World Journal of Agricultural Science and Technology
2024, Vol. 2, No. 3, pp. 102-110
https://doi.org/10.11648/j.wjast.20240203.14

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Research Article

Pre Extension Demonstration of Soil Test Crop Response Based Recommended Phosphorus Fertilizer for Maize in Bako Tibe and Gobu Sayo Districts of Western Oromia, Ethiopia

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Abstract

Pre-extension demonstration of soil test crop response based phosphorus fertilizer recommendation for maize was conducted in Bako Tibe and Gobu Sayo districts with the objective of participatory demonstration of soil test crop response based phosphorus recommendation under farmers' condition in 2022 cropping season. Two treatments were applied (T_1) blanket Recommendation (T_2) Soil Test crop response based recommended phosphorus fertilizer with improved maize (BH-661) variety. The trial was conducted on eleven farmers' fields which were used as replications. Plot size for each treatment was 10m x 20m with the spacing of 35cm and 75cm between plants and rows respectively using seed rate of 25 kg ha^{-1} and with recommended optimum N-fertilizer rate of 110 kg ha^{-1}. In each PAs, one FREG unit comprising of 20 farmers were established. About 185 (139 male and 46 female) participants were take part on field visit based training held during physiological maturity of maize. The average total biomass with soil test crop response based Recommended phosphorus fertilizer was 32,385 kgha^{-1} while blanket recommendation was 27,730 kgha^{-1}. Again the average grain yield for STCRBPR was 7,205kg ha^{-1} while blanket recommendation was 4,641kg ha^{-1}. Similarly, the results of the economic analysis indicated that the use of p-fertilizer based on soil test crop response and the blanket suggestion with MRR 500.93% could yield net returns of 188,029.36 and 119348 ETB per hectare, respectively. As a result, the suggested phosphorus fertilizer based on soil test crop response should be expanded/scaled up to include additional maize producer farmers in the region and surrounding districts.

Keywords

Blanket Recommendation, Pre Extension, Phosphorus Requirement Factor, P-critical Value, Soil Test Based

1. Introduction

Maize (Zea mays L.) is an important cereal crop, which ranks third after wheat and rice, based on area coverage and production in the world) [6]. According to Central Statistical Authority) (2018) report Maize is one of the worlds' three primary cereal crops. It occupies an important position in world economy and trade as a food, feed and industrial grain

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Received: 20 May 2024; **Accepted:** 28 June 2024; **Published:** 20 August 2024

crop. It is increasingly an important crop for food security and source of income smallholder farmers in Africa [1, 10]. It is stands out as a success story of the ambitious agricultural productivity development goals of the Ethiopian government to lift millions of smallholder households out of food insecurity [1]. Maize is one of the most important cereals cultivated in Ethiopia. It ranks second after Teff in area coverage and first in total production. It is largely produced in Western, Central, Southern and Eastern parts of Ethiopia.

Despite the large area under maize, the national average yield of maize is about 2.95 tha^{-1} [3]. This is by far below the world's average yield which is about 5.21tha^{-1} [6] The low productivity of maize is attributed to many factors like declining of soil fertility, poor agronomic practice, limited use of input, insufficient technology. Low soil fertility is one among the major factors limiting maize production and productivity in western Oromia, Ethiopia. This is common in many tropical cropping systems. Soil fertility is the inherent capacity of the soil to provide essential chemical elements for plant growth. A fertile soil is not necessarily a productive soil because productivity emphasizes the capacity of soil to produce crops and be expressed in terms of yields [8].

The three macro nutrients, N, P and K are usually considered the most important nutrients for plant production. We have focused on Phosphorous because the role of P is an important factor in food security but we recognize that numerous other factors are involved. Although blanket recommendations were issued some years ago, they might not be appropriate for the current production systems and are currently in use throughout the nation of Ethiopia. Farmers have been fertilizing their fields with the same rate of phosphorus fertilizer regardless of soil fertility fluctuations since the temporal and spatial variations in soil fertility have not been adequately taken into account. [9] The process of establishing a connection between a certain soil test result and the yield response from fertilizer addition of nutrients to the soil is known as soil phosphorus calibration. Additionally, it offers details on the quantity of nutrients to be added at a specific soil test value in order to maximize crop development while minimizing waste and validate the accuracy of the most recent P recommendations. [14]. Reliable soil test-based and site-specific nutrient management.

Finally, to solve the above problem Bako Tibe and GobuSayo districts were selected for pre-extension demonstration based on previously calibrated phosphorous. Pre extension demonstration activity were conducted before further popularization to evaluate the calibrated Phosphorus in the two districts and create awareness to the community.

2. Material and Method

2.1. Description of the Study Area

The experiment was carried out at Gobu Sayo and Bako Tibe Districts of Eastern Wollega and west shoa Zone of Oromia National regional state of western Ethiopia. Bako Tibe is located 250 Km west of Addis Ababa and geographically at latitude of 9^0 08'N and 37^0 03'E longitude with elevation of 1743 m.a.s.l (Figure 1). Gobu Sayo on the other hand located at about 265 km west of Addis Ababa and is contiguous with Bako Tibe district in the east. The district geographically lies between 9.170^0 N and 36.982^0 E longitude with elevation of 1944 masl. The annual rainfall of the two districts ranges minimum 887mm and maximum 1658mm. The area has a warm-humid climate, mean annual rainfall of 1237 mm that varies between 887 mm (year 2012) to as high as 1658 mm (year 2020) with maximum precipitation occurring from May to August. Annual mean minimum and mean maximum air temperatures of area ranges between 13.5°C and 29.7°C with a mean annual relative humidity of 52.15% [7]. The two districts were dominated by Nitisols. The economy of the area is based on mixed cropping system and livestock raring agricultural production system among which dominant crops are maize, teff, sorghum and Hot pepper. (Source: Agricultural office of the two districts).

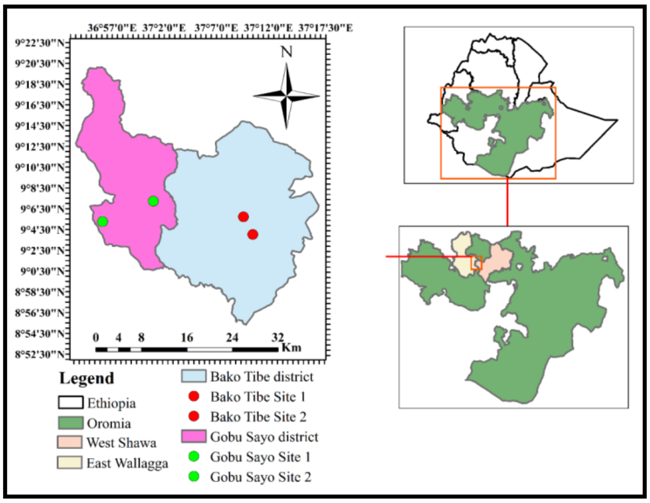

Figure 1. *Location map of the study area.*

2.2. Research Methodology

2.2.1. Site Selection and FRG Establishment

The Pre-extension demonstration of soil test crop response based recommended Phosphorus fertilizer for Maize (BH661) was conducted in Bako Tibe and Gobu Sayo districts of West Shoa and east wellega Zones respectively. The sample farmers were selected based on potential for maize production and Willingness of technology acceptance. From each district two representative Kebeles were selected and four farmers Research Group (FRG) were established. Accordingly, in each kebeles one FRG/FREG unit was established which consists of 15-20 members by taking into account all categories of farmers and the concept of gender disaggregation. The demonstration trial was laid out on 11 (eleven) farmers field. as replication. The plot size was 10m x 20m allotted for both STBCRPFR and farmer practice.

2.2.2. Soil Sampling and Analysis

Each trail field had one composite soil sample, which was taken between 0 and 20 cm below the surface and brought to a lab for physical preparation. Using common laboratory techniques, the phosphorus that was available was examined in the lab. The rate of fertilizer to be applied was determined based on the soil's initial phosphorus status. Thus, the formula is Pap (kg ha-1) = (Pc-Po)*Pf. Where Po is the initial P value for the trial field, and Pc is the critical P value and Pf is the P requirement factor, which were 14.5 ppm and 5.5 ppm, respectively, of the district. [10]. Moreover, the appropriate agronomic and management methods should be followed when applying the required nitrogen fertilizer rate of 110 kg ha-1 as soon as 30 days after planting.

2.2.3. Experimental Design and Procedure

The experiment was conducted on 11 farmer's field with plot size 10m*20m. The spacing between row and plant was 75cm and 35cm respectively. The space between block and plot also 1m and 0.5m respectively. By using 25kgha^{-1} of improved maize of BH-661 seed rate farm management was carried out by hosting farmers; whereas activities such as planting, first and second weeding, harvesting, threshing were handled by FRG/FREG members with the facilitation of the researchers.

2.2.4. Technology Demonstration Approach

Many extension activities were arranged at a representative site according to the rate of phosphorus fertilizer needed for the maize demonstration. Field visits and tours, trainings, and other methods are utilized to improve the learning and information sharing between farmers. Farmers, office specialists, and designated area managers (DAs) received training centered on field visits and demonstrated treatment variability on the host farmer's path. Researchers from Bako Agricultural Research Center trained the participants on the idea and fundamentals of crop response based fertilization (FRG), the function and accountability of FRG members in overseeing the trial, soil sampling techniques, and the significance of crop response based on soil test recommendations for phosphorus fertilizer. The training that was conducted throughout the crop maturity stage involved field visits.

2.3. Mood of Communication

During the execution of the demonstration activity, appropriate extension approaches or participatory extension-teaching methods (individual, group, and mass contact methods) were used alone or in a wise combination depending on the circumstances.

2.4. Economic Analysis

Marginal rate of return (MRR) was calculated both for farmer practice and soil test based crop response values by using the following formula.

$$\mathrm{MRR} = \frac{\text{Net income from STBCRPR}-\text{BR}}{\text{Total variable cost from STBCRPR}} * 100$$

2.5. Data Analysis Method

The soil data and yield data was managed by micro soft office excel computer and simple descriptive statistics Subjected to compare mean grain yield and biomass yield data. While the economic related data was analyzed using cost-benefit analysis.

3. Result and Discussion

3.1. Training and Field Day

Mini field day and training was given to farmers, DAs, woreda experts and other concerned bodies. Accordingly, a total of 185 stakeholders (139 male and 46 females) were participated on the training (Table 1). In addition, field visit was arranged to observe experimental site (Figures 2 and 3) participants observed different experimental site and appreciate performance of technologies. Participants reflect their feedback during the field visit conducted as the fertilizer application based on soil test promotes increased and efficient use of fertilizer for improving maize production in the future, and they request technical support to be befitted from technologies.

Table 1. *Gender disaggregated stakeholders participated on field visit based training events.*

Participants	District				Total
	Bako Tibe		Gobu Sayo		
	Male	Female	Male	Female	
Farmers (FRG)	58	18	40	22	138
DAs	4	-	3	1	8
Other stake holders	18	2	16	3	39
Total	80	20	59	26	185

Figure 2. *Field vist based training was given to farmers.*

Figure 3. *Field visit and discussions.*

3.2. Soil Reaction (pH) and Available Phosphorus

The pH (H_2O) of soil sample collected before planting were ranged from (5.02 to 5.2) (table 2). Accordingly, the soils were strongly acidic in reaction. [5] Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cation from highly weathered [8] The result indicate that soil pH affects the production of maize, which is below the world's average yield [6] The mean result of available phosphorus before planting ranged from (3.82-4.09) for the two districts. According to (Table 2) these result falls in low rate. The low contents of available P observed in the soil of the study areas were in agreement with the results reported by [4, 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.

Table 2. Over all Summary of the initial Soil Chemical Properties.

Parameters	Location			
	Bako Tibe	Gobu Sayo	Rating	Reference
pH (1:2.5) H2O	5.02 Strongly acidic	5.2	Strongly acidic	Jones, J. Benton (2003)
Avel P (ppm)	4.09 Low	3.82	Low	FAO. (2006).
%OC	2.27 Moderate	2.77	Medium/Moderate	Tekalign, (1991)
%OM	3.91 Moderate	4.78	Medium/Moderate	Tekalign, (1991)
%TN	0.15 Moderete	0.18	Medium/Moderate	Tekalign, (1991)

Key: pH-power of Hydrogen, avaP-available Phosphorus, %OC-Organic Carbon, %OM-Organic Matter, %TN-total Nitrogen.

3.3. Organic Carbon and Total Nitrogen

The initial organic carbon and total nitrogen for both locations were rated as medium/moderate (2.27%-2.77%). [12] This result revealed that the status of soil were at moderate level and need additional sources of organic carbon like FYM to increase the rates of %OC and %TN and which increases production and productivity of livelihood farmers. [15].

3.4. The Blanket Recommendation of NP-fertilizers and STBCRPR Per Demonstration Site

In order to produce maize in Bako Tibe and Gobu Sayo district, the ideal nitrogen rate of 110 kg N ha^{-1}, P-critical level of 14.5 ppm, and P requirement factors of 5.5 were identified. This paper served as the basis for calculating the rate of phosphorus fertilizer needed for the maize demonstration. As a result, the Ethiopian Ministry of Agriculture's recommended 1:1 ratio of NPS to Urea (100 kgha^{-1} of NPS and 100 kgha^{-1} of Urea) was used for the blanket recommendation (BR) treatment, while soil test crop response based phosphorus fertilizer recommendation was applied using calibration recommendation. [15]. The available phosphorus level at the demonstration site varied, as shown in table 2. The demonstration locations' starting available phosphorus ranged from 3.32 ppm to 4.4 ppm, falling into the low range (table 2).

3.5. Yield Performance of the Demonstration Site

The overall result of demonstration site of the trial conducted at Bako Tibe and gobu sayo Districts were showed that the highest mean grain yield of maize (7205 Kg ha-1) was obtained by the application of optimum 110 Kg ha^{-1} and P from Pa=(PC-Pi)*Pf [11]. The highest grain yield obtained was more greater than the grin yield obtained from farmers practice (4641 Kg ha^{-1}). Not only grain yield but also the mean total biomass of STCRBPFR was higher (323.85 Kg ha^{-1}) over blanket fertilizer recommendation (277.3 Kg ha^{-1}.

The aforesaid outcome and Dagnes's work were in agreement. According to him, fertilizer recommendations based on soil test crop response exhibit a greater yield than recommendations based just on fertilizer type. [4]. With a 57.55% grain yield advantage over the blanket type fertilizer prescription, the usage of the optimal nitrogen fertilizer and the site-specific suggested P-fertilizer rate affected the maize grain yield (table 3).

Table 3. Yield and Yield Components of the demonstration site.

Site		PH (cm)		TBM (kg/ha)		GY (kg/ha)	
	FF	BR	STBCRFR	BR	STBCRFR	BR	STBCRFR
	F1	2.98	3.1	355.2	372.96	53.4	78.1
	F2	3.08	2.78	315.24	371.48	56.5	83.7
Bako Tibe	F3	3.02	3.21	313.76	362.6	49	75.6
	F4	2.97	3.33	291.56	497.28	55.9	85.1

Site		PH (cm)		TBM (kg/ha)		GY (kg/ha)	
	FF	BR	STBCRFR	BR	STBCRFR	BR	STBCRFR
	F5	2.52	2.6	267.88	275.28	49	71.5
	F6	2.68	2.73	168.72	185	35	53.3
	F7	2.8	3.14	266.4	343.36	46.4	78.5
	F8	2.67	2.76	293.04	315.24	40.2	66.5
	F9	2.8	2.79	304.88	321.16	48.9	73.7
Gobu Sayo	F10	2.45	2.46	214.6	236.8	39	63
	F11	2.45	2.54	259	281.2	37.2	63.5
	Mean	2.77	2.86	277.30	323.85	4641	7205

Key: FF- Farmers' Field, PH- plant height, TBM- Total biomass, GY-Grain yield

Due to the application of optimum 110kg/ha N fertilizer and Site specific phosphorus fertilizer recommendation with extra NP-fertilizer used than that of Blanket type fertilizer recommendation. [4]. The use of optimum110kg/ha N and site specific recommended P-fertilizer rate was influenced the maize grain yield with 57.55% grain yield advantage over the blanket type fertilizer recommendation (figure 4).

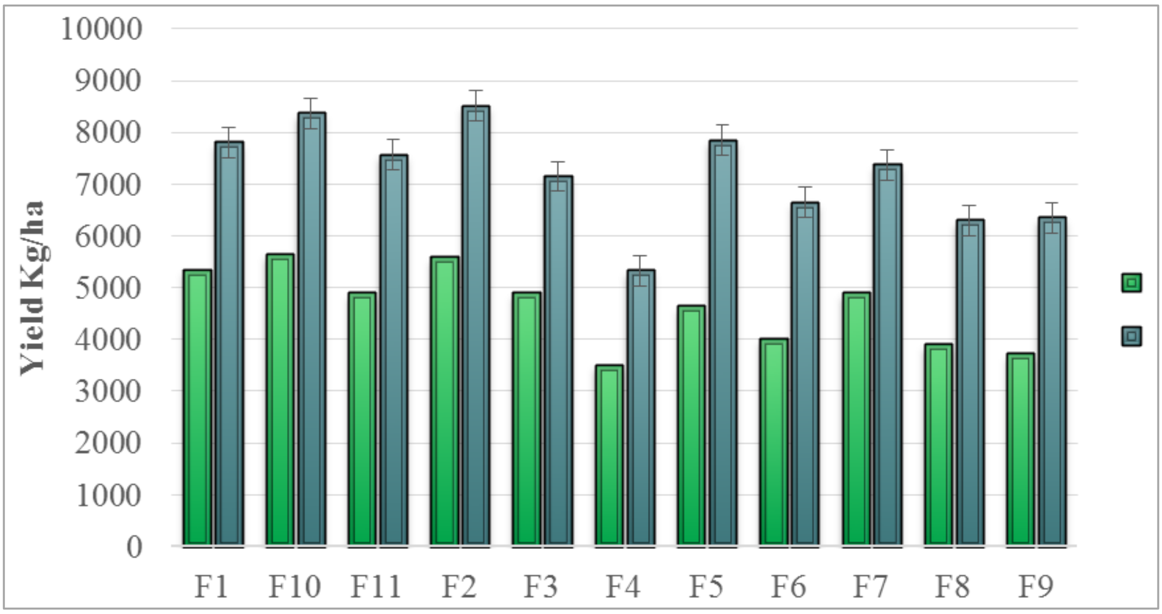

Figure 4. *Mean maize grain yield of STCRBPFR and BR across the demonstration site.*

3.6. Total Dry Biomass over the Demonstration Site

The cumulative mean of dry biomass (32,385 kg/ha) and (27,730 kg/ha) result was recorded from STCRBPR and blanket recommendation respectively. The optimum use of Nitrogen fertilizer and site specific phosphorus fertilizer recommendation still influence the blanket type fertilizer recommendation. (Figure 5).

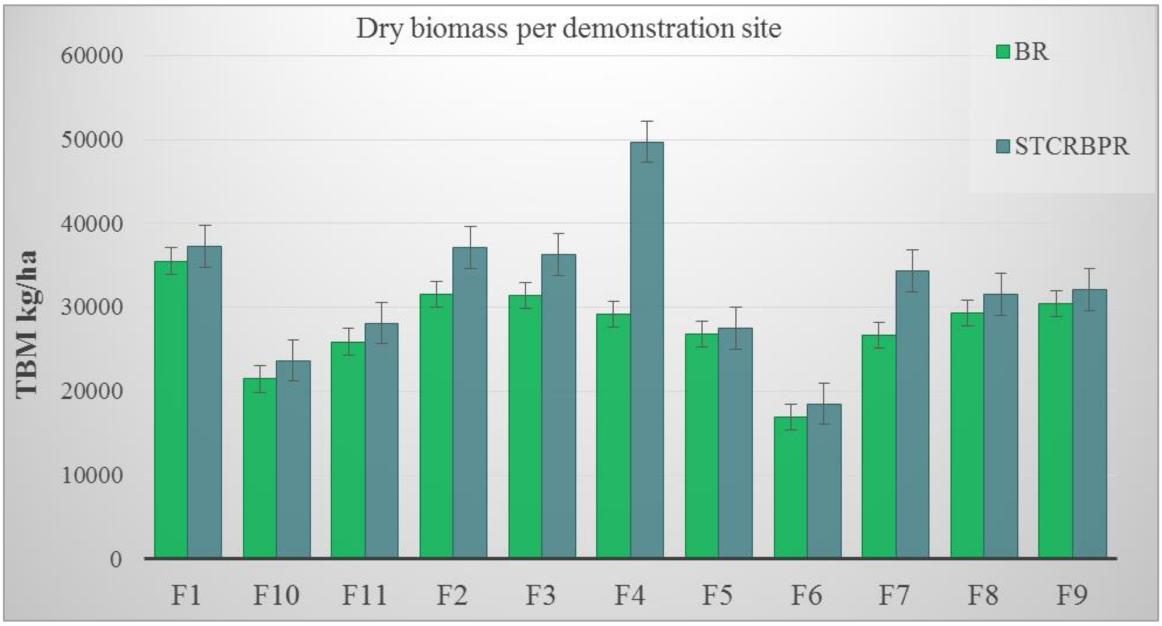

Figure 5. Total biomass STCRBPR Vs BR per demonstration site.

3.7. Economic Analysis

To assess the costs and benefits associated with different treatments the partial budget analysis techniques as described [2] was employed to calculate the Marginal Rate of Return (MRR). Economic analysis was done using the prevailing market prices for inputs at planting and for out puts at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian birr. Accordingly, inputs like seed, NPS and Nitrogen fertilizers price were 10,600 and 13,710.64 ETB for blanket recommendation and soil test based crop response fertilizer recommendation respectively during planting time were as Maize grain yield (Output) was 2800 ETB qt^{-1} at field price. The economic analysis result shows that net of return 500.93% for soil test crop response based phosphorus fertilizer recommendation. Accordingly, the economic analysis reviled that the highest net income (188,029.36 ETB) were obtained from soil test crop response based fertilizer recommendation and (119,348 ETB) from blanket recommendation per hectare could be gained from soil test crop response phosphorus fertilizer recommendation in the study area. (Table 5).

Table 4. Partial Budget Analysis for maize crop.

TRT	Yield Kg ha^{-1}	Unit price (ETB) Qt^{-1}	Gross Return (price*Qt)	Total variable cost (ETB)	Net Return (GR-TVC)	MRR (%)
Farmer's Practice	4641	2,800	129,948	10,600	119,348	-
STCRBPFR	7205	2,800	201,740	13,710.64	188,029.36	500.93

STCRBPFR= soil test crop response based phosphorus fertilizer recommendation

3.8. Participatory Evaluation and Farmer's Perception

All FRG members and neighboring farmers, develop agents, Woreda experts and researchers were closely evaluate the performance of soil test crop response based on their own criteria. The farmers' feedback or farmer's perception was collected during demonstration.

3.9. Pair-Wise Farmers' Preference Ranking

At the end of the evaluation process, result of the evaluation was displayed to the evaluators, and discussion was made on the way ahead. Number of cob per plant, disease tolerant and other traits were considered as the most selection criteria for each of maize under different practices.

***Table 5**. The farmers' preference result was summarized and presented in table below.*

Selection Criteria	1	2	3	4	5	6	7	8	9	10	Frequency	Rank
1		1	1	1	1	1	1	1	9	1	8	2nd
2			2	2	5	2	2	2	9	2	6	4th
3				4	5	6	7	8	9	10	0	7th
4					5	6	4	4	9	4	3	4th
5						5	5	5	9	5	7	3rd
6							6	6	9	6	5	5th
7								7	9	7	3	6th
8									9	8	2	7th
9										9	9	1st
10											1	8th

N. B. 1= Disease tolerant, 2= Lodging tolerant 3= Early maturity, 4=Cob length, 5= Number of cob/plant, 6= Grain color, 7= Crop stand, 8= Stay greenness; 9= high yielder and 10= Grain size.

Based on overall mean score the best preferred practice was evaluated and ranked. The best practice selected, accordingly, will be proposed for further scaling up. Therefore; STCBPFR was ranked and selected first by all the traits including yield then followed by Blanket recommendation.

***Table 6**. Depending on farmers' preference result ranking was made.*

No	Practice	Rank	Reason
1	Maize under soil Test Based	1st	High yielder, disease tolerant, lodging tolerant, high number of cobs per plant (mostly two cobs per plant), good plant stand, good cob length
2	Blanket Recommendation	2nd	Low yielder, medium in disease tolerant, medium in lodging tolerant, minimum number of cobs per plant (mostly 1 cob per plant), medium plant height/ stand, Medium cob.

4. Conclusion

According to the study, p-fertilizer recommendations based on crop response and yield performance of soil tests were more effective in reducing performance variability among demonstration sites than farmers' blanket fertilizer recommendations. Variations in soil fertility condition and management techniques may be the cause of yield performance variability. Even still, the average yield derived from soil test crop response phosphorus fertilizer recommendations was more than that of the fertilizer suggestion given by blanket. For maize output in the research area, the MRR showed that STCRBPR was more economically viable and profitable than fertilizer recommendations of a blanket kind.

5. Recommendation

To enhance production and productivity of maize at Bako Tibe and Gobu Sayo districts as well as adjacent districts having similar agro ecology and soil type the soil test based crop response phosphorus fertilizer recommendation should be further popularized through Scaling up approach with the participation of all stake holders.

Acknowledgments

The author would like to acknowledge Oromia Agricultural Research Institute for financial support and Bako Agricultural Research Center for providing logistics and necessary research materials. Again, my great heartfelt thanks go to all Soil Fertility Improvement Research team members for their unreserved contribution in all situations.

Conflicts of Interest

The authors declare no conflicts of interest.

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