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Research Article

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Soil test crop response based phosphorous calibration study on maize at Abay Choman district, Horo Guduru Wollega zone, Oromia region, Ethiopia

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ABSTRACT

Soil test crop response-based P calibration study can give farmers more economic use of fertilizers and better soil management practices. In a view of this, the trial was done in the Abay Choman district on ten experimental farmers' fields in the first year of the experiment (2018/19 cropping season) to determine the economic rate of N and on twenty farmers' fields in the second and third years of the experiment (2019/20 and 2020/21 cropping season respectively) to determine phosphorus critical level and requirement factor. In the first year of the experiment, the treatments were combined in factorial with four levels of phosphorus (0, 10, 20, 40 kg/ha) and four levels of nitrogen (0, 46, 92 and 138 kg/ha). While experiments in the second and third years of the experiment were six levels of Phosphorus 0, 10, 20, 30, 40 and 50 kg/ha. The treatments were laid out as a randomized complete block design (RCBD) with three replications. Representative soil samples were taken before planting and analyzed. Experimental sites that have a pH of < 5.5 were amended using the lime application before the setup of the experiment. Soil test results of the study sites before planting indicated that pH values of most soils were strongly acidic (<5.5) and available phosphorus of experimental soil ranged from 3.22 to 13.62 pp. The main effects of both N and P significantly influenced the mean grain yield of maize, but their interaction was not significant with a grand mean of 76.53 qt/ha during the N determination trial. Economic analysis using partial budget analysis showed 92 kg/ha of N was economically optimal for the production of maize in the Abay Choman district. The study also showed that P- the critical value (12 ppm) and P- the requirement factor (10.55 Kg P/ha) were determined for the phosphorus fertilizer recommendation in the study area. Thus, the farmers in the area might be advised to use soil test crop response-based fertilizer recommendations to increase the productivity of maize in and around the study district.

Keywords: Abay Choman, Calibration, Maize and Phosphorus

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INTRODUCTION

The land used is intensively in Ethiopia (Bacha *et al.*, 2001). However, P and N deficiency is a major constraint to crop production. Land productivity could improve only if the soil fertility problems were improved. Soil degradation is occurring at an alarming rate and threatens soil productivity and maize production in Western Oromia due to continuous cropping over the last three decades. To overcome the soil fertility problem, farmers in western Oromia use mainly chemical fertilizers and manures for crop production.

For instance, in mid-altitude areas like Bako, more than 80% of the farmers use chemical fertilizers (Abdissa *et al.*, 1999). The major sources of these chemical fertilizers were DAP (Di-Ammonium Phosphate) and Urea, which are becoming the most expensive input (personal observation). Therefore, it is understandable that soil test crop response-based fertilizer recommendations that can give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production are necessary. Bekele *et al.* (2002) observed encouraging results from the model calibration trial undertaken at the Hetosa district of Arsi Zone and forwarded the importance of undertaking similar trials across the country, Ethiopia. The use of fertilizers without first testing the soil is like taking medicine without consulting a physician.

So, sound soil test calibration is essential for a 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. 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 & Zhang, 2014). Fertilizer recommendations on soil test basis for economic crop production should be both location and crop type.

Objectives

To determine the economic rate of N fertilizer; to determine critical P concentration and P requirement factors so as to establish soil test-based fertilizer recommendation for Maize production in the Abay Choman district.

MATERIALS AND METHODS

Description of the Study Area

Abay Choman District is found in the Oromia regional state of Ethiopia, containing 19 kebeles, located at 9° 31' 42" to 9° 59' 48" N latitude and 37° 10' 03" to 37° 28' 44" E longitude and the capital of the district Fincha town is 289 km northwest of Finfinnee (Figure 1). The area receives high rainfall in one season of the year. The total area of the District is estimated to be 801.7 km^2; approximately 45, 37, 4, 3 and 11% of the total area are cultivated land, non-cultivated, water bodies, settlements, woodlands and forests, respectively (Belette, 2014).

The Ethiopian population projection by CSA for 2017, based on the 2007 national census reported a total population for this district to be 64,672, of whom 33,263 (51.43%) were male and 31,409 (48.57%) were female; 15,232 or 23.55% of its population were urban dwellers (CSA, 2013). The altitude of the study area ranges from 1,061 to 2,492 meters above sea level (masl) with two agroecological zones, mid-highland and lowland. The northern part of the district (low land), which is mainly situated at an altitude ranging from 1,138 to 1,687 masl in the Nile River Basin, is owned by Fincha Sugar Factory and is entirely being used for irrigated sugarcane (*Saccharum officinarum L.*) production. At altitudes ranging from 2,213 to 2,492 masl (mid-highland), smallholder farmers practice mixed farming systems that integrate both crops and livestock (animals used for traction, meat and milk).

The recent years' meteorological data of the nearby representative stations, Fincha Sugar Factory and Shambu Meteorological Stations showed that the mean annual minimum and maximum temperatures of the district are 13.4 and 27.2°C, respectively, and the mean annual rainfall is 1,399 mm (Belette, 2014). The area has a unimodal rainfall pattern and the highest intensity of rainfall is recorded in the month of July. The area is characterized as hot to warm moist lowland and tepid to cool moist mid-highlands (Mengistu, 2004).

Experimental Design and Procedures

The study was done for three consecutive years (2018/19-2020/21). In the first year of the experiment (2018/19 cropping season); the economic rate of N determination trial was done on ten (10) farmers' sites and in the second and third years of experiments

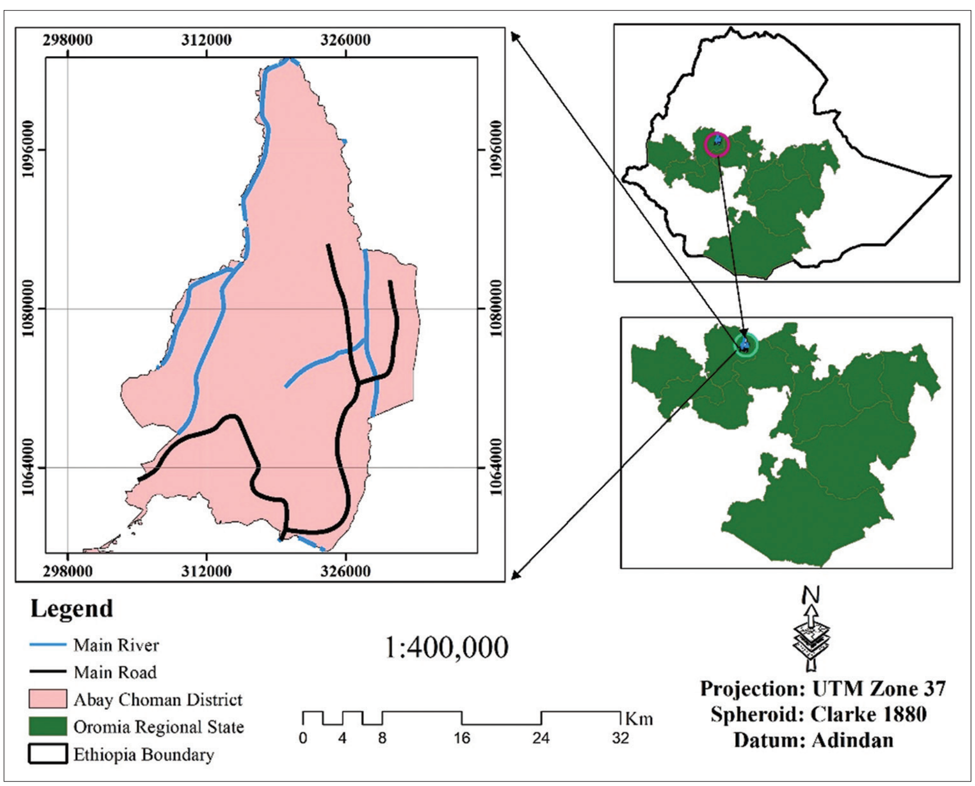

Figure 1: Locatian Map of the Study Area

(2019/20 and 2020/21 cropping season) Pc and Pf determination trials were done on twenty (20) farmers' sites. The specific Experimental sites in the districts were selected based on: Ranges of phosphorus contents (very low, low and medium were selected); the willingness of farmers to provide land and initiative to implement the activity; accessibility for supervision and vicinity to the road. A maize variety of *BH 661* was used. Composite soil samples were taken from all experimental fields before planting to analyze the selected chemical properties of the experimental soil. During the optimum N determination trial, the treatments were factorially combined with four levels of both P and N which are, 0, 10, 20, 40 kg P/ha and 0, 46, 92 and 138 kg N/ha. While six levels of P (0, 10, 20, 30, 40 and 50 kg/ha) were used during Pc and Pf determination trials. The treatments were replicated three times. N was split-applied (1/3 at planting and the remaining about three weeks after planting). The entire P rate was applied at sowing. Just three weeks after sowing, intensive soil samples were collected to determine Pc and Pf. Available P was determined using Olsen's method.

Critical phosphorus level was determined using the Cate-Nelson diagram method, where soil phosphorus values are put on the X-axis and the relative grain yield on the Y-axis. While the Phosphorus requirement factor was calculated using available phosphorus values in the samples collected from unfertilized and fertilized plots.

Data Analysis

The agronomic data were statistically computed using SAS software version 9.0. Mean separation was done by LSD at a 5% level. Economic analysis was performed following procedures described in CIMMYT (1998).

RESULT AND DISCUSSION

Initial Soil pH and Phosphorus of the Experimental Sites

Soil test results of the study sites before planting indicated that the pH values of most soils were strongly acidic according to Chude *et al*. (2005) rating. Available phosphorus of experimental soil in both districts ranged from 1.3 to 15.41 ppm (Table 1). This low available phosphorus could be due to fixation in such acidic soils. Mamo and Haque (1987) and Solomon *et al.* (2002) reported that the availability of P in most soils of Ethiopia declined by the impacts of fixation as a result of low pH. In order to increase the bioavailability of P in such soil, an increase in soil pH is the best management option to minimize fixation.

Yield Responses of maize to N and P fertilizers during Optimum N Determination Trial

The maize grain yield responses to the main and interaction effects of Nitrogen and phosphorus fertilizer were presented in the following Table 2. The main effects of N and P significantly influenced the mean grain yield of maize but their interaction was not significant with a grand mean of 76.53 qt/ha in Abay Choman district.

Table 1: Selected experimental soil properties of experimental sites before planting in Abay Choman District for the 2019/20 and 2020/21 cropping season

Sites	PH (H_2O)	Av. P (ppm)	Ex. Acidity (cmol(+)/kg)
1	5.01	5.25	0.15
2	4.69	3.22	0.12
3	4.85	8.19	0.16
4	4.75	11.45	0.18
5	4.86	7.74	0.16
6	5.21	10.1	0.19
7	5.54	12.85	0.23
8	4.52	4.44	0.14
9	4.54	11.38	0.20
10	4.55	9.13	0.20
11	4.56	13.22	0.18
12	5.21	11.62	0.18
13	4.74	9.42	0.27
14	4.79	12.62	0.24
15	4.71	13.62	0.18
16	4.65	12.02	0.15
17	4.68	11.42	0.19
18	4.7	11.22	0.20
19	4.58	13.62	0.22
20	4.52	11.22	0.13

Table 2: Main and interaction effects N and *P* on grain yield of Maize in Abay Choman district as the whole during N determination trial

Factors	Abay Choman District
Nitrogen (N)	***
Phosphorus (P)	**
N*P	NS
Mean (Kg/ha)	7653.45
CV (%)	17.87

The results clearly indicated that N and P were limiting nutrient factors. It is in general in accordance with the results of several studies, which showed the positive response of maize grain yields and yield related parameters (Khan *et al*., 2014).

Optimum N Fertilizer Rate Determination for Maize Production

Economic analysis using a partial budget showed that fertilizer rates of 92 kg N/ha were economically optimal for the production of maize in the Abay Choman district (Table 3).

Critical Phosphorus level Determination

The scattered plots using the Cate-Nelson diagram method showed that 12 ppm was a critical phosphorus level for maize production in Abay Choman (Figure 2). Soil phosphorus values are taken from each plot taken three weeks after planting put on the X-axis and the respective relative grain yield on the Y-axis.

Phosphorus requirement factor Determination

The Phosphorus requirement factor (Pf), for maize production at the Abay Choman district, was found to be 10.55 Kg P/ha

Table 3: Summary of partial budget analysis for optimum N fertilizer recommendation for maize production at Abay Choman district

N (kg/ha)	P (kg/ha)	AGY (Qt/ha)	GFB (ETB/ha)	FC (birr/ha)	TSC (birr/ha)	HBC (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
0	0	39.93	25953.57	0.00	1197.86	798.57	1996.4	23957.14	
0	10	45.02	29265.41	645.50	1350.71	900.47	2896.7	26368.72	267.88
0	20	50.71	32964.30	1291.00	1521.43	1014.29	3826.7	29137.58	297.72
0	40	58.69	38148.81	2582.00	1760.71	1173.81	5516.5	32632.28	206.81
46	20	70.90	46088.09	2639.00	2127.14	1418.10	6184.2	39903.85	56.12
46	40	75.76	49245.24	3930.00	2272.86	1515.24	7718.1	41127.14	105.83
92	0	66.86	43457.14	2696.00	2005.71	1337.14	6038.9	37418.29	244.69
92	10	68.62	44602.38	3341.50	2058.57	1372.38	6772.5	37829.93	56.11
92	20	75.36	48986.75	3987.00	2260.93	1507.28	7755.2	41231.54	346.13
138	0	64.52	41940.47	4044.00	1935.71	1290.48	7270.2	34670.28	228.15
138	10	69.64	45267.86	4689.50	2089.29	1392.86	8171.6	37096.21	269.11
138	20	73.29	47635.71	5335.00	2198.57	1465.71	8999.3	38636.43	186.10
138	40	78.95	51319.04	6626.00	2368.57	1579.05	10573.6	40745.42	133.96

Where AGY = Adjusted grain Yield; GFB = Gross field benefit; FC = Fertilizer cost; TSC = Total service cost; HBC = Harvesting and bagging cost; TVC = Total variable cost; NB = Net Benefit and MRR = marginal rate of return
Remark: Dominated treatments are not included in the table

Table 4: Pf Calculation for maize production in Abay Choman District

P rate (Kg/ha)	Av. P (ppm) in soil	P increased over Control	Pf (Kg/ha)
0	6.14		
10	7.40	1.26	7.92
20	8.44	2. 30	8.71
30	8.84	2.70	11.11
40	9.28	3.13	12.77
50	10.22	4.07	12.27
Mean			10.55

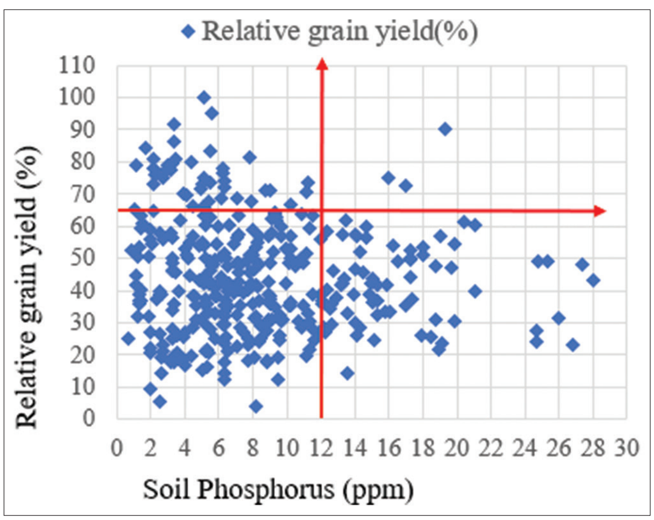

Figure 2: Scattered plot of relative grain yield (%) of maize and soil test phosphorus (Olsen) in Abay Choman District

(Table 4). It is computed from the difference between available soil test P values from plots that received 0-50 kg P/ha using the second formula mentioned above. This Phosphorus requirement factor enables us to determine the quantity of P required per hectare to raise the soil test by 1 ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level.

CONCLUSION AND RECOMMENDATION

The study showed that; P- critical value (12 ppm) and P- requirement factor (10.55 Kg/ha) were determined for the phosphorus fertilizer recommendation for maize production in Abay Choman District. Thus, the farmers might be advised to use soil test crop response-based fertilizer recommendations to increase the productivity of Maize in the Abay Choman District.

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