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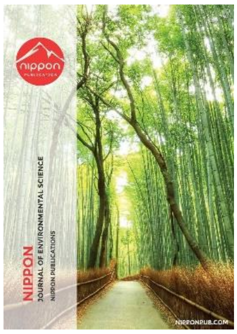

Full Length Research Paper

Validation of Fertilizer Requirement Map for bread wheat at Lume District, East Shewa Zone, Oromia, Ethiopia

Tilahun Abera*, Reta Worku, Tilahun Firomsa, Tadesa Hunduma, Bekele Abebe

Batu Soil Research Center, P. O. Box 59, Batu, Oromia, Ethiopia

*Corresponding Author: tileabera3@gmail.com

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Abstract. Fertilizer recommendations in Ethiopia in general and Lume district, in particular, are of blanket type for bread wheat production and are based on soil color characteristics rather than on soil test results and crop requirements. Hence Batu Soil Research Center was produced fertilizer requirement map and field experiments were carried out on nine peasant associations of Lume district to validate the quality of fertilizer requirement map on some yield components and yield of bread wheat crop. The treatments consisted of Control (unfertilized plot), Blanket (100/100 NPS/Urea), P-map (phosphorus applied from fertilizer requirement map) and P-required (Pc-P0)*P_f) were laid out with simple adjacent plots and replicated over nine location (Peasant association). The Analysis of Variance indicates that Bread wheat grain Yield, Biomass and Harvest index were highly significantly (P<0.01) influenced by treatment applied. P-required (Pc-P0)*$P_{f)}$ gave the highest (4039 kg ha^{-1}) grain yield and (9964 kg ha $^{-1}$) Biomass yield except (47.33%) harvest index which was recorded by P-map (phosphorus applied from fertilizer requirement map). While the lowest (1072 kg ha^{-1}) grain yield and (3294 kg ha $^{-1}$) Biomass and (32.03%) harvest index were recorded by unfertilized plot. However, the economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map (phosphorus applied from fertilizer requirement map) is profitable for Bread wheat crop production and recommended for farmers in Lume district.

Keywords: Bread wheat, Blanket recommendation, P-map, P-required, validation of fertilizer requirement map.

1. INTRODUCTION

Wheat is the dominant crop in temperate countries being used for human food and livestock feed. Now, approximately 80% of the wheat area in Ethiopia is planted to bread wheat (Negassa et al., 2013). Global wheat production in 2018 was estimated at 734 million tons with 214 million ha area harvested. Similarly, wheat production in Ethiopia in 2018 was estimated at 4.24 million tons with 1.75 million ha harvested (FAOSTAT, 2018). In Ethiopia wheat is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 m above sea level and with mean minimum temperatures of 6°C to 11°C (MoA, 2012). It is one of the most important cereals cultivated in Ethiopia. It ranked fourth after tef (*Eragrostis tef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area and production during 2015-16 cropping season, (CSA, 2016). It covered an area of 1.66 million ha with a total production of 4.21million tons and mean productivity of 2.535 t ha^{-1} during 2015-16 cropping season (CSA, 2016). There are two types of wheat grown in Ethiopia: durum wheat, accounting for 40 percent of production, and bread wheat, accounting for the remaining 60 percent (Bergh et al., 2012).

In Ethiopia, wheat grain is used in the preparation of a range of products such as: the traditional staple pancake (“injera”), bread (“dabo”), local beer (“tella”), and several others local food items (i.e., "dabokolo","ganfo", "kinche”). Besides, wheat straw is commonly used as a roof thatching material, and as a feed for animals. It accounts for about 11% of the national calorie intake (Demeke and Marcantonio, 2013). However the country is not self-sufficient in wheat, a substantial gap primarily due to inefficient transfer of technology and the lack of necessary inputs for wheat production (Geleta et al., 1994).

Fertilizer recommendations, in Ethiopia in general and Lume district, in particular, are of blanket type and are based on soil color characteristics rather than on soil test results and crop requirements. Such a practice leads to inefficient use of fertilizers by the crop since the amount to be applied can be more or less than the crop requires. As a result, the farmer may not be able to obtain the maximum benefit that is worthy of the money he has spent in purchasing the input. That is where site specific fertilizer recommendations are more comprehensive and beneficial since they can help to tailor fertilizer use more efficiently.

The science of soil-testing for nutrient management and fertilizer recommendations is widely accepted among Soil scientists and agronomists. Nutrient management recommendations should be established through soil test and plant tissue correlation and calibration procedures. Sound soil test calibration is specific for each crop type and they may also differ by soil type, climate, and the crop variety (Sonon and Zhang, 2014) and relates soil test measurement in terms of crop response (Bray, 1945; Rouse, 1965) and essential that the results of soil tests be calibrated against crop responses from applications of the plant nutrients in question as it is the ultimate measure of a fertilization program.

A fundamental assumption of site specific Soil fertility management is that economically optimum application rates of fertilizers. Soil fertility map is very important for fertilizer recommendations. To do soil fertility maps and fertilizer requirement maps, composite soil samples should be collected from mapping units and their digital soil fertility maps have to be prepared by using geostatistical interpolations to predict for non-sampled locations based on laboratory results of each parameters (Singh et al., 2010). The maps created with commonly used sampling and interpolations procedures may be found marginally to poor-quality in some cases. Therefore planers and users should evaluate map quality at test sites before adoption of maps for the whole recommendation (Mueller et al., 2001). Soil fertility Map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either by with in validation or cross validation analysis.

Validation involves independent sample collection and compares measured and estimated values for every validation points. Cross validation is often used to assess map quality because of it needs no additional resources and data. Cross validation involves removing an observation data from prediction. In some condition the validation of prepared soil fertility maps were done for two consecutive years as well as every year and if variation is significant, the maps should be readjusted by more sample collection (Mueller et al., 2001).

Batu Soil Research Center has finalized soil fertility and fertilizer requirement map for Wheat at lume District. The maps were done based on their P_c (phosphorous critical level) and pf (phosphorous factor which rise soil p by one ppm) that were developed by calibration studies conducted for Wheat. These outputs were initially geo referenced and by using ArcGIS10.1 their maps were created by Geo-statistical interpolation mainly Ordinary kriging. Hence validation of these maps are very important to demonstrate outputs by supporting with field/farm/ experiment, however the cross Validation were done at stage of interpolation selection.

Therefore this activity was conducted with the following objectives:-

- ✓ To validate fertilizer requirement map for bread wheat
- ✓ To introduce soil fertility and fertilizer requirement map at Lume district

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The experiment was conducted on 9 farmer's field in 9 (nine) Peasant Association, in Lume District, East Shewa Zone of Oromia Regional State in Central Ethiopia. The study was conducted at Lume district, East Shewa Zone of Oromia regional state, which capital town located at 73 kilometers far from Finfine (Addis Ababa) to the East. Geographically Lume district is located between 8^0 27'00" to 80 49'00" North and 39^0 5'00" to 39^0 16'00" East with total area coverage 67514.73hectares. The Elevation ranges from 1590 to 2512 meters above sea level, whereas the average elevation is 1909 meters above sea level.

2.2. Experimental Materials

- ✓ Bread wheat variety Qaqaba
- ✓ Blended fertilizer in the form of NPS (19% N, 38% P_2O_5 and 7% S) used as a source of N: P: S and Recommended optimum nitrogen (46 kg N/ha).

2.3. Way of evaluating the quality of fertilizer requirement Map

Soil fertilizer requirement map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either by with in validation or cross validation analysis. The maps were developed through soil sample collected from each mapping units developed at stage of base map preparation. These samples were analyzed for each parameter like NPK, pH, CEC, EC and texture at Batu Soil laboratory. These outputs were initially geo referenced and by using ArcGIS10.1, their maps were created by Geo-statistical interpolation mainly Ordinary kriging.

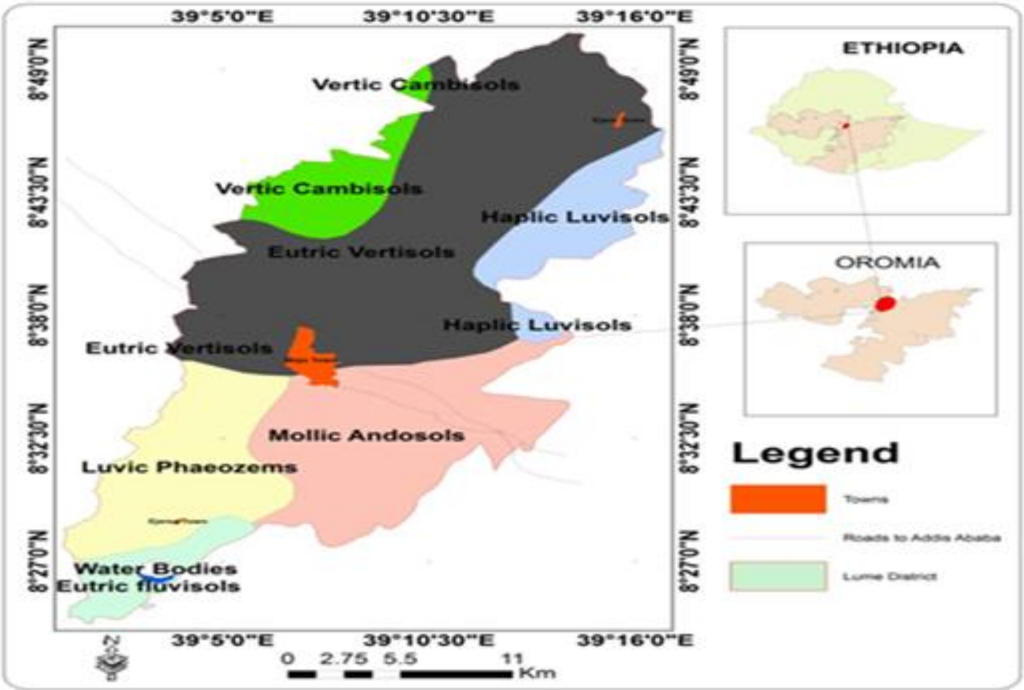

Figure 1. Location Map of Lume District

Farmers research group (FRG) or Farmers Research Extension group (FREG) establishment: The study was conducted on farmers' fields across the district for two consecutive years. First, nine different Peasant associations per district were selected for each year systematically based on their accessibility and potential. From these selected Peasant association, nine Farmers Research Extension group (FREG) groups, each consisted of 10-15 members for each PA's and organized considering gender and youth (40% women) with full participation of developing agent. Then after training these FREG's groups, one model farmer who can provide farm land for bread wheat production was selected from each FREG group, based on their willingness, with active participation of local development agent. Finally, one composite soil sample at 0-20cm depth was collected from each farm land in zigzag sampling method (a total of six composite samples). After labeling the sample, it was taken to Batu soil laboratory and analyzed for available P in order to identify the level of P in the soil to calculate amount of P fertilizer to be applied for bread wheat.

For the experiment, land preparation were done using the local ox plow by farmers with close supervision of researchers and Development agents (DAs) because all activities of plot management was accomplished by him, hence the approach was Cost-sharing mechanisms (Farmers provide farm land and handle all aspects of field/plot management while center was provide all agricultural input, technical support, training and guidance). Then, the amount of seed and fertilizer per plot was planted. Generally, with continuous field management, there were data collections across the location with full participation of DAs and farmers, and regular group discussion with farmers and DAs, to assess change in level of knowledge and skill of them to identify training need based on observed gaps in each crop growing stages. Besides, to popularize or for advocacy purpose, mini field day was organized at maturity stage of crop.

2.3.1. Reading phosphorus applied from fertilizer requirement map

Reading P-map (phosphorus applied from fertilizer requirement map) values for experimental sites by using the coordinate points of experimental sites the values of phosphorous requirement to be applied for bread wheat variety Qaqaba was collected and multiplied by P- factor of the district then converted to the fertilizer type to be used as kg/ha at the experimental sites.

2.3.2. Soil Sampling and Analysis

Validation of fertilizer requirement map involves independent sample collection and compares measured and estimated values for every validation points. Accordingly, based on fertilizer requirement map (Figure 2), from bread wheat growing potential Peasant association, those have different rate of fertilizer application and land unit that have large area coverage were identified and 20-25 composite soil samples from each field were collected to a depth of 0 - 20 cm from willingly selected 9 farmers' of 9 (nine) farmer research group established.

Five to fifteen soil samples were collected from each mapping unit to get one composite soil sample. Then the composite soil samples were air dried, grounded, and sieved using 2 mm sieve and were analyzed for soil texture, soil pH, EC and available phosphorus, using standard laboratory procedures at Batu Soil Research Center.

Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Van Reeuwijk, 1992). EC also measured in water at soil to water ratio of 1:2.5 by using Electrical conductivity meter. Soil texture was analyzed by Bouyoucous hydrometer method (Bouyoucous, 1951). After the samples were analyzed in Laboratory based on their coordinate points and related soil phosphorous values and Crop phosphorous critical level i.e. bread wheat the PR (phosphorous requirement for bread wheat) was determined as the (Nelson and Anderson, 1977) equation.

- PR= (PC- PO)* Pf

Whereas PR = Phosphorus requirement; PC = Phosphorus critical; and Pf = Phosphorus requirement factor; PO= Initial soil phosphorous

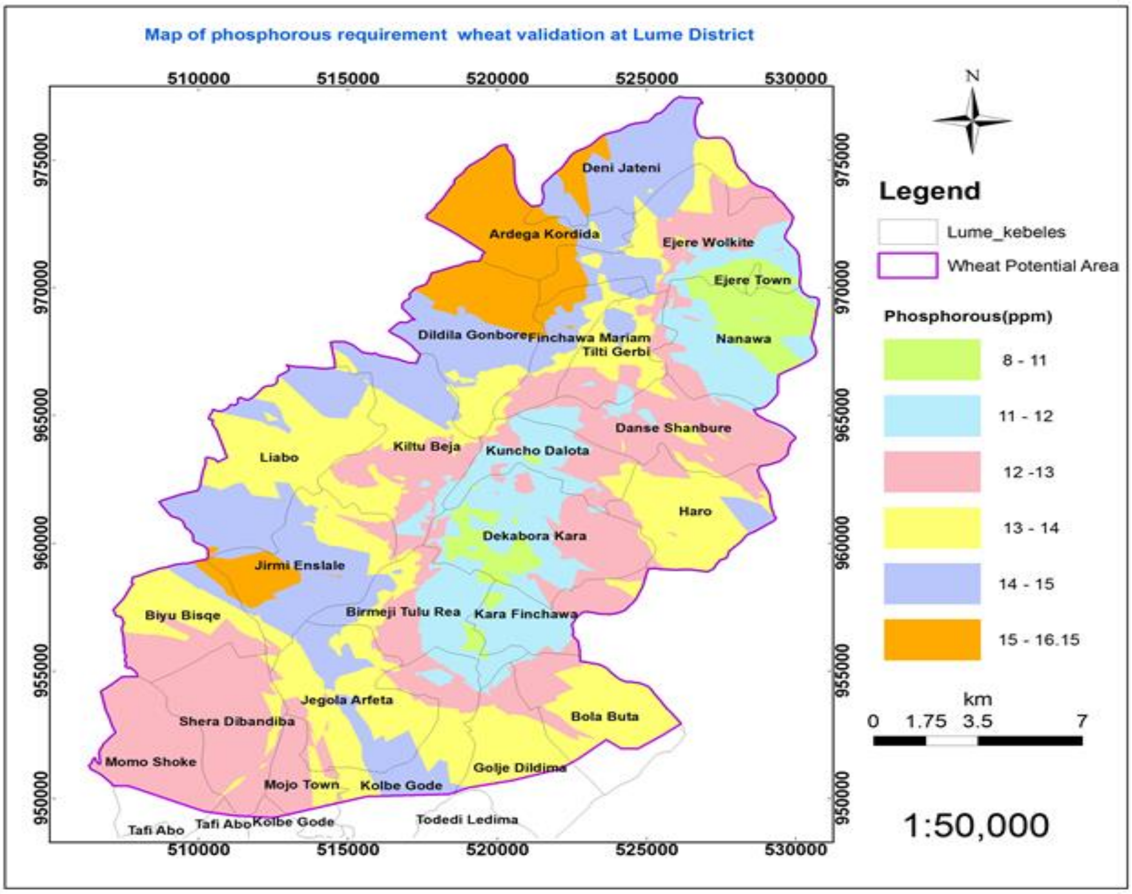

Figure 2. Validated phosphorus requirement map for wheat at Lume District

2.4. Treatments and Experimental Design

There were four treatments used for validation trail that include Bread wheat phosphorus fertilizer requirement (PR), Phosporus-map (P-map) that developed using fertility map and Blanket recommendation (100kg NPS and 100kg Urea) and control (without fertilizer application). While, value of PR for bread wheat was calculated from based on already determined Phosphorous critical and requirement factor for Bread wheat crop (Kefyalew et al., 2018). Whereas *Pc= 19 ppm and Pf = 4.92 ppm* and *Applied P = (Critical P - Po)* Pf.* The treatments were laid out with simple adjacent plots with nine replications over locations. The gross each plot size was 10 m x 10 m (100 m^2). Spacing of 1.0 m and 0.5 m was maintained in between adjacent blocks and plots, respectively and harvested from $4m^2$. The details of the treatments are shown in Table 1. Nitrogen fertilizer in the form of Urea (46%N) was used according to the recommended optimum rate of 46 kg N ha^{-1} (Kefyalew et al., 2018.)

Table 1. Quantity of fertilizer treatments used for Validation of fertilizer requirement map of wheat crop in kg/ha.

Sites	p-required		p- map		Blanket		Control
	Po (ppm)	P applied *Pc=19,pf=4.92*	Po (ppm)	P applied *Pc=19,pf=4.92*	NPS	Urea	No fertilizer
1	8.74	50.48	13.03	29.37	100	100	0
2	7.36	57.27	11.77	35.57	100	100	0
3	9.32	47.63	11.77	35.57	100	100	0
4	12.3	32.96	10.51	41.77	100	100	0
5	9.12	48.61	10.51	41.77	100	100	0
6	13.88	25.19	10.51	41.77	100	100	0
7	6.62	60.91	11.77	35.57	100	100	0
8	11.7	35.92	13.03	29.37	100	100	0
9	9.1	48.71	11.77	35.57	100	100	0

Whereas, po= initial soil phosphorus, Pc= critical soil phosphorous, pf= phosphorous requirement factor, Yld= yield, Bm = biomas, p- map= phosphorus applied from fertilizer requirement map, p-required = (Pc-P0)*P_f); Blanket= farmer practice

2.5. Management of the Experiment

The experimental field was prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done in July 2016 using seed rate of 150 kg ha^{-1}. Full dose of Phosphorous as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage.

While conducting the experiment others necessary agronomic management practices was carried out uniformly for all treatments. The crop was harvested at harvest maturity and was sun dried till constant weight before threshing.

2.6. Data Collection and Measurement

Aboveground dry biomass yield: The aboveground dry biomass yield was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: The grain yield was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): The harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

Thousand kernel weight: Thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

2.7. Statistical Analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

2.8. Partial Budget Analysis

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that will be tested. The discarded and selected treatments' using this technique was referred to as dominated and un-dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula MRR (%) = $\frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$

Where NB_a = Net Benefit (NB) with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest Total Variable cost (TCV).

3. RESULTS AND DISCUSSION

3.1. Yield Components and Yield of bread wheat

Table 2. Grain yield, Biomass, Harvest Index and thousand kernels weight of bread wheat variety as influenced by different method of phosphorus fertilizer application.

Treatments	GY(kg ha^{-1})	BM (kg ha^{-1})	HI (%)	TKW (g)
P- required	4039 ^{a}	9964 ^{a}	40.69 ^{ab}	32.64
P- map	3833 ^{a}	8744 ^{b}	43.77 ^{a}	32.65
Blanket	2656 ^{b}	6844 ^{c}	38.99 ^{b}	32.77
Control	1072 ^{c}	3294^{d}	32.03 ^{c}	31.55
LSD (0.05)	468.8	1122.6	3.531	NS
CV (%)	16.6	16.0	9.3	8.3

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; TKW = Thousand kernels weight; BM= Biomass yield; GY = Grain yield; HI% = Harvest index in percent; Pr = phosphorus required (45 kg P ha^{-1}); p- map= phosphorus predicted (36 kg P ha^{-1}), Blanket (100/100 NPS/Urea kg ha^{-1}, control (no fertilizer application).

Analysis of Variance indicates that Wheat Grain yield, Biomass yield and Harvest index were highly significantly ($P<0.01$) influenced by different method of phosphorus fertilizer application (phosphorus required, phosphorus predicted, blanket and control). However, thousand kernels weight was not significantly affected by treatment applied.

As indicated in Table 2, the highest (4039 kg ha^{-1}) grain yield, (9964 kg ha^{-1}) Biomass yield were recorded by P-required except (43.77%) harvest index which was recorded by P- map while the lowest (1072 kg ha^{-1}) grain yield, (3294 kg ha^{-1}) Biomass yield and (32.03%) harvest index were recorded by nil fertilizer application. P-required increased bread wheat grain and biomass yield by 272% and 202% over control, 52% and 45.58% over blanket respectively. Moreover, Grain and Biomass yield of bread wheat significantly increased from control to P-required however, grain yield at p-required and P-map was statistically at parity.

The highest grain yield at the highest P rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the three nutrients which enhanced yield components and yield. Nitrogen affects the vegetative as well as yields whereas phosphorus plays a fundamental role in metabolism and energy producing reaction and can withstand the adverse environmental effects, thus resulting in enhanced grain yield. The result is also in agreement with Bereket et al. (2014) who reported that grain yield of bread wheat significantly increased due to the main effect of nitrogen and phosphorus fertilization and obtained highest grain yields (4443 kg ha^{-1}) and (3988 kg ha^{-1}) at application of 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}a respectively. Similarly, Endalkachew (2006) also reported that above ground biomass and grain yield were significantly ($p \leq 0.01$) influenced by the P rates application of 30 kg P ha^{-1} increased the grain yield and biomass yield of wheat by 23.73% and 15.17% respectively when compared with the no P application.

3.2. Partial Budget Analysis

To identify treatments with the optimum return to the farmer’s investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers, 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in Table 4 the partial budget and dominance analysis showed that the highest net benefit 32396 Birr ha^{-1} was obtained in the treatment that was treated with P-required (Pc-P0)*P_f). While the lowest net benefit (9648 Birr ha^{-1}) was obtained in the control treatment. However, the highest marginal rate of return 1299% with the second Net return (31226 Birr ha^{-1}) was obtained from plot treated with P-map (phosphorus applied from fertilizer requirement map). According to this criterion, a farmer’s investment of birr 1 in P-map on bread wheat variety (Qaqaba) recoups the birr one and gives an additional 12.99 Birr similarly, a farmer’s investment of birr 1 in P-required (Pc-P0)*P_f) recoups the birr one and gives an additional 1.71Birr .

Table 1. Partial budget and marginal analysis of treatment applied over nine sites for bread wheat

Treatments	P (kg ha^{-1})	N (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR %
Control	0	0	1072	9648	0.00	9648	-
Blanket	16.5	46	2656	23904	2514.00	21390	467
P-required	45	0	4039	36351	3955.00	32396	171
P-map	36	5	3833	34497	3271.00	31226	1299

Where, NPS cost = 14.54 Birr kg^{-1}, UREA cost = 10.60 Birr kg^{-1}of N, NPS‚ Bread wheat grain per ha= 9 Birr kg^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized

4. CONCLUSION AND RECCOMENDATION

Ethiopia is not self-sufficient in wheat and its production and productivity have been far below the potential and hampered by low and declining soil fertility resulting in loss of essential plant nutrients such as phosphorus. This is because of primarily, blanket way of fertilizer application without considering agro-ecology, environmental effects, spatial and temporal soil fertility variations. Such practice leads to inefficient use of fertilizers by wheat since, the amount to be applied can be more or less than the crop requires. Therefore, soil test based crop response and site specific P fertilizer application with fertilizer requirement map are very important for fertilizer recommendations to improve the trend and increase crop yield; However, the Map was created with commonly used sampling and interpolations (ordinary kriging) procedures may be found marginally to poor-quality in some cases and the quality of the map evaluated at test sites before adoption of map for the whole recommendation. Hence field experiments were carried out on nine peasant associations to validate the quality of fertilizer requirement map on some yield component and yield of wheat crop. The treatments consisted of Control (unfertilized plot), Blanket (100/100 NPS/Urea), P-map (phosphorus applied from fertilizer requirement map) and P-required (Pc-P0)*P_f). The treatments were laid out with simple adjacent plots and replicated over location.

The Analysis of Variance indicates that Bread wheat grain Yield, Biomass and Harvest index were highly significantly ($P<0.01$) influenced by P-required (Pc-P0)*P_f) and gave the highest (4039 kg ha^{-1}) grain yield and (9964 kg ha $^{-1}$) Biomass yield. While the highest (43.77%) harvest index was recorded by P-map (phosphorus applied from fertilizer requirement map). while the lowest (1072 kg ha^{-1}) grain yield was recorded by control treatments (no fertilizer application). The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map (phosphorus applied from fertilizer requirement map) is profitable which gave the highest 1299% marginal rate of return with 31226 (Birr ha^{-1}) Net return and recommended for farmers of Lume District.

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