Research Article

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Phosphorus calibration study under soil test based maize response in bedele district of oromia, west Ethiopia

Abstract

Periodic assessment of soil fertility status and plant nutrients requirement of a given area has vital role in enhancing crop production on sustainable basis. In view of this, on-farm study was carried out in Bedele district of Oromia. The aims of the study were to determine phosphorus critical level and requirement factor for phosphorus recommendation of hybrid maize (BH-660) variety for the district. The treatments of the experiments were four levels of phosphorus (0, 10, 20 and 40kg P/ha), and 92 kg N/ha were laid out in RCBD with two replications. Soil samples were collected from surface soil of the experimental plots (0-20cm depth)before and after planting for laboratory analysis of soil pH (H_2O) and available P which is used to. determine phosphorus critical level and requirement factor The results of the study revealed that the soil reaction pH (H_2O) were extremely acidic to strongly acidic ranged from 4.43 to 5.42, Very low available P from 1.82 to 4.78 ppm. The study also showed that phosphorus critical level (6ppm) and requirement factor (23.55) were determined for phosphorus recommendation for maize production in the area. The validity of phosphorus critical level was verified by conducting verification trials; accordingly, the economic evaluation showed that STBCRPR would yield 2.23 Ethiopian birr for every birr invested. Thus, farmers in the area might be advised to use soil test based crop response phosphorus recommendation to increase the productivity of maize.

Keywords: maize (BH-660), nitrogen, phosphorus, p critical, requirement

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Abbreviations: TVC, total variable cost; T1, without fertilizer; T2, blanket fertilizer application; MRR, marginal rate of return; P, phosphorus

Introduction

Phosphorus (P) is the most important nutrient element (after nitrogen) limiting agricultural production in most regions of the world. It is extremely chemically reactive, and more than 170 phosphate minerals have been identified. In all its natural forms only a very small proportion exists in the soil solution at any one time. Plant roots acquire P as phosphate, primarily in the form of $H_2PO_4^-$, from the soil solution.[1] The concentration of P in soil solution provides useful information about P nutrition since concentration gradients are the driving force for flow of P to the roots and its uptake by roots also is concentration dependent.[2] Plant-available P may be considered in either its quantitative or intensive dimension. The quantity of available P is time-specific and crop-specific, because it is the amount of P that will come into the soil solution and be taken up by the crop during its life cycle. The intensity of available P (availability) is most easily identified with its concentration in the soil solution.

Phosphorus is abundant in soil; however, the concentration of plant available P in the soil solution is generally low.[3] These values were 0.1 to 10 µM,[4] Phosphorus concentration in soil solution and P-buffer capacity are among the most relevant factors responsible for the availability of P to plants.[5] The soil property controlling the relationship between the solid phase P and its concentration in solution is known as the buffering capacity. Soil pH influences chemical properties and biological processes, including solubility, mobility, and availability of nutrients and trace metals. in alkaline soils, P can precipitate with Ca forming insoluble hydroxyl apatite, octacalcium phosphate, and dicalcium phosphate.[6] In acidic soils, P can precipitate as minerals of Fe, and.[7] Both of these minerals decrease the availability of P for plant growth.[6] Clay fractions such as amorphous hydrated oxides of Fe and Al, in addition to gibbsite, goethite, and kaolinite are responsible for the greatest P fixation.[8] As a result, P is one of the most limiting nutrients for crop production.

Maize is one of the most important cereals in productivity and second in area coverage after *teff* in Ethiopia,[9] Research results in high potential maize growing areas are high. However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties even in high maize growing potential areas of western Oromia.[10] One of the main causes for this discrepancy is the low use of external inputs, leading to negative balances for N, P and K,[11] The Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion.[12–13] Unless something is done to restore soil fertility first, other efforts to increase crop production could end up with little success.[14]

Soil tests for plant available P are used world-wide to determine the current P status of soils so as to estimate fertilizer P requirements for specific yield goals.[15] Sound soil test calibration is essential for successful fertilizer program and crop production.[16] Matching fertilizer application rates and use of effective fertilizer materials to crop needs is an essential component of optimizing crop production.[17] Therefore, 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.

However limited availability of site-specific fertilizer recommendations can undermine yield increment obtained from fertilizer application. Blanket NP fertilizer recommendation for maize has been given throughout the country for different soil, agro-ecology and farming systems in Ethiopia. Using blanket fertilizer recommendations may lead to low crop responses and poor soil fertility management. This is because blanket recommendations can be higher or lower than crop requirement. The use of site specific fertilizer recommendations by amount and sources is very important for sustaining crop yield and soil fertility.[18] Therefore, the objective of this paper was to calibrate Phosphorus under site specific soil test based maize response in Bedele district of Oromia, western Ethiopia.

Materials and methods

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 **(**Olsen method**).** Similarly, after 21 days of planting, intensive composite soil samples were collected from each experimental plot to determine available P.

Treatments, experimental designs and procedures

On-farm study was conducted in Bedele district to determine phosphorus critical level and requirement factor for phosphorus recommendation of hybrid maize (BH-661) variety. Four levels of P (0, 10, 20 and 40kg P/ha) were used in the experiment, and Nitrogen 92 kg N/ha, which is determined for maize production in the area,[19] were laid out in RCBD with two replications. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. The gross plot size was (5mx6.4m) with (5mx4.8m.) net plot. DAP and TSP fertilizers were applied at planting. Nitrogen was applied at 35 days after planting in the form of urea. During the different growth stages of the crop, all the necessary field management practices were carried out as per the practices followed by the farming community. Maize grain yield was calculated for relative percentage yield to correlate with soil data.

Determination of phosphorus critical level

Phosphorus critical level was determined following the Cate-Nelson graphical method.[20] 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. Relative maize grain yield values (%) for each plot was calculated by maize grain yield (kgha^{-1}) from each plot times 100 divided by maximum maize grain yield (kgha^{-1}). The Cate-Nelson graphical method is based on dividing the Y-X scatter diagram into four quadrants and maximizing the number of points in the positive quadrants. The positions of the lines on the overlay with respect to the axes of the graph were transferred to the graph by making marks on the edges of the graph. The two intersecting lines were then drawn lightly on the graph. The point where the vertical line crosses the X-axis is defined as soil test based crop response phosphorus critical level. It is the point where, soil test phosphorus value below which, there is phosphorus response and above which, there is no phosphorus response on crop yield. Moreover, Critical limit for the soil test value is the limit below which a positive or economic response to added fertilizer is possible and above which the response diminishes at a faster rate.[20]

Determination of phosphorus requirement factor

Phosphorus requirement factor is the amount of P in kg needed to raise the soil phosphorus by 1ppm. It was determined by analyzed soil available phosphorus from soil samples collected after planting for each applied fertilizer rate and mean value of each unfertilized and fertilized rates calculated using soil available P values in samples collected from unfertilized and fertilized plots. It also determined by the relation between each fertilizer rate and averaged corresponding soil test P value for each fertilizer rates. Finally divided by corresponding fertilizer rates and the mean value is phosphorus requirement factor of the test crop**.**

$$\text{Phosphorus requirement factor is equal to} = \frac{kg\ P\ applied}{\Delta\ soil\ P}$$

where, Δ soil P=change soil P

Rate of phosphoru**s** to be applied=(P critical level–P initial)*Prf, where Prf, phosphorous requirement factor

Verification of phosphorus critical level and requirement factor

The validity of phosphorus critical level and requirement factor was verified by conducting verification trials; The treatments of the Verification trial were Control (without fertilizer) (T1), Blanket fertilizer application (T2) and STBCRPR (T3) laid out in RCBD replicated per farmer's field. Phosphorus recommendation was applied according to the formula P (kg/ha)=(P critical level–P initial)*Prf, where Prf=phosphorous requirement factor. This recommendation was compared with blanket fertilizer application and control.

Economic analysis

Economic analysis was based on CIMMYT.[21] To estimate economic parameters, products were valued based on local market price collected during January 2014 where maize grain was (4.00 ETB kg^{-1}) at field price. Fertilizers price of DAP and Urea were 15.12 and 11.26 ETBkg^{-1}, respectively. A wage rate of 50.00 ETB per work-day was used.

Results and discussions

Soil reaction (pH) and available phosphorus

The pH (H_2O) of the soil samples collected before planting were ranged from (4.43 to 5.42)(Table 1) Accordingly, the soils were extremely to strongly acidic in reaction.[22] Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils.[23] The result showed that soil pH affects maize production which is less than the maize requirement proposed.[24] Available Phosphorus (Olsen method) collected before planting were ranged from (1.82 *to* 4.78) ppm (Table 1). The available P contents of the soil were very low.[25] The low contents of available P observed in the soil of the study areas are in agreement with the results reported by,[12–13] who reported that the Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion.

Table 1 Initial pH and soil phosphorus

Sites	pH(H_2O)	Available P(ppm)
1	5.16	2.36
2	5.31	3.58
3	4.85	4.78
4	5.01	4.23
5	4.89	2.98
6	4.43	4.73
7	5.08	2.12
8	5.42	1.98
9	5.16	1.82
10	4.84	2.51
Average		3.11

Phosphorus critical level and requirement factor

The study also showed that P-critical level (6ppm) (Figure 1) and P- requirement factor (23.55) (Table 2) were determined for phosphorus fertilizer recommended for the area.

Verification of phosphorus critical level and requirement factor

There were significant differences (P≤0.05) among the treatments in maize grain yield. The maximum mean grain yield (5601.0kg ha^{-1}) was recorded from the application of STBCRPR, whereas the lowest (2511.4kg ha^{-1}) was recorded from the control plot (Table 3). STBCRPR gave 55% higher yield advantage than blanket (farmer's practices) fertilizers application.

Economic evaluation of maize production with soil test based crop response phosphorus calibration study at Bedele district

The partial budget presented in (Table 4) showed that the least total variable cost (TVC) was recorded by control treatment (without fertilizer), while the highest net benefit (NB) was obtained from STBCRFR (7322.82 ETB ha^{-1}), which gave higher NB than Blanket (Farmers Practices) fertilizers application. The analysis of marginal rate of return (MRR), on the other hand, revealed that the rate of return per unit cost of production was highest from STBCRFR (% MRR=223.11). This showed that it would yield 2.23 Ethiopian Birr for every Birr invested.

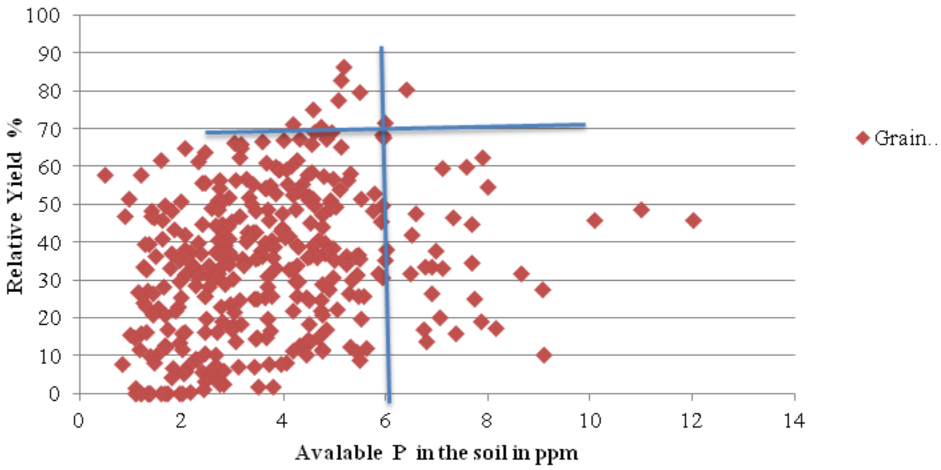

Figure 1 Phosphorus critical level for maize at Bedele district.

Table 2 Phosphorus requirement factor for maize at Bedele district

Fertilizer P applied (kg P/ha)	Olsen P (ppm) Mean	P-increase over Control	P-requirement factor (Pr)*
0	3.11	-	
10	3.61	0.5	20.00
20	3.92	0.81	24.69
40	4.65	1.54	25.97
Average			23.55

Table 3 Verification of phosphorus critical level and requirement factor

Treatments	Yield ha^{-1} (kg)
STBCRPR	5601.0[a]
Blanket (Framers Practices)	3600.0[b]
Control	2511.4[c]
LSD (5%)	741.03
CV (%)	30.43

Means within a column sharing common letter(s) are not significantly different at P≤0.05 probability level; STBCRFR, soil test based crop response fertilizer recommendation; LSD, least significant difference;

CV, coefficient of variance

Table 4 Partial budget with dominance and marginal rate of return analysis to establish the profitability of maize production with soil test based crop response phosphorus recommendation at Bedele district

Partial budget with dominance					
Treatments	**Yield (Kg ha^{-1})**	**GFB (ETB ha^{-1})**	**VC(ETB ha^{-1})**	**NB(ETB ha^{-1})**	**Dominance**
				-	
Control (without fertilizer)	2511.4	10045.6	10550	-504.4	
Blanket recommendation	3600	14400	12604	1796	Un dominated
STBCRPR	5601	22404	15081.18	7322.82	Un dominated
Marginal rate of return (MRR %)					
Treatments	**TVC (ETB ha^{-1})**	**NB (ETB ha^{-1})**	**Incremental**		**MRR (%)**
			cost	**benefit**	
.Control (without fertilizer)	10550	504.4			
Blanket recommendation	12604	1796	2054	1291.6	62.88
STBCRPR	15081.18	7322.82	2477.18	5526.82	223.11

ETB, ethiopian birr; GFB, gross field benefit; TVC, total variable cost; NB, net benefit; MRR, marginal rate of return; STBCR PR, soil test based crop response phosphorus recommendation

Conclusion and recommendation

STBCRPR was superior to both farmers' practices and control, Hence STBCRPR is selected for the recommendation for maize in Bedele district. Phosphorus critical level (6ppm) and requirement factor (23.55) are recommended for maize production in Bedele district. The economic evaluation showed that STBCRPR would yield 2.23 Ethiopian birr for every birr invested. Thus, farmers in the area might be advised to use soil test based crop response phosphorus recommendation to increase the productivity of maize. Similarly, a considerable soil acidity and low fertility of the soil are threatening the agricultural production in the area calling for proper soil fertility management practices.

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Conflicts of interest

Author declares that there is no conflict of interest.

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