
Soil Test Based Crop Response Phosphorus Calibration Study on Bread Wheat in Degem District of North Shewa Zone, Oromia

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Abstract: Soil test based crop response phosphorous calibration study was conducted Degem district on bread Wheat crop during the main cropping season of 2017 -2019 with the objectives to determine Pc and Pf for bread wheat crop, to establish site-specific soil test based phosphorus fertilizer recommendation and to prepare guideline for bread Wheat fertilizer application. RCBD design was used with 3 replication using 4 rates of N (0, 46, 92 and 138 kg ha⁻¹) and 5 rates of P₂O₅ (0, 23, 46, 69 and 92 Kg ha⁻¹) in a factorial combination to determine optimum level of N- rate for bread wheat crop production. And in the second and third year 6 levels of P₂O₅ (0, 23, 46, 69, 92 and 115 Kg ha⁻¹) and 92 kg N ha⁻¹ of optimum nitrogen rate obtained were applied uniformly for all plots to determine P-critical value (Pc) and P-requirement factor (Pf) for bread Wheat. A total of experimental plot size 5m*4m (20 m²) and Seeds were sown using a seed rate of 150 kg ha⁻¹ in a plot size of 5 m x 4 m (20m²) by broadcasting. Fertilizers were applied based on the treatments. Grain yield of bread wheat was analyzed using R-Software. Composite Surface soil samples from 0-20 cm depth were collected from each experimental plot before planting for laboratory analysis of selected soil chemical properties. Similarly, after 21 days of planting, composite soil samples were taken at (0-20 cm depth) using auger for each treatment and replications separately and the sample were subjected to laboratory analysis using Olsen method to analyze available P content in the soils. The result of the study showed that low to extremely high available P ranged from 4 -55.06 ppm. The mean maximum grain yield (3665 kg/ha) was obtained from the application of 92 kg N /ha and 92 kg P₂O₅ /ha where as the lowest (1260 kg /ha) was obtained from control (with out fertilizer). Fertilizer combination of 138 kg N/ha and 92 kg P /ha compared to 92 kg N /ha and 92 kg P / ha showed no significant difference on bread wheat grain yield. Therefore, 92 kg N /ha was selected as N fertilizer recommended for Degem district. From phosphorous calibration study, P-critical value (22 ppm) and P-requirement factor (5.85) was determined for phosphorus fertilizer recommendation for bread wheat crop production in the area. Therefore, the obtained result has to be verified and the economic benefit must be studied across farmers' fields.

Keywords: Calibration, Soil Test, RCBD Design, Economic Benefit

1. Introduction

The population of Ethiopia is currently growing at a faster rate and demands an increased proportion of agricultural products. On the other hand, growth in food production is not in equal footings with population pressure (Central Statistical Agency, 2015). Strengthening food production capability of the country by wisely exploiting its existing human and

natural resources is critical option to avert the existing situation. But, Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion restrains agricultural crop production and economic growth.

The degree of response of soils to applied phosphorus fertilizer is influenced by the soil, amount of available soil phosphorus, amount of clay, organic matter and soil moisture level (Miller *et al.*, 1995). The effect of Pongrain yield was

highly significant with a general increase in yield as the level of P_2O_5 increased up to 69 kg/ha (Asnakewet *et al.*, 1991).

Nitrogen affects crop performance through its ability to determine photosynthetic capacity. Application of nitrogen at onset of stem elongation greatly stimulated leaf area growth, which resulted in significantly greater assimilation capacity, both before and after anthesis (Schulthess and Jutzi, 1997).

However, 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 (Scoones and Toulmin, 1999).

Continuous cropping, high proportions of cereals in the cropping system, and the application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Workneh and Mwangi, 1992). Hence, identification of proper fertilizer mix is beneficial at the macroeconomic level by improving the efficiency of fertilizer procurement and resource allocation.

Therefore, profitable crop production requires adequate levels of phosphorus (P) and other nutrients. For this careful planning is required because of volatile grain and fertilizer prices. So, sound soil test calibration is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of a fertilization program.

An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop (Sonon and Zhang, 2008). Hence, calibration is a vital tool to attain the objective while calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety. That means, fertilizer recommendations on soil test basis for economic crop production should be both location and situation specific and can be modified with changes in soil test value as well as input output ratios. Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, fertilizer application schedules should be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Santhi *et al.* 2002).

As in all other regions of the country, fertilizer recommendations in Degem district is also not based on soil test results.

Therefore, this study was initiated with the objectives to determine P-critical and P-requirement factor (pf) and to establish site-specific soil test based phosphorus fertilizer rate recommendation for bread wheat production on major soil of the districts.

2. Materials and Method

2.1. Site Description

The trial was conducted in Degem districts of North Shewa Zone, Oromia. The District is found in the North-

Western direction at a distance of 123 km from Addis Ababa capital city of Ethiopia and 10 km from Fitcha, capital city of North Shewa, Oromia. It has an astronomical location which extends from 38°25'0" E-38°45'00 E and 09°03'0"N-10°30'0"N longitude and latitude respectively.

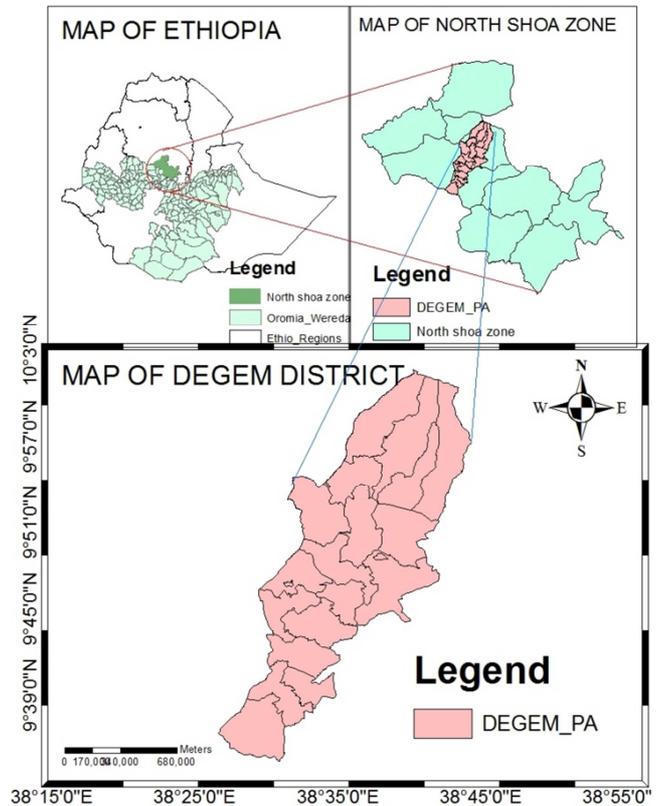


Figure 1. Location map of Degem District.

2.2. Experimental Design, Treatment and Procedure

On farm study was conducted in the district during the main cropping seasons (2017 to 2019) to determine Optimum level of Nitrogen fertilizer, P-critical value and P-requirement factor for P-fertilizer recommendation of bread wheat for the district. The treatment of the experiment were factorial combination of 4 rates of N (0, 46, 92 and 138 kg ha⁻¹) and 5 levels of P_2O_5 (0, 23, 46, 69 and 92 Kg ha⁻¹) in the first year to determine optimum level of N- rate for bread wheat production in the district (Table 1).

Table 1. Treatment Description.

N-level1 Treatment	N-level2 Treatment	N-level3 Treatment	N-level 4 Treatment
(T1-T5)	(T6-T10)	(T11-T15)	(T16-T20)
N: P_2O_5 kg/ha	N: P_2O_5 kg/ha	N: P_2O_5 kg/ha	N: P_2O_5 kg/ha
T1 (0:0)	T6 (46:0)	T11 (92:0)	T16 (138:0)
T2 (0:23)	T7 (46:23)	T12 (92:23)	T17 (138:23)
T3 (0:46)	T8 (46:46)	T13 (92:46)	T18 (138:46)
T4 (0:69)	T9 (46:69)	T14 (92:69)	T19 (138:69)
T5 (0:92)	T10 (46:92)	T15 (92:92)	T20 (138:92)

Gross plot size: 3m x 4m.

Harvested area: 2m x 2m.

Single factor of six (6) level of P_2O_5 (0, 23, 46, 69, 92 and 115 $Kg\ ha^{-1}$) and 92 kg N/ha treatments combinations were used in the P-calibration experiment in second and third year to determine P- critical value and p-requirement factor. Land was prepared using oxen plow. Bread wheat seed and fertilizers were broadcast. The trial was conducted in completely randomized block design (RCBD) in three replications on net plot size 5m*4m =20m².

Recommended and sufficient amount of nitrogen (92 kg/ha) was applied uniformly for all plots. Improved variety of bread wheat Danda'a was used as a test crop. Seeds were sown using a seed rate of 150 kg ha⁻¹ in a plot size of 5 m x 4 m (20m²) by broadcasting. Fertilizers were applied based on the treatments.

2.3. Soil Sampling and Analysis

Out of the 41 farmers' field analyzed, twenty farmers' fields (eight and twelve in 1st and 2nd year respectively) were selected those that vary with respect to soil test value, over the whole range from very low to very high (low, medium and high P soils) as test sites.

Similarly, after 21 days of planting, composite soil samples were taken at 20 cm depth using auger for each treatment and replications separately and the sample were subjected to laboratory analysis using Olsen Method to analyze available P content in the soils, which enables to determine P critical level and P-requirement factor.

2.4. Determination of Phosphorus Critical Level and P-requirement Factor

2.4.1. Determination of P-requirement Factor (Pf)

Based on P laboratory analysis result of post planting soil samples (available P values in samples collected from unfertilized and fertilized plots) data P-requirement factor was calculated that P applied to determine the quantity of P required per hectare to rise the soil test by 1 mg /kg which is equal to $Pf = \frac{\Delta P}{\Delta soil\ P}$ and to determine the amount of fertilizers required per hectare to bring the level of available P above the critical level.

Phosphorus requirement factor (Pf) was calculated using available P values in soil sample collected and analyzed from each unfertilized and fertilized experimental plot, after that the relation between each fertilizer rate and averaged corresponding soil test P value for each fertilizer rate was calculated.

2.4.2. Determination of Phosphorus Critical Level (Pc)

For determination of P-critical value, the Cate-Nelson diagram method (Nelson and Anderson, 1977) was used, where soil P values were put on the X- axis and relative yield values on the Y-axis, and scatter points were divided into two populations. This was achieved by overlay of a clear plastic sheet having a pair of perpendicular lines drawn on it to produce four quadrants. The overlay was the positioned on the graph in such a way that the maximum number of points fell in the positive quadrants while the lowest number fell in the negative quadrants. The vertical line defines the

responsive and non –responsive ranges while the optimum is indicated by the point where the vertical line crosses the x-axis. The two intersecting lines were then drawn lightly on the graph. The point where the vertical lines cross the X-axis is defined as 'critical soil test level'. Data from 20 sites for each crop and all treatment with their replications were used for such analysis.

2.5. Economic Analysis

Economic analysis was undertaken to investigate the economic feasibility of the treatments. Partial budget analysis was done to identify economical feasibility among different Nitrogen level fertilizer rate for bread wheat crop production. The average open market price (Birr/ kg) of wheat, price of Urea (N) and DAP (P) fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MARR) should be 100% (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis.

2.6. Agronomic Data Collection

During the different growth stages of the crop, all necessary field management practices were carried out as per the practice followed by the farming community.

Agronomic data were collected on planting date, maturity date, plant height, biomass and grain yield.

All Agronomic and soil data were properly managed using EXCEL computer software. Grain yield were analyzed using R software program.

3. Result and Discussion

3.1. Soil Available Phosphorous

Available Phosphorous (Olsen method) collected before planting was ranged from 4 ppm to 55.06 ppm. The available P content of the soil was ranged from low to extremely high (Olsen et al., 1954).

Table 2. Initial available soil phosphorous status before planting in Degen district.

Site	Available p (ppm)
Site 1	4.0
Site 2	6.6
Site 3	6.6
Site 4	10.6
Site 5	8.6
Site 6	7.3
Site 7	18.0
Site 8	6.0
Site 9	14.87
Site 10	14.58
Site 11	46.07
Site 12	9.54
Site 13	36.29
Site 14	22.01
Site 15	46.77
Site 16	21.25

Site	Available p (ppm)
Site 17	15.16
Site 18	55.06
Site 19	38.34
Site 20	33.10
Average	21.037

3.2. Nitrogen Fertilizer Determination

The main effects of both N and P fertilizer were highly significant ($p < 0.01$) and the interaction effects were significant ($p < 0.05$) for some grain yield of bread wheat. Bread wheat experimental data analysis result indicated that, all treatments significantly produce mean grain yield as compared to the control except treatment 3 (0N: 46 P₂O₅).

Accordingly, the mean maximum grain yield (3665 kg/ha) was obtained from the application of 92 kg N /ha and 92 kg P₂O₅ /ha where as the lowest (1260kg /ha) was obtained from control (Table 3). This result signifies that the existence of positive interaction of P and N fertilizers for the production of bread wheat, and the responsiveness to the application of high level fertilizer phosphorus. Similarly, previous research output reported by Desta (1978), Mesfin (1980) and Asnake and Tekalign (1991), also supports this experimental result. However, fertilizer combination of 138 kg N/ha and 92 kg P /ha compared to 92 kg N /ha and 92 kg P / ha showed no significant difference on bread wheat grain yield. Therefore, 92 kg N /ha was selected as N fertilizer recommended for the area.

Table 3. Interaction effect of NP on bread wheat grain yield (kg/ha) in Degem district in 2017 cropping season.

N-level	P ₂ O ₅					Mean
	0	23	46	69	92	
0	1260.00 ⁱ	1605.00 ^{gh}	1441.67 ^{hi}	1705.00 ^{gh}	1858.33 ^e	1574
46	2141.67 ^f	2266.67 ^f	2250.00 ^f	2383.33 ^f	2366.67 ^f	2281.67
92	2730.00 ^e	3046.67 ^d	3071.67 ^d	3806.80 ^a	3665.00 ^{ab}	3264.03
138	3083.33 ^d	3278.33 ^{cd}	3420.00 ^{bc}	3388.333 ^c	3541.67 ^{bc}	3342.33
LSD (5%)	263.95					
CV (%)	14.04					

Note: The mean with the same letters are not significantly different at $P < 0.05$.

3.3. Phosphorus Critical Value and P-requirement Factor

The result of the study revealed that P-critical value (22 ppm) (figure 2) and P-requirement factor 5.85 (table 4) were determined for phosphorus fertilizer recommended for the area.

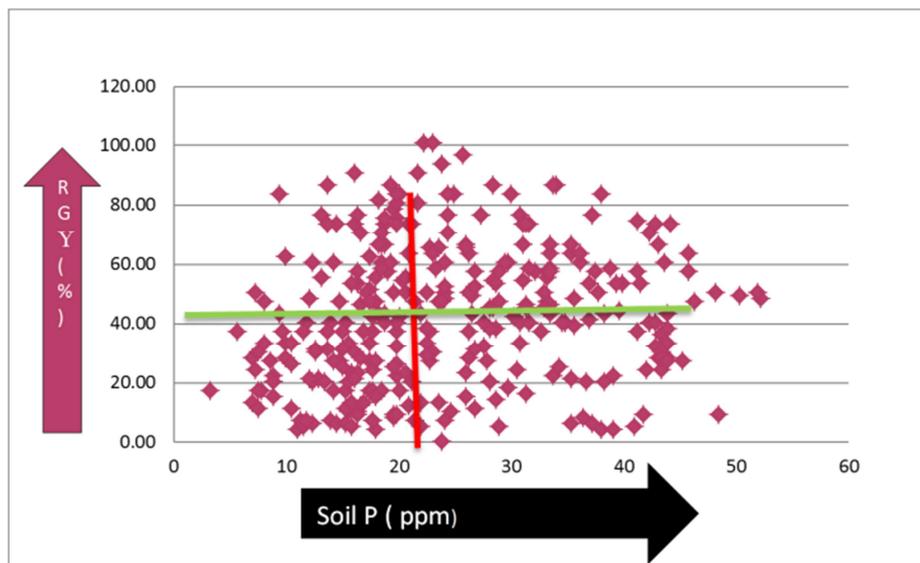


Figure 2. Critical P-concentration as determined by Cate- Nilson method.

Table 4. Phosphorus Requirement factor for Bread wheat for Degem District.

P-fertilizer applied	Olsen P (ppm) Mean	P level increase over thecontrol (Olsen method)	P-requirementfactor (pf)
0	20.71	-	-
10	24.61	3.9	2.56
20	24.83	4.12	4.85
30	24.96	4.25	7.06
40	25.99	5.28	7.58
50	27.66	6.95	7.20
Mean	5.85		

Table 5. Marginal rate of return analysis.

SN	Fertilizer rate	Variable Input (Kg/ha)	Unit price (ETB)	TVC	Output (Kg/ha)	Unit price (ETB)	Gross Income	Net Income	MRR (%)
		Urea							
1	N-level 1	0	10.4	0	1574	10	15740	15740	-
2	N-level 2	100	10.4	1040	2281.667	10	22816.67	21776.67	580.45
3	N-level 3	200	10.4	2080	3264.027	10	32640.27	30560.27	712.51
4	N-level 4	300	10.4	3120	3342.333	10	33423.33	30303.33	466.77

Economic Analysis for Optimum Nitrogen determination on Bread Wheat production in Degem District in 2017

The partial budget presented in (table 5) indicated that the least total variable cost (TVC) was recorded by control treatment, while the highest net income was obtained from N level 3.

The Marginal rate of return were found to be range from 466.77% in N level 4 to 712.51% in N level 3 (92 kg N /ha and 92 kg P /ha) as indicated in (Table 5).

4. Conclusion and Recommendation

In Ethiopia, chemical fertilizers are as one of the most important inputs for maintaining soil fertility and maximizing agricultural production and productivity of the country. Crop production can be profitable if and only if adequate and balanced levels of phosphorus (p) and other nutrient are used. Sound soil test calibration is essential for successful fertilizer program and crop production.

Phosphorus calibration study has been conducted on bread wheat for two years (2017-2019 growing season) at Degem district.

Accordingly, Optimum nitrogen rate (92 kg N/ha), critical P (Pc) concentrations (22 ppm) and P (Pf) requirement factors (5.85) for bread wheat have been determined, at Degem bread wheat growing area.

Farther verification of the result on farmers field could be a prerequisite before disseminating the technology to the user.

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