International Journal of Applied Agricultural Sciences
2021; 7(6): 277-282
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20210706.14
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Pre-extension Demonstration of Soil Test Crop Response Based Recommended Phosphorus Fertilizer for Maize in Chora District in Southwestern Part of Oromia, Ethiopia

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To cite this article:
Suleiman Aman, Gedefa Sori. Pre-extension Demonstration of Soil Test Crop Response Based Recommended Phosphorus Fertilizer for Maize in Chora District in Southwestern Part of Oromia, Ethiopia. *International Journal of Applied Agricultural Sciences*. Vol. 7, No. 6, 2021, pp. 277-282. doi: 10.11648/j.ijaas.20210706.14

Received: October 27, 2021; **Accepted**: November 26, 2021; **Published**: December 11, 2021

Abstract: Pre-extension demonstration of soil test crop response based phosphorus fertilizer recommendation for maize was conducted in Chora district with the objective of participatory demonstration of this technology under farmers' condition in 2019 cropping season. Two treatments were (T_1) blanket recommendation and (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 16m x 32m with the spacing of 50cm and 80cm between seeds and rows respectively using seed rate of 25 kg ha^{-1} and with recommended optimum N-fertilizer rate of 92 kg ha^{-1}. In each PAs, one FREG unit comprising of 20 farmers were established. About 90 (66 male and 24 female) participants were take part on field visit based training held during physiological maturity of maize. The average grain yield obtained with soil test crop response based Recommended phosphorus fertilizer was 59.64 qt ha^{-1} while blanket recommendation was 44.59 qt ha^{-1} with yield advantage of 34% in the study area. Likewise, economic analysis result showed that net of return 28836.10 and 23811.00 ETB per hectare could be gained from soil test crop response based p-fertilizer recommendation and blanket recommendation respectively with MRR 125.47%. Therefore, soil test crop response based recommended phosphorus fertilizer should further scale up/out to reach more maize producer farmers in area.

Keywords: Pre-extension, Soil Test, Fertilizer Recommendation, Maize, Farmer Practice, FRG

1. Introduction

Maize is one of the most important cereals broadly adapted worldwide [1] It is largely produced in Western, Central, Southern and Eastern parts of Ethiopia. In Ethiopia, its total annual production and productivity exceeds all other cereals by 23.24% and second after tef in area coverage by 16.12% and its production was estimated as 3.94 ton ha^{-1} [2]. 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 [3]. One of the main causes for this discrepancy is the low use of external inputs, leading to negative balances for N, P and K [4].

With rapid population growth, continuous and intensive cropping without restoration of the soil fertility, has depleted the nutrient base of most soils [5] resulting in poor crop yields. Nutrient depletion could be even worse in highly populated countries such as Ethiopia [6]. Hence, low soil fertility is one among the major factors limiting maize production and productivity in Ethiopia [7]. In addition, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation [8].

Phosphorous is the most yield limiting of soil supplied elements and soil phosphorus tends to decline when soils are used for agriculture [9]. Other studies have reported that Nitisols and other acid soil areas in Ethiopia have low available phosphorus content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion [10].

Blanket recommendations that are presently in use all over the Ethiopian country were issued several years ago, which may not be suitable for the current production systems [11]. Since the spatial and temporal fertility variations in soils were not well considered, farmers have been applying the same Phosphorus fertilizer rate to their fields regardless of soil fertility differences.

Soil phosphorus calibration is a means of establishing a relationship between a given soil test value and the yield response from adding nutrients to the soil as fertilizer. Likewise, it provides information on how many nutrients should be applied at a particular soil test value to optimize crop growth without excessive waste and confirm the validity of current P recommendations [12]. Sound soil test based and site specific nutrient management is essential in reversing this trend and increase crop yield in agricultural land. Results of soil tests must be calibrated against crop response from applications of the plant nutrients in question [13].

Soil calibration study predicts the probability of response from applying a given nutrient which must be determined experimentally in the field [14]. Calibrations are specific for each crop type, soil type, soil pH, climate plant species, and crop variety [15, 16]. Currently, soil fertility research improvement is geared towards site specific fertilizer recommendation. Therefore, the establishment of a reliable soil test based crop response can assist in the determination of phosphorus requirements. Moreover, it involves a correlation to find an extracting for soil nutrients for a laboratory test that was the best mine an amount of a nutrient proportional to what a plant extracts [15].

To overcome this maize limiting factors; the recommended doses of fertilizer application is very imperative that take into consideration the nutrient status of the individual fields. Previously, soil test crop response based phosphorus calibration study was conducted for maize in Chora district [17]. Hence, site-specific soil test based fertilizer recommendation rate ensures balanced nutrition to crops and affordability of fertilizers for smallholder farmers. Therefore, study was initiated to undertake participatory demonstration of soil test crop response based phosphorus fertilizer recommendation for maize under farmers' condition.

2. Research Methodology

2.1. Description of the Study Area

Chora district is located at 519 km from the capital city of Ethiopia, Addis Ababa and 36 km from Buno Bedele zonal capital town, Bedele. The district is located at an average elevation of 2000 m.a.s.l and located at 08°13'33.7" to 08°33'55.0"N (latitude) and 035°59'59.7" to 036°15'15.8"E (longitude). It is characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The annual rainfall ranges from 1000-1500mm. The district is 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 wheat. Chora has 33 kebeles among which 3 kebeles were used for this study.

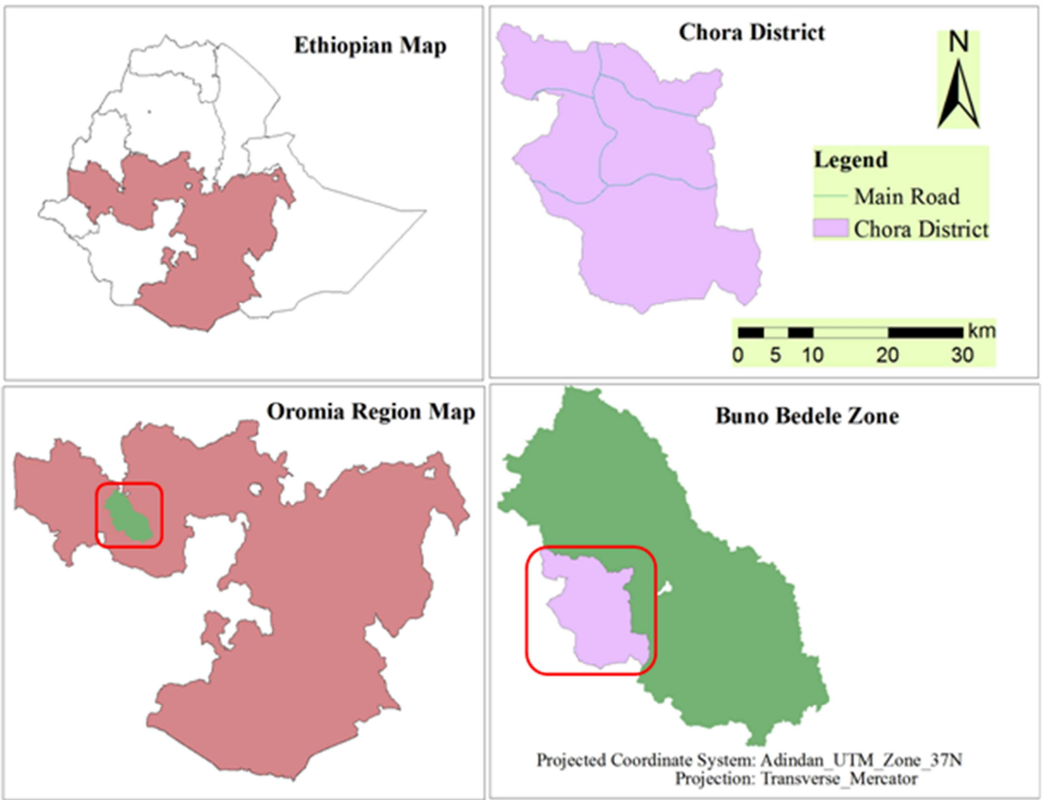

Figure 1. *Map of the Study Area.*

2.2. Site Selection

Pre-extension demonstration of soil test crop response based recommended Phosphorus fertilizer for Maize (BH661) variety was carried out in Chora district of Buno Bedele zone. Purposive sampling method was employed to select the district based on the potential for maize production and completed calibration study. Similarly, from the district three representative Kebeles were selected based on their road accessibility and production potential of the crop.

2.3. Farmer Selection

FRG approach was followed in order to simplify the demonstration process and enhance active participation of FRG/FREG members and concerned stakeholders during the implementation of the activity. Accordingly, in each kebeles one FRG/FREG unit was established which consists of 20 members by taking into account all categories of farmers and the concept of gender disaggregation. During FRG members selection; farmers' willingness to be held as member, good history of compatibility with groups, proximity and commitment to share innovations to other farmers were considered. From the established FRG/FREG members in each kebeles, four representative hosting farmers were selected in collaboration with community leaders, SMS, DAs and the members themselves. Accordingly, it was laid out the demonstration trial on 11 (as one host farmer live out the membership duo to security problem) farmers' field by considering each farmer field as replication of the trial.

2.4. Field Design and Materials

The whole demonstration plot size of 32m x 32m was allotted for both soil test crop response based phosphorus fertilizer recommendation and farmer practice for maize replicated per 11 farmers field by using the recommended spacing of 80 and 50 cm between rows and seed (two seed per hole) respectively using the seed rate of 25 kg ha^{-1}.

The slop of trial field, crop rotation and road accessibility was considered and one composite soil sample per trail field was collected at the depth of 0-20 cm to analyze available phosphorus in the soil with standard laboratory procedures. Depending on initial phosphorus status in the soil, rate of fertilizer to be applied was calculated with P (kg ha^{-1})=(Pc-Po)*Pf formula. Where: Pc=Critical P value and Pf=P requirement factor which were 8.5 ppm and 6.64 respectively of the district and Po=Initial P values for the trial field. In addition, the recommended nitrogen fertilizer rate, that was 92 kg ha^{-1} applied at 30 days after planting with the necessary agronomic and management practices. Farm operations 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.

2.5. Technology Demonstration Approaches

FRGs members and other follower farmers were encouraged to participate on different extension events organized at well representative site. These are the mechanisms used to enhance farmer-to-farmer learning and information exchange such as trainings, field visits/tours and FGD. Field visit based training was provided for farmers and experts (DAs and SMS) on convinced (well variability between the treatments) host farmers trail field. The training was provided by BeARC researchers on the concept and principles of FRG, the role and responsibility of the FRG members in managing the trial, method of soil sampling and importance of soil test crop response based recommended phosphorus fertilizer to build the knowledge and skills of the participants toward the technology. The conducted field visit based training during crop maturity stage strengthens the linkage among researchers-development agents and farmers in the study area.

2.6. Mood of Communication Used

In extension, there are no one-size-fits-all solutions. Hence, appropriate extension approaches (participatory) and all extension-teaching methods (individual, group and mass contact methods) were employed alone or in a judicious combination according to the situations during the implementation of the demonstration activity.

2.7. Data Collected and Method of Analysis

The grain yield, number of farmers and other stakeholders participated on field visit based training data were recorded. Cost incurred and profit obtained data was collected. Simple descriptive statistics were used to analyze the quantitative data while the economic related data was analyzed using cost-benefit analysis.

3. Results and Discussions

3.1. Participatory Field Visit Based Training for Participants

Participatory field visit based training was given to participants on the concept and principles of FRG, the role and responsibility of the FRG members in managing the trial, method of soil sampling and importance of soil test crop response based phosphorus fertilizer recommendation and at the end of the training; participants visit the trial field as all FRG members practice on their own field and while others share the experience. A total of 90 participants among which 62 farmers (44 male and 18 female), 6 DAs (6 male and 0 female) and 22 other concerned stakeholders (16 male and 6 female) were participated on field visit based training.

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

District	Participant	Male	Female	Total
	Farmers	44	18	62
Chora	DAs	6	-	6
	Other stakeholders	16	6	22
Total		66	24	90

3.2. The Recommended Phosphorus and Nitrogen Fertilizers per Demonstration Site

As [17] reported during calibration study; optimum nitrogen rate 92 kg N ha^{-1}, P-critical level (8.5 ppm) and P-requirement factors (6.64) were determined for maize production in Chora district. Based on this report the rate of phosphorus fertilizer required for maize demonstration was determined. As a result, soil test crop response based recommended Phosphorus fertilizer treatment was implemented using calibration recommendation whereas blanket recommendation (BR) treatment was implemented using 1:1 ratio of NPS and Urea (i.e., 100 $kgha^{-1}$ of NPS and 100 $kgha^{-1}$ Urea recommended by the Ethiopian Ministry of Agriculture and Rural Development.

***Table 2.** The NP fertilizer recommendation per demonstration site.*

Sites	P_o (initial p values) (ppm)	P_c (P critical level) (ppm)	Pf (Requirement factor)	Rate of P-fertilizer applied Kg/plot		Rate of N-fertilizer applied Kg/plot	
				BR	STCRBFR	BR	STCRBFR
site 1	1.019	8.5	6.64	5.1	15.3	5.1	10
site 2	1.533	8.5	6.64	5.1	14.3	5.1	10
site 3	0.698	8.5	6.64	5.1	16.0	5.1	10
site 4	5.067	8.5	6.64	5.1	7.0	5.1	10
site 5	1.644	8.5	6.64	5.1	14.0	5.1	10
site 6	0.296	8.5	6.64	5.1	16.8	5.1	10
site 7	4.211	8.5	6.64	5.1	8.8	5.1	10
site 8	0.822	8.5	6.64	5.1	15.7	5.1	10
site 9	1.073	8.5	6.64	5.1	15.2	5.1	10
site 10	2.046	8.5	6.64	5.1	13.2	5.1	10
site 11	1.157	8.5	6.64	5.1	15.0	5.1	10
Average	1.78	8.5	6.64	5.1	13.75	5.1	10

Note: BR=Blanket Recommendation; STCRBFR=soil test crop response based fertilizer recommendation.

The result presented on Table 2 indicates that the available phosphorus level within the demonstration sites were inconsistent. Available P of the demonstrated sites was ranged from 0.3 - 5.1 ppm which categorized under very low range (Table 2). The inconsistency of available P entire the farmers' field was due to inherently low P content, high P fixation capacity, crop harvest and soil erosion of Ethiopian agricultural soils particularly the Nitisols and acid soils [10]. Therefore, the soil of the study areas needs application of phosphorus containing fertilizers for maize production.

3.3. Yield Performance of the Demonstration Site

The result of the trial conducted at Chora district showed that maize grain yield was higher (68 qt ha^{-1}) with application of optimum 92 kg ha^{-1}N and site-specific Phosphorus fertilizer recommended [17]. As reported by [17] with extra use of NP fertilizers recommendation, the maize grain yield and economic profitability was not added in the study area. The highest mean grain yield (71 qt ha^{-1}) was recorded with the soil test based calibration result treatment which was higher than the farmer practice (24 $qtha^{-1}$). Dange Chimdessa reported that, soil test crop response based fertilizer recommendation shows the higher yield as compared to blanket fertilizer recommendation [18]. The use of optimum 92 kg ha^{-1} N and site specific recommended P-fertilizer rate was influenced the maize grain yield with 34% grain yield advantage over the blanket type fertilizer recommendation (Table 3).

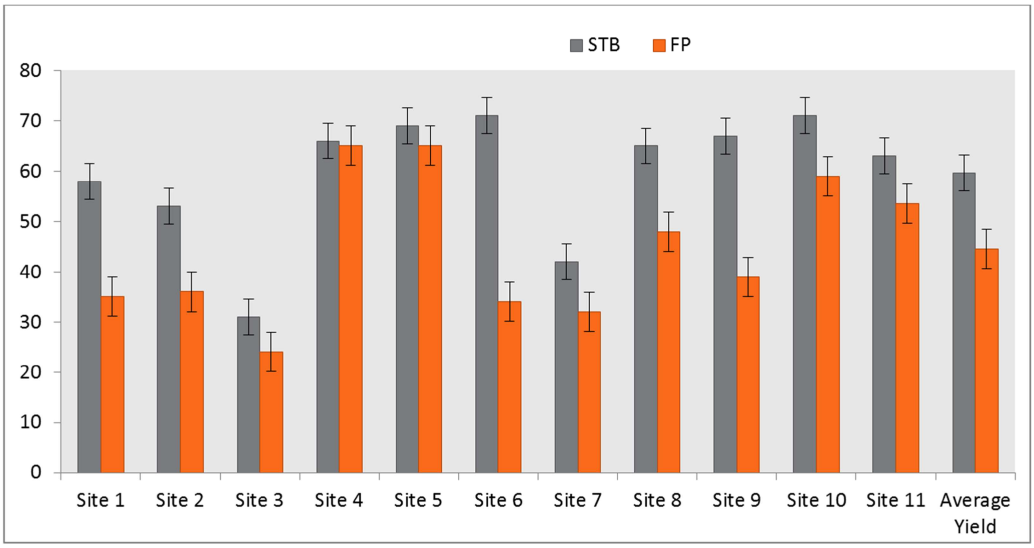

***Figure 2.** Average maize grain yield across the demonstration sites.*

Table 3. *Average maize grain yield per treatments.*

Treatments	Grain yield (qt ha^{-1})		Average	% increment
	Minimum	Maximum		
Blanket Recommendation	24	31	44.59	34% yield increment over the blanket type for grain yield
STCRBFR	65	71	59.64	

Note: STCRBFR=soil test crop response based p-fertilizer recommendation

3.4. Economic Analysis

To assess the costs and benefits associated with different treatments the partial budget technique as described by [19] was applied on the yield results. Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian birr (ETB ha^{-1}).

Accordingly, inputs like seed, NPS and N-fertilizer price were 5280, 1549 and 1394 ETB qt^{-1} respectively during planting time whereas maize grain yield (output) was 600 ETB qt^{-1} at field price. The economic analysis result show that net of return 28836.10 and 23811.00 ETB per hectare could be gained from soil test crop response p-fertilizer recommendation and Farmer Practice respectively in the study area.

Table 4. *Partial budget analysis.*

Treatments	Yield (kg ha^{-1})	unit Price (ETB qt^{-1})	Gross Return (Price x Qt)	Total variable costs (ETB ha^{-1})	Net Return (GR-TVC)	MRR (%)
Blanket recommendation	44.59	600.00	26754	2943.00	23811.00	-
STCRBFR	59.64	600.00	35784	6947.90	28836.10	125.47

Note: STCRBFR=soil test crop response based P-fertilizer recommendation, ETB=Ethiopian Birr

4. Conclusion and Recommendations

In spite of the inevitable variability in performance between and even within the demonstrated sites, yield performance of soil test crop response based p-fertilizer recommendation was still promising over farmer blanket type of fertilizer recommendation. The variability in yield performance might have stemmed from difference in the status of soil fertility and its management practices. Despite this fact, the average yield obtained from soil test crop response based recommended phosphorus fertilizer was higher than that of blanket type fertilizer recommendation. Likewise, the average net of return gained from soil test crop response based recommended phosphorus fertilizer was more profitable than that of blanket recommendation. Therefore, the scaling up/out of soil test crop response based recommended NP-fertilizers should be carried out for further maize production in the study area.

Acknowledgements

The authors would like to thank Oromia Agricultural Research Institute (IQQO) and Bedele Agricultural Research Center (BeARC) for funding the research and providing all the necessary facilities required for the research, respectively. Our special thank also forwarded to all staff members, especially to Laboratory Technicians team for their support of soil samples analysis data on time.

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