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Demonstration of Soil Test Crop Response Based Phosphorus Fertilizer Recommendation on Bread Wheat in Yaya Gulele District, North Shewa Zone, Oromia, Ethiopia

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Abstract: Wheat is a major crop produced in Ethiopian high lands which is a staple food crop. Regardless of this fact, average productivity of the crop both at National and Regional level is very low as contrasted with the world average yield due to different factors and among them low soil fertility is a major. Hence, Pre-extension demonstration of soil test based crop response phosphorus calibration study on bread wheat was conducted at YayaGuleledistrict of North Shewa zone during 2019/20 cropping season with the objectives to demonstrate P-critical value and P-requirement factor for phosphorus recommendation of bread wheat. Five kebeles were purposively selected based on the wheat production potential in the study area. A total of six farmer's fields with initial phosphorus concentration below critical Phosphorus Concentration for the district were selected. One Farmers Research Group comprising 15 farmers by considering gender was established at each kebeles and training was delivered for farmers, DAs, and district experts on soil test crop response based phosphorus recommendation for bread wheat production. The bread wheat crop were fertilized by blanket recommendation (100:100 kg ha^{-1} of Urea and DAP) and soil test crop response based phosphorus recommendation on 20m*20m plot size. The phosphorus fertilizer rate was calculated based on the formula [(23-pi)*3.76] established for the district. Improved variety of bread wheat Danda'a was used as a test crop with 150 kg ha^{-1} seed rate. Grain yield and farmer feedback/preference were collected. The results of the study revealed that the soil reaction (H_2O) were moderately to slightly acidic with the value ranged from 5.54 to 6.54, low to high available P with the value ranged from 7.92 to 20.73 ppm. The result of the study also showed that, the highest grain yield and net income were obtained from application of Soil test based P-fertilizer recommendation supplemented with 92 kg ha^{-1} of N and which gave 49.48%yield advantage over the blanket fertilizer recommendation. The MRR obtained from Soil test based P-fertilizer recommendation was economically feasible and the highest MRR and net income were obtained from soil test based fertilizer recommendation. Thus, farmers in the district of YayaGulele could be advised to use soil test based crop response phosphorus recommendation to increase the bread wheat production.

Keywords: Pre-extension Demonstration, FRG, Soil Test Based Fertilizer Recommendation, MRR, Net Income

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 [1] 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 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 [9].

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 [6, 10, 14]. 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. 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 [8].

Soil test based crop response phosphorus calibration study and verification of Soil test based phosphorus recommendation on wheat crop was conducted in Yaya Gulale district having different P and N levels and promising result was obtained. The finding of the study indicated that Critical phosphorus concentration (23ppm) and Phosphorus requirement factor (3.76) was verified along with blanket recommendation and without fertilizers on farmers' field [4]. Accordingly, fertilizer application based on soil test significantly increased yield of bread wheat and thus improves its production. Therefore, this activity was initiated to demonstrate P - critical value and P- requirement factor for bread wheat obtained from P-fertilizer calibration study.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted in Yaya Gulele district on wheat production potential kebeles (small administrative unit). The district far 114 Km from Finfinne to North West. The geographical location ofdistrict ranges from 09°33'0" to 09°42'0"N and 38°30'00" to 38°45'00" E. The mean annual rainfall of the district is 1000 mm and 25°C annual mean temperature.

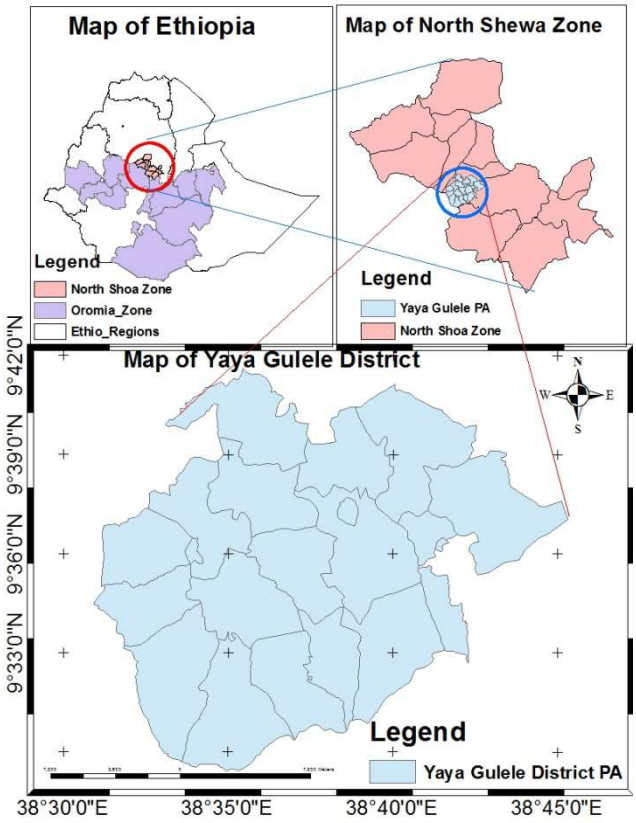

Figure 1. *Location map of the study area.*

2.2. Site Selection, Soil Sampling and Experimental Procedures

Wheat production potential kebeles (small Administrative unit) were selected from the districts. Accordingly, to select experimental sites, 30 soil samples were collected from different farmer's field before planting at a depth of 0-20 cm following the standard procedures. The collected soil samples were analyzed for pH by pH meter [13] and available phosphorus by spectrophotometer [7]. Then the farmer's field was selected based on the analyzed soil sample results in which available soil phosphorus below critical phosphorus (Pc) was selected for the experiments. Then Phosphorus fertilizer requirement was calculated using the formula as;

$$\text{Phosphorus fertilizer rate (kg/ha)} = (pc\text{-}pi)*p_f$$

Where; Pc=Critical phosphorus concentration (23 ppm),
Pi = Initial available P,
Pf = Phosphorus requirement factor 3.76.

Then the demonstration was conducted on 6 farmer's fields with 20m*20m plot area plot area for each treatment. Blanket recommendation and soil test based P-fertilizer recommended rate with recommended nitrogen level (92 kg of N ha^{-1}) were used as a treatment. The improved bread wheat variety danda'a was used. DAP and Urea was used as source of fertilizer. Uniform field management was conducted for all plots.

2.3. FRG Establishment and Training

The activity was conducted in purposively selected five kebeles from the district based on their wheat production potential, initial available phosphorus level of soil and their accessibility for supervision. The FRG member farmers were selected based on their lands suitable and sufficient to accommodate the trials, willingness to be held as member and share innovations to other farmers. Selection of farmers was done with the collaboration of development agents and district experts. Then the selected farmers in each kebeles were grouped in to Farmers Research Group (FRG) considering gender issues (women, men and youth). In each selected kebeles, one FRG units comprising of 15 farmers and one experimental field was established with the rest of farmers were being participant farmers. Totally, five FRG were established in the district.

After the establishment of FRGs a theoretical training session was arranged to farmers, development agents and experts on a topic of soil test based crop response phosphorus fertilizer recommendation for wheat production and improve farmer's knowledge and perception towards the technology in the study areas.

2.4. Data Collected

Grain yield, farmers' perception towards the growth performance of bread wheat due to fertilizer application through the soil test based crop response phosphorus fertilizer recommendation and total number of farmers participated in training was collected.

2.5. Data Analysis

The collected data was analyzed using SPSS and interpreted as mean and standard deviation. Partial budget analysis was done to identify economically feasible fertilizer recommendation rate between blanket and soil test based fertilizer rates application according to [2].

Thus, marginal rate of return (MRR) were calculated by using the formula given by;

$$MRR = \frac{NetIncomeFromFertilizedField - NetIncomeFromUnfertilizedField}{TotalVariableCostFromFertilizerApplication}$$

3. Result and Discussion

3.1. Soil Reaction (pH) and Available Phosphorus of Experimental Field

The soil pH (H_2O) of the study area was moderately to slightly acidic with the value ranged from 5.54 to 6.54 according to the ratings suggested by [11]. Thus, the pH of the experimental soil was within the range for productive soils. The available phosphorus content of soils was low to high with the value ranged from 7.92 to 20.73 ppm according to the ratings suggested by [3] (Table 1). Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for crop production.

Table 1. *Soil pH and Available Phosphorus of experimental field.*

Farmers field (site)	pH	Avail. P
Site 1	5.54	7.92
Site 2	5.64	20.73
Site 3	5.94	19.9
Site 4	6.16	14.4
Site 5	6.54	11.78
Site 6	5.58	10.44
Mean	5.80	13.90
SD	0.39	5.19

Where: SD = Standard Deviation.

3.2. Response of Bread Wheat Grain Yield to Blanket and Soil Test Crop Response Based Phosphorus Fertilizer Recommendation

The result of the study shows that wheat grain yield was highly increased with the application of 92 kg ha^{-1} of N and site specific fertilizer recommendation which gives 49.48% advantage over the blanket type of fertilizer recommendation. The highest mean grain yield (2995.83 kg ha^{-1}) was recorded with the soil test based calibration result which was higher than blanket fertilizer application (2004.20 kg ha^{-1}). Similarly, [4, 5, 12] reported that, soil test based phosphorus fertilizer recommendation gave the maximum grain yield of wheat and advantageous than blanket recommendation.

Table 2. *Bread wheat grain yield (kg ha^{-1}) during 2019/20 cropping season.*

Site (Farmers field)	Blanket recommendation	Soil test based P-fertilizer Recommendation	Yield advantage (%)
1	1450	2625	81.03
2	1875	3225	72
3	1450	2750	89.66
4	2125	2500	17.65
5	2500	3125	25
6	2625	3750	42.86
Mean	2004.20	2995.83	49.48
SD	505.33	465.14	
CV (%)	25.21	15.53	

Where: SD = Standard Deviation, CV = Coefficient of Variation.

3.3. Provision of Training

Before implementing the demonstration of soil test based phosphorus fertilizer recommendation technology, training for the participant farmers and different stakeholders was provided. Eighty three (83) participant farmers from district were selected by collaboration with district Agriculture and Natural Resource Office. Beneficiary farmers, Kebeles development Agents and district experts were selected for the training. The training was provided on soil test based phosphorus fertilizer recommendation technology and agronomic practices. The main

aims of training was to create awareness of farmers, development agents (DA's) and district as expert and to compare results finally obtained from demonstration. A total of 83 participants (63 farmers, 12 experts and 8 DA's) were trained (Table 3). Also, participants were shared their best experiences on how soil fertility management.

Table 3. *Number of participants on training.*

Topic of training	Location	No of FRG	Farmers trained (FRG)		Expert		Total
Pre-Extension demonstration of soil test crop response based phosphorus recommendation on bread wheat	AGP II district (Yaya Gulele)	5	M	F	M	F	
			63	12	5	3	83

Where: No = Number, AGP II = Agricultural Development Program Two, FRG = Farmers Research Group, M = Male, F = Female.

From the training, farmers were learned from researchers, DA's and also from each other. The participants had got better knowledge and skill on soil test based crop response phosphorus fertilizer recommendation for bread wheat production. In addition to this, farmers asked further research work on other major crop to increase the crop production. This showed that, the level of knowledge of farmers improved through trainings. Thus, researchers got feedback for future research work through linkage with development agent, farmers, experts and other stakeholders to strengthen the demonstration of technology. Therefore, all participants in the technology training prefer soil test based crop response phosphorus fertilizer recommendation for bread wheat production over the blanket fertilizer application and show the interest to practice site specific fertilizer recommendation for their future wheat production.

Table 4. *Partial Budget Analyses of bread wheat Grain yield.*

Fertilizer rate	Variable Input (Kg/ha)		Unit price (ETB)		TVC	Output (Kg/ha)	Unit price (ETB)	Gross Income	Net Income	MRR (%)
	DAP	Urea	DAP	Urea						
Blanket recommendation	100	100	12.73	10.4	2313.0	2004.2	20	40084	37771.0	-
Soil test based P-recommendation	156.27	138.35	12.73	10.4	3428.2	2995.83	20	59916.6	56488.4	545.98

Where: TVC=Total variable cost; MRR=Marginal rate of return.

3.4. Partial Budget Analysis

To estimate the economical significant of the different fertilizer rates, partial budget analysis [2] 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 2019/20 harvesting season (personal observation) farm gate price of 20 ETB (Ethiopian Birr) per kg of wheat, 12.73 and 10.4 Birr per kg of DAP and Urea, respectively were used to calculate variable cost. The Marginal Rate of Return (MRR) was found to be 545.98% for soil test based phosphorus fertilizer recommendation rate (Table 4). The economic analysis showed that the highest net income (56488.40 ETB) was obtained from soil test based P-fertilizer recommendation with marginal rate of return (545.98%) which is greater than the minimum rate of return (MRR) 100% [3]. Thus, the MRR showed that it would yield 5.45 birr for every birr invested.

4. Conclusion and Recommendation

The pre extension demonstration was conducted in YayaGulele district to demonstrate the determined optimum amount of nitrogen (92 kg N ha^{-1}), P requirement factor (3.76ppm) and the critical P concentration (23 ppm) for bread wheat in YayaGulele districts. Five FRG were established in purposively selected kebeles and training was provided on the topic of soil test based crop response fertilizer recommendation for farmers, developmental agents, experts and stakeholders in the district.

An optimum nitrogen (92 Kg ha^{-1}) rate and soil test based phosphorus fertilizer recommendation influence grain yield of bread wheat. Accordingly, the maximum grain yield was (2995.83 kg/ha) with 49.48% of yield advantage over the blanket fertilizer recommendation. The economic analysis also showed that the highest net income (56,488.40 ETB) was obtained from soil test based fertilizer recommendation with marginal rate of return (545.98%) which is greater than the acceptable minimum rate of return (100%) which was economically feasible. Although, based on the training delivered, all participants prefer soil test crop response based phosphorus fertilizer recommendation for bread wheat production show the interest to practice site specific fertilizer recommendation for their future wheat production.

In general, the study indicated that soil test based crop response fertilizer recommendation is superior than the farmers practice/blanket fertilizer recommendation in terms of yield, net benefit and MRR. Therefore, site specific soil test based crop response fertilizer recommendation could be recommended for further scaling up and popularization in YayaGulele district of North Shewa Zone.

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