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Verification of Phosphorus Critical Level for Bread Wheat (*Triticum aestivum* L.) in Dugda District of East Shewa Zone of Oromia, Ethiopia

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Abstract: *Verification of phosphorus critical level for bread wheat was conducted in Dugda District in 2021 cropping season with the objectives to verify phosphorus critical (Pc) level and determined during soil test crop response based phosphorus fertilizer calibration and to create awareness on soil test crop response based fertilizer recommendation. A Composite soil samples at the depth of 0-20 cm in zigzag method were collected from farmers' fields. Likewise, soil samples analyses were made to identify available P in the level of the required phosphorus in the select crop fields for actual experiment. The treatments included (1) soil test based phosphorus calibration result; (2) farmers' practice in the area which was assessed from the surrounding farmers' and (3) no fertilizer application (control) and each treatment was planted on 10*10m experimental plot & the design was randomized complete block design replicated over farmers. Bread wheat, Kakaba variety, was used with seed rate of 150 kg ha^{-1}and other cultural practices such as weed and rust management were used from which had been recommended for the area. The partial budget analysis showed that the highest net income (130,433.81 ETB ha^{-1}) was from soil test based recommended and the lowest net benefit (59,560.20 ETB ha^{-1}) was obtained from control treatment with marginal rate of return (3106.54%) which is greater than the minimum rate of return (MRR) 100%. The result showed that the average grain yield of 5157 kg ha^{-1} was obtained from the application of soil test based phosphorus calibration (Pc and Pf) followed by blanket recommendation (4243 kg ha^{-1}) and (2282 kg ha^{-1}) for the control treatment. The recommended N rate, 69 kg N ha^{-1} with soil test based phosphorus critical level gave 44.25 % grain yield advantage over the control. In general, soil test and crop response based fertilizer recommendation for crops increases crop yields through application of adequate nutrient rates for the identified soil nutrient deficiencies in specific locations.*

Keywords: *Verification, Farmer, Concentration, Application and Calibration*

1. INTRODUCTION

Bread wheat (*Triticum aestivum L.*) is one of the most important cereal crops globally and is a main food for about one third of the world's population (Hussain et al., 2002). Wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area. Likewise, cereals contributed 87.97% (about 277,638,380.98 quintals) of the grain production and the wheat 15.33% (48,380,740.91 quintals) of the grain production (CSA, 2019). Moreover, wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisols areas (Amanuel et al., 2002).

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). Additionally, the nutrient deficiencies identified in this study could be due to either inherently low availability of these nutrients in the soils or as a consequence of continuous intensive cropping without applying fertilizer or manure containing these nutrients (Hailu et al., 2015). Similarly, 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. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P rate to their fields regardless of soil fertility differences (Gete et al., 2010).

Phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrient to the soil as fertilizer. So that it provides information how much nutrient should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations (Getachew et al., 2013). Likewise, they enable to revise fertilizer recommendations for an area based on soil and crop type, pH and soil moisture content at time of planting. 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 (Girma et al., 2016). Hence, calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. Generally, soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, optimum return from the investment on input and minimum environmental pollution are the two major issues to be addressed while prescribing soil test based nutrient recommendations (Singh et al., 2010).

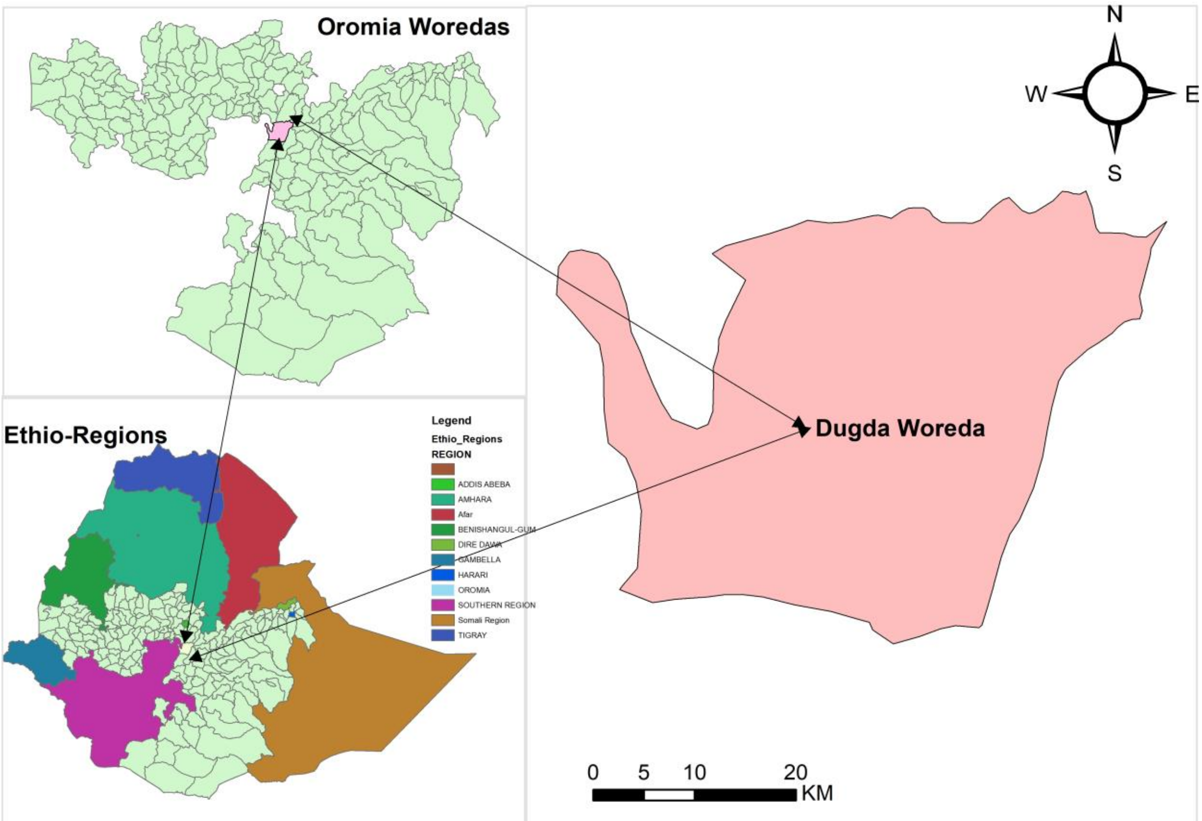
Therefore, to alleviate this problem Batu Soil Research Center undertaken soil test crop response based fertilizer calibration Kofole District on bread wheat and determined optimum nitrogen to be applied, P critical and P-requirement factors. But to ensure confidence in recommendations, these determined values should be verified for grain yield and economic benefit as compared to blanket recommendation and control. Therefore, the objectives of this verification were to verify phosphorus critical (Pc) level determined during soil test crop response based P fertilizer calibration, and to create awareness on soil test crop response based fertilizer recommendation.

2. Materials and Methods

Description of the Study Area

Wheat is grown mainly by subsistence farmers in East Shewa Zone of the highlands of the country. The experiment will be undertaken at Dugda District which is located at 060 50' to 070 09' N and 38038' to 39004' E in the humid temperate climatic zones.

Fig1. Map of the study area



Experimental design and treatments

For verification, first selection of the sites was done and 10 composite soil samples were collected at the depth of 0-20 cm in zigzag method from ten farmers' fields for Eutric Vertisols. Moreover, available phosphorus was determined by extraction with 0.5 M $NaHCO_3$ according to the methods of Olsen et al. (1954). Among ten (10) farmers, six (6) were selected for actual experiment based on initial phosphorus concentration categories below critical P-concentration for Kofole District. Therefore phosphorus fertilizer requirement was calculated from the formula:

Phosphorus fertilizer rate = (pc-pi)*pf;

Where, **Pc-** critical phosphorus concentration which was determined from the calibration study (**10 ppm**), **Pi-**Initial available P obtained from laboratory analysis from each farmers' fields and

Pf- phosphorus requirement factor derived from the calibration experiment **(6.45).**

Verification of phosphorus critical level was done with three treatments (1) soil test crop response based P criticl level; (2) farmers' practice in the area (blanket recommendation) and (3) control (no fertilizer application). It was conducted on 10*10m plot for each treatment with 20 cm row spacing. The experiment was laid out in randomized complete block design and replicated over farmers' fields. The fields were prepared by the local ox plow and after bund application of fertilizer; it was incorporated by the local plow during sowing. Urea split application was used, and top dressing of urea and incorporating it with soil was done 25-30 days after sowing and all cultural practices with recommended production practices were used. Weeds were controlled by Pallas. Yellow rust was controlled by spraying fungicide (Reoxido) at the rate of 0.5 Liter ha^{-1} immediately at the appearance of the symptom of the disease.

Data collection and analysis

Agronomic data collected were plant height, biomass yield, grains per spike, spike length, 1000 kernel weight (TKW) and grain yield. Generally all data were properly managed and subjected to the analysis of variance using the SAS computer package version 9.0 (SAS Institute, 2002) statistical software.

Cost–benefit analysis

The partial budget, dominance and marginal analyses were done for both farmer practice and soil test based values using CIMMYT (1988)**.** Total variable cost was cost incurred due to application of P fertilizer (separately for soil test based P critical level result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred were the same for all treatments. The discarded and selected treatments using this technique were referred to as dominated and un-dominated treatments, respectively.

3. Results and Discussion

3.1. Soil available phosphorus

The available P content of the soil was ranged from very low to medium according to Cottenie (1980) with the value ranged from 2.36 to 8.26 ppm (Table 1). Therefore, the soil of the study area needs application of phosphorus containing fertilizers and phosphorus fertilizer requirement was calculated from the formula: **Phosphorus fertilizer rate = (pc-pi)*pf** for crop production.

Table1. *Available soil phosphorous status before planting in Dugda District, East shewa Zone*

Sites	Site code	Available soil phosphorus (mg kg^{-1} soil)
1	F1	**4.06**
2	F2	**8.26**
3	F3	**4.52**
4	F4	**5.48**
5	F5	**3.36**

6	F6	**7.16**
7	F7	**6.20**
8	F8	**3.88**
9	F9	**5.28**
10	F10	**2.36**
Average Initial P		**5.06**

3.2 Grain yield

Analysis of variance revealed that the trials conducted in Dugda District shows that grain yield of bread wheat was highly increased with application of site specific fertilizer recommendation. This gave 2875 kg ha^{-1} yield advantages over the control treatment and 914 kg ha^{-1} over farmer practices with grain yield increment (Table 2). The optimum N was 69 kg N ha^{-1} which influence highly yields of bread wheat in the district. Accordingly the site specific fertilizer recommendation rates were influence grain; biomass yield and the mean maximum of grain yield were 5157 kg ha^{-1} of 44.25 % grain yield and 52.21 % straw yield advantage over the control treatment. Therefore the yield increment due to the soil test based phosphorus fertilizer recommendation rate (STBR) was perceived positively. Moreover, different stakeholders should work and harmonize on the transfer of the technology and additionally further effort should be made to disseminate the Soil test based phosphorus fertilizer recommendation rate (STBR) to farmers or end users. Generally this study in line with Kefyalew et al.(2017) mean comparison of grain yield was also computed at ($\alpha < 0.05$) for verification experiment and the study revealed that mean grain yield of the calibrated phosphorus (critical concentration) treatment showed 320 & 877 kg for bread wheat yield increment over blanket recommendation and control plot, respectively.

Table2. *Effect of verification of phosphorus critical level on yield and yield components of bread wheat in Dugda District*

Treatments	Plant height (cm)	Spike length (cm)	Seed per spike	Biomass yield (kg/ha)	Grain yield (kg/ha)	TKW (gm.)
Control	77.88 a	6.96	42.48	7100 a	2282 [a]	45.80 a
FP	90.36 b	7.10	46.68	12000 b	4243 [b]	51.60 b
ST	95.28 b	7.58	46.64	13600 c	5157 [c]	52.40 b
LSD(0.05)	6.30	NS	NS	1.35	7.49	3.981
CV (%)	4.90	7.70	7.50	8.50	12.70	5.50

Means followed by the same letter with in the same column of the respective treatments are not significantly different ($P \leq 0.05$) according to fishier Test, ST = Soil Test, FP = Farmer practices, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

3.3. Economic analysis

The partial budget analysis (CIMMYT, 1988) was employed to calculate the Marginal rate of return (MRR) to investigate the economic feasibility of treatments. Based on actual unit prices during the year 2022 harvesting season (personal observation) farm gate price of 29.00 ETB (Ethiopian Birr) per kg of wheat. Bread wheat seed price 39.30 Birr per kg, 17.05 & 16.70 Birr per kg of Phosphorus from NPS & Nitrogen from Urea respectively were used to calculate variable cost. The Marginal Rate of Return (MRR) was found to be 3106.54% for soil test based fertilizer rate and farmer practice was dominated soil test based fertilizer rate. The partial budget analysis showed that the highest net income (130,433.81 ETB) was obtained from soil test based recommended treatment. Marginal rate of return (3106.54%) which is greater than the minimum rate of return (MRR) 100 % (Table 3). Generally, this study in line with Dejene et al. (2020) the economic analysis showed that the highest net income (51284 ETB) was obtained from soil test based recommended treatments with marginal rate of return (857.27%).

Table3. *Partial Budget analysis for the verification trial of bread wheat at Dugda District*

Treatments	GY (kg ha^{-1})	AGY (kg ha^{-1})	GFB (ETBha^{-1})	TVC(ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Control	2282	2054	59560.20	0	59,560.20	0
FP	4243	3819	110742.30	3419.93	107,322.37	1396.58
ST	5157	4641	134597.70	4163.89	130,433.81	3106.54

ETB, Ethiopian birr; GFB, gross field benefit; TVC, total variable cost; NB, net benefit; MRR, marginal rate of return, ST, Soil Test, Fp, Farmer Practice, grain yield, AGY, adjusted grain yield.

4. Conclusion and Recommendations

Verification of phosphorus critical level with farmer practices and control on the selected farmers' fields was encouraging indicator of use of soil test crop response based fertilizer recommendation for bread wheat. Accordingly, verifying phosphorus critical level influences biomass yield and the mean maximum of grain yield were 5157 kg ha^{-1} of 44.25 % grain yield and 52.21 % straw yield advantage over the control treatment. The economic analysis showed that the highest net income (130,433.81 ETB) was obtained from soil test based recommended fertilizer application with marginal rate of return (3106.54%). Therefore farmers had positive responses on soil test based phosphorus fertilizer recommendation. Further effort should be made to disseminate the soil test based phosphorus fertilizer recommendation. Generally different stakeholders should work and harmonize on the transfer of the technology to farmers or end users.

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