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Calibration of Phosphorus Fertilizer for Barley (*Hordeum vulgare L.*) on Different Soils of Wolaitain the Southern Ethiopia

Research Article

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Abstract

Global foodproduction strongly depends on availability of nutrients. Assessment of future global phosphorus (P) fertilizer under different levels of food demand requires a model-based approach. Site specific soil-test based crop response phosphorus fertilizer calibration experiment was conducted in Wolaita zone of the southern Ethiopia on barley during 207/18 cropping seasons with objective to determine phosphorus critical. Phosphorus requirement factor and economical P fertilizer level for barley on major soil type of barley growing area of Wolaita zone. This calibration study was conducted on four sites using four levels of P(0. 22.9, 45.80, and 68.70 kg ha^{-1}) were arranged in a randomized complete block design with three replication, critical level Po determination using C'ate-Nelson diagram method. The critical concentration and requirement factor of Phosphorus on barley in the study area were 8.8 mg kg^{-1} and 9.17 mg kg^{-1} respectively. Hence, it could be concluded that the highest grain yield, P requirement factor and P critical obtained could serve in areas where the rainfall distribution and soil type is similar with study district where this experiment was conducted. Further studies should be done on phosphorous use efficiency and other related plant nutrition parameters.

Keywords: Barley; Cate-Nelson Method; Critical P; Requirement Factor; Soil Test.

Introduction

Phosphorus (P) is an essential element for all plants. Plants will grow slowly with low levels of P in the soil; however, for agricultural production purposes, the soil should provide a sufficient concentration of P for optimum plant growth [12]. Phosphorus is among the most important limiting nutrients in most soils of Sub-Saharan Africa [14]. This could be due to low P content in the parent material from which the soils were derived, and due to depletion of soil reserve P through intensive cultivation, without adequate external replenishment [8, 3, 4]. Similar to the Ethiopian soils are generally low in P [3, 4].

Fertilizer use trend of the country had been focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of di-ammonium phosphate (18-46-0) and urea (46-0-0) for almost all cultivated crops and were applied as blanket recommendation [1, 17]. The blanket recommendations are, regardless of considering the physical and chemical properties of the soil as well as does not taken to account climatic condition and available nutrient present in the soil [16, 2].

In southern Ethiopia, most of the farmers usually apply P fertilizers without judging the P status of the soils for which calibrationP study have significant role to play Fluvisols, Cambisols, Arenosols, Vertisols and Nitisols are the common types of soils in the southern Ethiopia is low in P [20]. As indicated by Mesfin et al. (2019) [11], there are different blanket fertilizer recommendations for various soil types of Wolaita zone of the southern Ethiopia at different locations. Phosphorus fertilization and its management is a means of improving soil P for crop production in the cropping system. Better management of P fertilizer can be achieved by studying the calibration P behavior of the soil. Calibration P helps in predicting the fertilizer P needed to replenish the soil solution P to a level optimum for a particular crop [13]. However, currently the Ministry of Agriculture and Agricultural Transformation Agency advanced set 100 kgNPS ha^{-1} and 100 kg ha^{-1} of urea [9]. The blanket recommendation leads to excess or low application of chemical fertilizers, which aggravates stunted growth of plants due to toxicity or deficiency of the essential elements. However, for many years no studies have been conducted on site-specific fertilizer recommendation rate. But, since 2014 Ethiopian soil information system have been started calibration studies for

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some cereal crops and developed some critical concentrations and requirement factors of phosphorous fertilizer recommendation [9]. Therefore, this study aimed to establish soil test based phosphorus recommendation (Pc and Pf) for barley in the Districts.

Materials and Methods

Description of experimental sites

The study was conducted in site 1 (SodoZuria), (site 2) Damot Gale,(site 3) Damot Sore and (site 4) Boloso Sore distracts, Wolaita zone, Southern Nations', Nationalities and Peoples' Regional State (SNNPRS) of Ethiopia (Figure.1). The sites are located between 037°35'30" - 037°58'36"E and 06°57'20" - 07°04'31"N with altitudinal range of 1895 to 2950 m above sea level. The zone has three agro-ecological zones,56% of the area is mid land; 35 % of the area is low land; and the rest 9% of the area is covered by high land. The area has a bimodal rainfall pattern and about 31 and 39% fall during Autumn (March- May) and Summer (June- August) seasons, respectively. The mean average monthly temperature for the last nine years is 20°C (NMA, 2017).

Site Selection

For selecting representative experimental locations, composite soil samples were collected from 9 farmers' fields in each district. A total of 36 samples were collected from 0-20cm depth using soil augers and twelve composites were made for each district within the four locations, where barley (HB1307) is a dominant crop. Based on available soil P values determined by Bray II method [5], fields were categorized into low by Pushparajah (1997) [19] who classified the range of available P < 11, 11-20, 20-30 and > 30 mg kg^{-1} as low, medium, high and very high, respectively.

Treatments and Experimental Design

Phosphorus response experiments with barley were conducted on four sites in the Wolaita zone of the southern Ethiopian during the 2016 cropping seasons. The experiment was laid out in randomized complete block design with replicated three times. The treatments, comprising four levels of P fertilizer (0, 22.9, 45.8 and 68.7 kg P2O5 ha^{-1}), were arranged in a randomized complete block design (RCBD) with three replication. The size of each plot will be 3 m x 3 m, space between plots and blocks were 1m and 1.5 m, respectively. All doses of P (triple superphosphate) were applied as basal dressing at sowing.

Soil Sampling and Analysis

Composite surface soil samples (0-20cm depth) were collected from each experimental site before planting to determine initial soil pH (H_2O) and available P (Bray II method). Similarly, after planting, intensive composite soil samples were collected from each experimental plot to determine available Pwas determined using [5], Particle size distribution was determined by hydrometer method [7], the pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter [18]. Soil organic carbon content was determined by the wet digestion method as described by [21]. Total nitrogen was determined using Kjeldhal method [10]. Exchangeable basic cations and cation exchange capacity of the soils were determined by using 1MN-H_4OAc (pH.7) method [6]. Exchangeable Ca and Mg in the leachate was determined using atomic absorption spectrophotometer (AAS), whereas K and Na were measured by using a flame photometer.

Figure 1. Location map of the experimental sites.

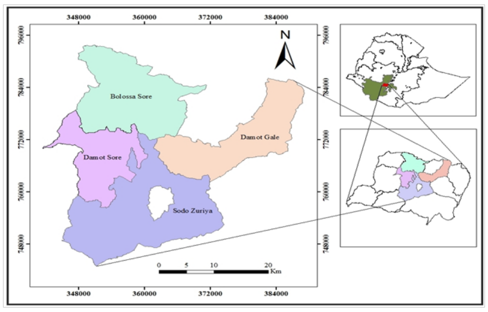

Table 1. Soil physicochemical properties of experimental sites.

Soil properties	Site 1	Site 2	Site 3	Site 4
Sand (%)	41	30	66	28
Silt (%)	30	32	16	26
Clay (%)	29	33	18	40
Textural class	clay loam	clay loam	sandy loam	loam
pH (H_2O)	5.21	5.7	5.66	5.48
OC (%)	0.88	0.49	0.88	0.78
Available P (mg kg^{-1})	7.6	8.39	8..48	8.73
TN %	0.11	0.24	0.11	0.23
Exch. K ($cmolkg^{-1}$)	8.76	11.26	11.13	10.43
Exch.Ca ($cmolkg^{-1}$)	4.39	3.22	3.13	3.37
Exch. Mg ($cmolkg^{-1}$)	0.24	0.31	0.21	0.26
Exch.Na ($cmolkg^{-1}$)	0.23	0.14	0.16	0.26
CEC ($cmolkg^{-1}$)	19.22	18.8	20.6	17.60

Determination of Critical P Concentrations

For the determination of critical values of P, the Cate-Nelson diagram method was used (Nelson and Anderson, 1977). Where after planting analyzed soil available phosphorus values were put on the X-axis and the relative maize grain yield values (%) on the Y-axis.At eventually, the diagram of the results is divided into four quadrants that maximize the number of points in the positive quadrants and minimize the number of points in the negative quadrants. The observations in the upper left quadrant overestimate the fertilizer P requirement while the observations in the lower right quadrant underestimate the fertilizer requirement. The optimum is indicated by the point where the vertical line crosses the x-axis and critical P value was determined using relative grain yield against the soil test values at different rates of applied phosphorous fertilizer for a given of nutrient rate.

Determination of P Requirement Factor

This factor enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg kg^{-1}, and to determine the amount of fertilizer required per ha to bring the level of available P above the critical level. It was calculated using available P values in samples collected from unfertilized and fertilized plots after 30 days starting from sowing date. Finally, the P requirement factor was obtained using the available soil test P values of the soil samples that received different P fertilizer rates. Pc and Pf was calculated as follows rate of P2O5 $kgha^{-1}$ fertilizer to be applied = (Pc -Po) x Pf

Where:

Pc = critical P concentration
Po = initial P values for the site
Pf = P-requirement facto

Partial budget analysis

The cost of 100 kg urea (1260 birr) and TPS (1800 birr) used for the benefit analysis. Benefit cost optimum was calculated by gross (net) revenue (NR) divided by total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988). Labor costs were calculated by assuming 50 ETB per day per person and revenue was calculated by assuming 6 ETB kg^{-1} of barley grain yield.

Results and Discussions

Critical Phosphorus Concentration (Pc)

Critical P (Pc) value was determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative yield values on the Y-axis. According to the Cate- Nelson method, the critical levels of Bray- II P in the top 20 cm of soil about 8.8 mg kg^{-1} at values of greater than or equal to 8.8 mg kg^{-1}, the crop achieved about 80 % of its maximal yield in the absence of P fertilizer application (Figure 2). This implies that P fertilizer application could be recommended for a build-up of the soil P to this critical value, or maintaining the soil P at this level. Increasing P beyond this level, the cost of additional P fertilizer to produce extra yield would likely be greater than the value of additional yield. Thus, in soils with available P status below 8.8 mg kg-1, yield of barley could show a significant response to applications of P fertilizers. Whereas in areas with available P status greater than 8.8 mg kg^{-1}, the P concentration in the soil exceeds crop needs (68.7P_2O_5) so that further addition of P fertilizer may not outcome increase.in a profitable value.

Phosphorus requirement factor (Pf)

Phosphorus requirement enables to determine the quantity of P required per ha to raise the soil test by 1 mg kg^{-1}, and to determine the amount of fertilizer required per ha to bring the level of available P above the critical level. The Pf computed from the difference between available P values in soil samples collected from plots, which were received 0, 22.9, 45.8 and 68.7 kg P_2O_5 ha^{-1}. As indicates in the below table 1 and the average value of P- requirement factor was 9.17 mg kg^{-1}.

Figure 2. Comparative grain yield influenced by different soil P test.

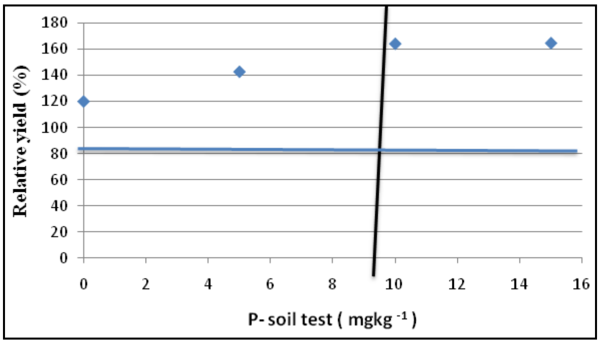

Table 2. Determination of P requirement factor (Pf) for barley at Wolaita zone.

P_2O_5 rate (kg ha^{-1})	Soil test Phosphorus (Po) (mg kg^{-1})		Δ P	Pf
	Range	Average		
0	8.6-18.60	13.6	-	-
22.9	9.49-18.10	13.79	0.19	9.81
45.8	10.48-21-82	16.15	2.36	8.47
68.7	11.64-27.14	19.39	3.24	9.25
Mean				9.17

Table 3. P critical and P requirement factor as base of fertilizer recommendation.

S/no	Locations	Initial P (mg kg^{-1})	(Pc -Po) x Pf	P_2O_5 ($kgha^{-1}$)
1	Site 1	7.61	(8.8-7.6)x9.17	11.004
2	Site 2	8.79	(8.8-8.79)x9.17	0.092
3	Site 3	8.48	(8.8-8.48)x9.17	2.934
4	Site 4	8.73	(8.8-8.73)x9.17	0.642

Table 4. Partial budget with dominance and marginal rate of return analysis to establish the profitability of barley production with soil test based crop response phosphorus recommendation at wolaita zone, southern Ethiopia.

Treatment P205 $kgha^{-1}$	Actual yields (kg ha^{-1})	Adjusted grain yield	Fertilizer cost (Birr)	Total variable cost (TVC) (Birr)	Total revenue	Net revenue	Gross net revenue
0	1203	1082.7	1082.7	0	0	6496.2	
22.9	1428	1285.2	900	1060	7712.82	6652.82	6.27
45.8	1640	1476.2	1800	1960	8857.62	6897.62	3.51
68.7	1645	1480.8	2700	2860	8883	6023	2.11

Phosphorus fertilizer recommendation

When a sufficient amount of data has been generated, such information could easily be compiled as a guideline to be used by extension agents for fertilizer recommendations to small holder farmers based on soil test values. When the soil test value is below the critical level addition all information is needed on the quantity of P required elevating the soil P to the required level. This is the P requirement factor , the amount of P required to raise the soil test P by 1mg kg^{-1}, computed from the from the difference between available soil test P values from plots that received 0 – 68.7P_2O_5 kg P ha^{-1} (Table 2). Accordingly the calculated table 2 was 0.09178- 11.004 P_2O_5 kg ha^{-1} and the overall mean 9.17mg kg-1of all sites and treatments for the study area of Wolaita zone. Thus the rate of P fertilizer required per ha can be calculated using the soil critical P concentration, initial soil P determined for site 2 and site 4 were not required more than applied rates (Table 3) and the P requirement factor as indicated above in the table 2.

Partial Budget Analysis

The benefit cost associated with different treatments, the partial budget technique of CIMMT (1988) was applied on grain yields. The partial budget analysis indicated that treatments resulted in maximum relative costs (6897.62Birr ha^{-1}), while the highest net benefit was obtained from 45.80 P_2O_5kg ha^{-1}, which gave higher net revenue than farmers' practices fertilizers application. The dominated treatment (68.70P_2O_5 kg ha^{-1}) was rejected from further economic analysis. To identify treatments with the benefit cost optimum to the farmer's investment, benefit cost ratio analysis was performed on non-dominated treatments. The analysis of gross net return, on the other hand, revealed that the rate of return per unit cost of production was highest from control (6496.2Birr ha^{-1}). This showed that it would yield 6 and 50 Ethiopian Birr for every Birr and day per person invested.Therefore, application of (45.80P_2O_5 kg ha^{-1}) is profitable and recommended for farmers and other areas with similar agro-ecological conditions.

Conclusions and Recommendation

Site specific soil test-based crop response fertilizer recommendation study in WolaitaZone of the southern Ethiopia on barley resulted in determination of optimum phosphors, P critical and P requirement for specific area. Accordingly, optimum Prate (0-68.70 P_2O_5kg ha^{-1}), critical P concentrations (8.8mg kg^{-1}) and P requirement factors (9.17) were determined for barley in four district, which could be extrapolated to similar agro-ecological zones of the Wolaita Zone Further studies should be done on phosphorous use efficiency and other related plant nutrition parameters.

References

[1]. Abiye A, Tekalign M, Peden D, Diedhiou M. Participatory On-farm conservation tillage trial in Ethiopian highland vertisols: The impact of potassium application on crop yield. ExplAgric. 2004;40:369-79.

[2]. Kidanemariam A. Recommendation of Phosphorus fertilizer based on soil-test and response of tef to nitrogen and Phosphorus Fertilizers. Ethiopian Journal of Natural Resources. 2008.

[3]. AMelese A, Gebrekidan H, Yli-Halla M, Yitaferu B. Phosphorus status, inorganic phosphorus forms, and other physicochemical properties of acid soils of Farta District, Northwestern Highlands of Ethiopia. Appl Environ Soil. 2015 Feb 26;2015.

[4]. Ayenew B, Tadesse AM, Kibret K, Melese A. Phosphorous status and adsorption characteristics of acid soils from Cheha and Dinsho districts, southern highlands of Ethiopia. Environ Syst Res. 2018 Dec;7(1):1-4.

[5]. Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 1945 Jan 1;59(1):39-46.

[6]. Chapman HD. Cation-exchange capacity. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties. 1965 Jan 1;9:891-901.

[7]. Day PR. Hydrometer method of particle size analysis. Methods of soil analysis. American Society of Agronomy. Madison, WI, USA. 1965.pp: 562-563.

[8]. Elser JJ, Elser TJ, Carpenter SR, Brock WA. Regime shift in fertilizer commodities indicates more turbulence ahead for food security. PLoS One. 2014 May 1;9(5):e93998.

[9]. EthioSIS (Ethiopia Soil Information System). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia.

[10]. Jackson ML. Soil Chemical Analysis. Prentice Hall Grice. Englewood Cliffs, USA; 1973. pp.284.

[11]. Kassa M, Haile W, Kebede F. Evaluation of adsorption isotherm models for potassium adsorption under different soil types in Wolaita of Southern Ethiopia. Communications in soil science and plant analysis. 2019 Feb 21;50(4):388-401.

[12]. Morris ML. Fertilizer use in African agriculture: Lessons learned and good practice guidelines. World Bank Publications; 2007.

[13]. Moazed H, Hoseini Y, Naseri AA, Abbasi F. Determining phosphorus adsorption isotherm in soil and its relation to soil characteristics. Journal of Food, Agriculture & Environment. 2010 Apr 1;8(2):1153-7.
[14]. Morris ML. Fertilizer use in African agriculture: Lessons learned and good practice guidelines. World Bank Publications; 2007.
[15]. NMA (National Meteorological Agency). 2017. National Meteorological Agency, Hawassa Meteorological Service Center, Ethiopia.
[16]. Kotu BH, Verkuijl H, Mwangi WM, Tanner DG. Adoption of improved wheat technologies in Adaba and DodolaWoredas of the Bale Highlands, Ethiopia. CIMMYT; 2000.
[17]. Shahidur Rashid, Gashaw Abate, Solomon Lemma, James Warner, LeulseggedKasa, Nicholas Minot. Barley value chain in Ethiopia: Research for Ethiopia's agriculture policy (reap): Analytical Support for the Agricultural Transformation Agency; 2015.
[18]. Page AL, Miller RH, Keeney DR. Methods of soil analysis, part 2. Chemical and microbiological properties. 1982;2:643-98.
[19]. Pushparajah E. World fertilizer use manual. International board for soil research and management, Bangkok, Thailand. 1997.
[20]. ZinabuWolde Z, Haile W, Singh D. Phosphorus sorption characteristics and external phosphorus requirement of Bulle and WonagoWoreda, Southern Ethiopia. Adv Crop Sci Tech. 2015 Apr 29:1-7.
[21]. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science. 1934 Jan 1;37(1):29-38.