cost effective and economically feasible.

Table 3. Partial budget analysis for verification of bread wheat at Horo District.

Treatments	UREA (qt/ha)	DAP (Qt/ha)	GY (Qt/ha)	AGY (Qt/ha)	GFB (ETB/ha)	FC (birr/ha)	TSC (birr/ha)	HBC (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
C	1	0.00	16.472	15.5	18566.4	2804.6	1547.2	773.6	5125.4	13441.0	
FP	0.6087	1.00	21.194	20.2	24232.8	2369.9	2019.4	1009.7	5399.0	18833.8	1970.7
RR	0.4158	1.49	28.75	27.8	33300.0	1488.3	2775.0	1387.5	5650.8	27649.3	3501.6

Where: qt = Quintal; ha = Hectare; GY = Grain yield; AGY = Adjusted Grain Yield; GFB = Gross field benefit ETB = Ethiopian birr; FC = Fertilizer cost; TSC = Total Service cost; HBC = Harvesting and bagging cost; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return; C = Control (without P fertilizers); FP= Farmers practiced fertilizer rate and RR = Soil test based Fertilizer rate; FC = Fertilizer cost and DAP = Diammonium Phosphate.

4. Conclusion and Recommendation

In Ethiopia, the blanket recommendations that are presently in use all over the country were issued several years ago, which may not be suitable for the current production. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. Based on the results of this study, it is generally concluded that, soil test crop response-based fertilizer application (P application) gave consistently high grain yield of bread wheat the study area showing that the soil of the study area is deficient in P content.

Since by applying recommended rate of P and optimum urea fertilizer application rate, yield of bread wheat could be increased by 36% over the blanket fertilizer recommendation of DAP and urea. The implication was that application of fertilizer based on site specific soil test crop response based is useful to attain the demand of bread wheat for the current population growth by boosting yield by more than 50%. Result of economic analysis also showed that recommended rate of fertilizer with site specific recommendation is ideal to obtain higher yield in the study area.

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