Sustainability in Environment
ISSN 2470-637X (Print) ISSN 2470-6388 (Online)
Vol. 9, No. 4, 2024
www.scholink.org/ojs/index.php/se

Original Paper

Determination of NPS Fertilizer Rate on Bread Wheat (*Triticum Aestivum* L.*)* in Yaya Gullele District of North Shewa Zone, Oromia, Ethiopia

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Received: August 23, 2024 Accepted: October 02, 2024 Online Published: October 17, 2024
doi:10.22158/se.v9n4p24 URL: http://dx.doi.org/10.22158/se.v9n4p24

Abstract

Inappropriate crop management practices are among the key elements that contributed to the low production of wheat. Moreover, the application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. Hence, a field experiment was conducted in the 2020 & 2021 main cropping season to determine the NPS fertilizer rate in relative to determined the P-critical and P-requirement factor for wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of wheat in Yaya gulale District. Accordingly the result indicated that, plant height was not significantly ($P > 0.05$) influenced by the NPS fertilizer rate but spike length, biomass, and grain yield were highly significantly ($P < 0.05$) affected by the NPS fertilizer rate. The highest plant height (86.72cm), spike length (6.57cm), biomass yield (12163kg ha^{-1}) and grain yield (3327 kg ha^{-1}) of wheat were recorded by the application of 75% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis indicates that, application of NPS fertilizer at the rate of 75% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of wheat was more economically beneficial for the district. In conclusion, farmers and other end users could be advised to use 75% PC from NPS fertilizer rate with recommended nitrogen for wheat production in the district and other areas having similar soil types and agro- ecology.

Keywords

Bread wheat Pc,Pf, NPS fertilizer rate, Recommended Nitrogen, yield

1. Introduction

Ethiopia is the largest wheat producer in sub-Saharan Africa with about 0.75 million ha of durum and bread wheat (Hailu *et al.,* 1991). Wheat is one of the major cereal crops grown in the Ethiopian highlands, which lie between 6 and 16° N, and 35 and 42° E, at altitudes ranging from 1500 to 3000 m. At present, wheat is produced solely under rain fed conditions. Currently, about 60% of the wheat area is covered by durum and 40% by bread wheat. Wheat is the fifth most important cereal crop both in area and production after Teff, maize, barley and sorghum (Hailu *et al.,* 1991).

Soils in sub-Saharan African (SSA) are degraded with low nutrient availability. This is partly a result of erosion, leaching, and depletion through clearing and cultivation of the land with minimal use of external sources of nutrients (Stoorvogel *et al.,* 1993; Bekunda *et al.,* 1997). The rate of soil fertility decline depends on soil erosion, nutrient removal in harvests, the rate at which nutrients are returned to the soil through the use of both inorganic fertilizer and organic manures, and the rate of mineralization of soil mineral and organic matter nutrients. The economic consequences of soil fertility/nutrient depletion are great with reduced farm production and food security.

For the last three decades, Ethiopian agriculture depended solely on imported fertilizer products, only urea and diammonium phosphate (DAP), sources of N and P. However, recently it is perceived that the production of such high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. In Ethiopia, major prone areas to Sulfur deficiency are the central highlands, because of their high crop production, which is driven by high market access in the big towns/cities in the center of the country. Reasons that lead to S deficiency in soils of central high lands include improved use of high analysis fertilizers that contain no S, intensive agriculture that leaves behind little organic matter (OM), and/or complete removal of OM for alternative uses, including farm yard manure (FYM), increased crop yields due to high yielding varieties, resulting in more Sulfur removal, and intensive cropping systems that include legumes and oil crops that mine more Sulfur.

Sulfur is a nutrient most overlooked in Ethiopian agriculture. In Ethiopia, the incidental addition of Sulfur from low analysis sources is nil due to a shift to high analysis fertilizers. It is true that farmers and extensions can indeed aim at increasing crop yields only in quantity by applying significantly higher amounts of NP from urea and DAP. But, in such conditions, failure to supplement Sulfur in balanced fertilizer programs can rapidly deplete available soil reserve leading to hidden Sulfur deficiency. Regardless of its importance, very little research is done on the status of soils and crops, and the available information/data are quite scanty.

Furthermore, nitrogen and phosphorus are considered the most deficient nutrients in the soils of Ethiopia (Asnakew *et al.,* 1991). This indicates that nitrogen and phosphorus are the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies within adjacent farms or plots mainly due to preceding individual farmers's soil management practices.

Therefore, developing site specific fertilizer recommendations that consider existing soil nutrient supply and recommend fertilizer based on crop nutrient demand to achieve target yield is required. The site and crop specific fertilizer recommendation is very useful for easy adoption of technologies as it better increases productivity as compared to the blanket recommendation. Site and crop specific recommendation is resulted from solving the real production constraints in the specific area.

Since, Ethiopia is moving from blanket recommendations to soil test based fertilizer recommendations, Fitche Agricultural Research Center conducted research to determine critical phosphorus and phosphorus requirement factors for bread wheat in the Yaya Gulale district, North Shewa Zone. However, the effect of the NPS fertilizer rate was not determined for bread wheat in the study area. Thus, based on the determined Pc (23 ppm) and Pf (3.76), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine the NPS fertilizer rate relative to the determined P-critical for bread wheat and estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in the Yaya Gulale district.

2. Materials and Methods

2.1 Description of the Experimental Site

The experiment was conducted in the Yaya Gullele district during the 2012 and 2013 cropping seasons on wheat potential kebeles.The district is located 131 kilometers far from Finfinne in North West direction. The district has a total population of 155,233 with 52 and 48 percent males and females, respectively. The district is located between $09^0$29’30” to $09^0$41’30”N and $38^0$30’00” to $38^0$45’00”E and at an average elevation of 2800 masl. The mean annual rainfall of the area is 1000mm which ranges from 800 to 1200 and bimodal rainfall pattern. The average daily minimum and maximum temperatures of the district are 16 and 20 ^{0}C, respectively.

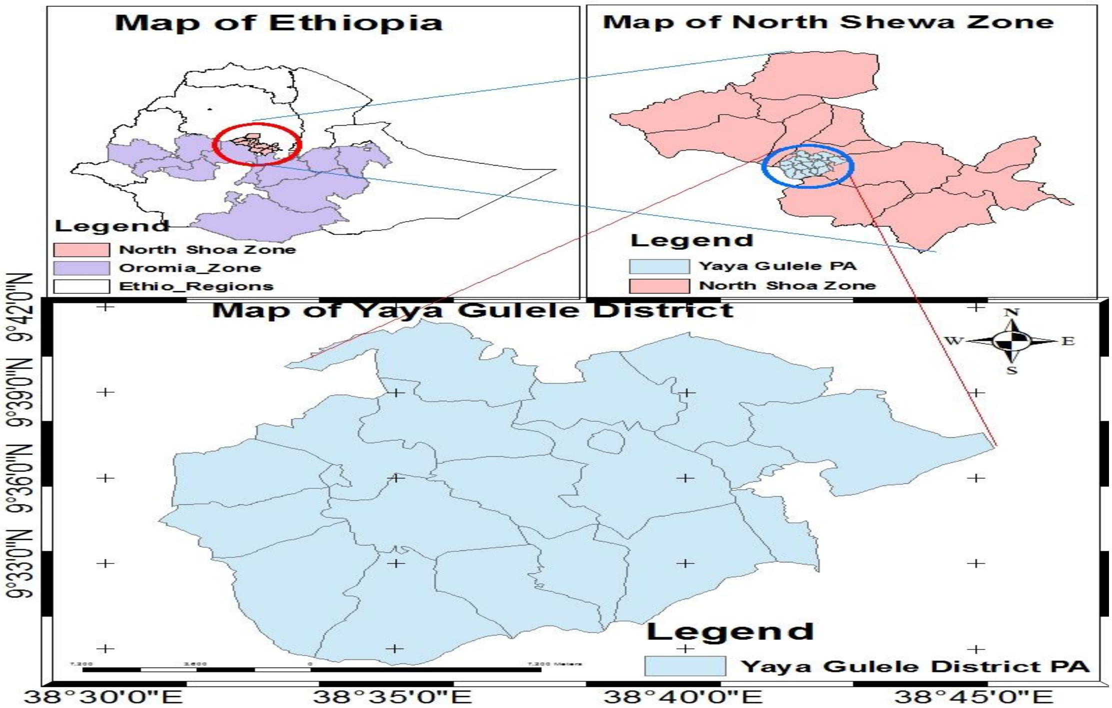

Figure 1. Location map of Yaya Gulele District

2.2 Site Selection, Soil Sampling, and Analysis Methods

Wheat production potential kebeles were selected with the office of Agriculture and Natural resource office from Yaya gulale District. Accordingly, the 11 farmer's fields were selected based on their willingness to handle the experimental fields. Before planting, 30(thirty) surface composite soil samples were collected from the farmers' field for analysis at a depth of 0-20 cm in a zig zag method. Soil samples were collected using auger. The collected surface soil samples from the experimental field were air dried, grinded and allowed to pass through 2 mm sieve for further analysis in the laboratory (FAO, 2008).

The collected soil samples were analyzed for the parameters of pH (H_2O) in the suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982). A Organic carbon was determined by Wakley and Black procedure. Organic matter was estimated as organic carbon multiplied by 1.724. Total Nitrogen was determined by the micro Kjeldahl method and available P was determined by Olsen's method using a spectrophotometer (Olsen *et al*., 1954). Then the farmer's field was selected based on the analyzed soil sample results in which the available soil phosphorus below critical phosphorus (Pc) was selected for the experiments.

2.3 Experimental Design and Treatments

The experimental field study was arranged with a total of 6 treatments in a randomized complete block design (RCBD) in three replications. The recommended Nitrogen (92 kg ha^{-1}) for the district was used. The gross plot size was 3m*3m and the space between the block and plot was 70cm and 30cm respectively. The required amount of seeds were weighed per plot by considering the recommended rate (150 kg ha^{-1}) of wheat seed per hectare. Urea, NPS, and DAP (Di ammonium Phosphate) were used as a source of nitrogen and phosphorus containing fertilizers. Uniform field management practices for all plots were conducted. A bread wheat variety (Sanate) was used as a test crop.

The treatment were:

T1=Control (No fertilizer).

T2=25% P-critical in NPS +Recommended Nitrogen

T3=50% P-critical in NPS + Recommended Nitrogen

T4=75% P-critical in NPS + Recommended Nitrogen

T5=100% P-critical in NPS + Recommended Nitrogen

T6=100% P-critical in DAP + Recommended Nitrogen

Note: Where recommended Nitrogen is 92Kg N/ha.

The determined P-critical value (23 ppm) and phosphorous requirement factor (3.76) were used to calculate the rate of phosphorus fertilizer to be applied. Thus, the Phosphorus fertilizer rate was calculated by using the formula given below;

Rate of P-applied= (pc-pi)*pf

Where

Pc: Critical phosphorus concentration

P: Initial available P

Pf: Phosphorus requirement factor which was derived from the calibration study

2.4 Data Collected

Wheat grain yields were harvested at the ground level from the net plot area. Then plant height and spike length was measured at harvest. After threshing, grain yield were cleaned and weighed. The total above ground biomass yield for each respective treatment was recorded. Economic data such as production cost (input cost), gross income, and net income based on the current market price of the yield and input was recorded.

2.5 Data Analysis

All data recorded and collected were subjected to the procedure of analysis of variance (ANOVA) using GenStat 18th edition software program. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at a 5% significant level.

2.6 Economic Analysis

Partial budget analysis was done to identify economic feasibility. The average open market price (Birr kg^{-1}) of tef, price of fertilizers was used for analysis. For a treatment to be considered a worthwhile option to farmer, the minimum acceptable rate of return (MRR) should be 100 % (CIMMT, 1988), which is suggested to be realistic. This enables to make recommendations from marginal analysis. The Marginal rate of return (MRR) was calculated by using the formula given below;

$$\text{MRR (\%)} = \frac{\text{Net Income From Fertilized Field} - \text{Net Income From Unfertilized Field}}{\text{Total Variable Cost From Fertilizer Application}}$$

3. Result and Discussions

3.1 Status of Soil Chemical Properties of Experimental Site

The pre-sowing composite surface soil sample (0-20 cm) collected from the experimental site was analyzed for some selected soil chemical properties (Table 1). The pre sowing soil analysis showed that the experimental soil has a pH (H_2O) of 5.63 found in moderately acid according to the rating of Tekalign (1991). FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil is within the range for productive soils. The soil organic carbon and total nitrogen content of 2.2% and 0.2 % were found in medium/ moderate range respectively as ratting of Tekalign (1991). The available phosphorous content of the study area is 8.03ppm found in the medium range as the rating of Olsen *et al*., (1954).

Table 1. Soil Status of the Experimental Site

Site	PH	OC (%)	TN (%)	Av.P (ppm)
1	5.88	1.7	0.15	12.73
2	5.82	2.19	0.19	5.31
3	5.75	2.99	0.26	12.52
4	5.87	2.39	0.21	4.63
5	5.58	2.29	0.2	10.1
6	5.6	2.19	0.19	6.68
7	5.67	2	0.17	4.84
8	5.27	3.89	0.34	6.55
9	5.29	1.2	0.1	14.9
10	5.73	1.6	0.14	8.25
11	5.46	1.5	0.13	1.79
Mean	5.6	2.2	0.2	8.03

Where OC= Organic Carbon, TN= Total Nitrogen, Av P = Available phosphorous.

Response of yield and yield component of Wheat to NPS Fertilizer Rate

Plant height

From the analysis of variance plant height was not significantly influenced due to the effect of NPS fertilizer rate ($p>0.05$). The mean of the tallest plant height of 86.72cm was recorded from the application of 75% PC from NPS with optimum N fertilizers while the shortest plants 57.21cm were recorded from zero plot fertilizer application (Table 2). The result indicated that plant height increased with an increased up to the optimum NPS fertilizer rate based on calibrated phosphorus supplemented by Nitrogen fertilizer. The increment in plant height might be due to an increase in cell elongation and vegetative growth attributed to the different nutrient content of NPS fertilizer and the increase of sulfur content caused a significant increase in wheat root and shoot growth as well as nutrient uptake. In conformity with this result, Tilahun and Tamado, 2019, Abera *et al.,* 2021 and Tigist *et al.,* 2021 reported that increased application of balanced fertilizer significantly increased plant height of wheat.

Spike Length

The result of analysis variance showed that spike length was highly significant ($P < 0.05$) , and affected by the NPS fertilizer rate. The tallest (6.57cm) and the shortest (4.29cm) spike length was recorded from the application of 75% PC from NPS supplemented with optimum N fertilizers and unfertilizer fields respectively (Table 2). The fertilizer application up to 75% PC from NPS an indicate increasing tendency of spike length with optimum nitrogen fertilizer. This might be due to an adequate and balanced nutrient supply especially nitrogen, phosphorus and sulfur available in the formulation of applied NPS fertilizer as in the fact that it has a great role in cell division and grain filling there by it attributes to increased spike length. These results are in agreement with Diriba *et al.,* 2019 reported that spike length was significantly affected by NPS fertilizer rate and the longest spike length was observed at the highest application of fertilizers.

Table 2. Effects of NPS Fertilizer Rate and Recommended Nitrogen on Yield Components of Bread Wheat

Treatment	pH (cm)	SL (cm)	Biomass kg ha^{-1}	Grain yield kg ha^{-1}
without fertilizer	57.21^{b}	4.29^{e}	4437^{e}	1130^{e}
25% P-critical from NPS +Recommended Nitrogen	76.09^{a}	5.57^{d}	8447 ^{d}	2348^{d}
50% P-critical from NPS+ Recommended Nitrogen	79.44^{a}	5.88^{cd}	9694 ^{c}	2664^{cd}
75% P-critical from NPS +Recommended Nitro	86.72^{a}	6.57^{a}	12163^{a}	3327^{a}
100% P-critical fromNPS+Recommended Nitrogen	84.19^{a}	6.31^{ab}	11463 ^{ab}	3114 ^{ab}
100% P-critical from DAP fertilizer +Recommended Nitrogen	81.66a	6.207bc	10598bc	2911bc
$LSD_{0.05}$	12.04	0.344	912.690	335.9
CV (%)	32.0	12.2	19.9	26.8

Means with the same letter in columns are not significantly different at 5% level of significance's, PH=plant height, SL= Spike length CV=Coefficient of variation, LSD=Least Significance Difference.

Biomass Yield

Biomass yield was significantly ($P < 0.05$) affected by the NPS fertilizer rate. The highest biomass yield 12163 kg ha^{-1} was obtained at an application of 75% P-critical from NPS fertilizer with recommended Nitrogen and the lowest biomass yield of 443 kg ha^{-1} was registered from the control plot (Table 2). The result is consistent with that of Usman *et al.,* 2020, and Diriba *et al.,* 2019 who reported an increase in biomass yield of bread wheat with increased application of balanced fertilizers with nitrogen.

Grain Yield

Grain yield is the result of many complex morphological and physiological processes occurring during the growth and development of crops (Khan *et al.,*2008). The analysis of variance showed that the grain yield of wheat was significantly ($P < 0.05$) influenced by the NPS fertilizer rate. The highest grain yield (3327 kg ha^{-1}) was obtained from the application of 75% P-critical from NPS fertilizer rate supplemented with optimum recommended Nitrogen while the lowest (1130 kg ha^{-1}) grain yield was recorded from the fields without fertilizers. The highest grain yield at the highest rates of NPS and nitrogen might be connected with provision of adequate plant nutrient requirements which results in the induction of more productive tillers that directly correlated with the production of better yields. This result is in agreement with Abera *et al.,* 2021 who reported that, the maximum grain yield of bread wheat was recorded at the highest application of balanced fertilizer .

Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. The economic analysis showed that the highest net benefit (110941.16 ETB ha^{-1}) was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (39550.0ETB ha^{-1}) was obtained from the unfertilized treatment (Table 3). The highest marginal rate of return (MRR) (1297.12 %) obtained from the fertilizer application of 75 % P-critical from NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}). The MRR was indicated that bread wheat producers can get an extra 12.97 ETB for 1.00 ETB investments in the NPS and N fertilizers application on the rates of 75 % P-critical in NPS fertilizer with recommended Nitrogen fertilizer. Therefore, application of NPS fertilizer at the rate of 75 % P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of bread wheat was more economically profitable.

Table 3. Marginal Analysis of Bread Wheat Yield as influenced by NPS Fertilizer Supplemented by Nitrogen Rate

Treatment	Variable Input (Kg ha^{-1})	Unit price(ETB)	TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB	Net Income (ETB ha^{-1})	MRR (%)

								ha^{-1})		
	DAP/NPS	Urea	DAP/NPS	Urea						
without fertilizer	0	0	0	0	0	1130	35	39550	39550.0	
25% Pc NPS +N	85	165	1363.7	2476	3839.7	2348	35	82180	78340.3	1010.24
50% Pc NPS +N	170	130	2727.4	1950.79	4678.19	2664	35	93240	88561.81	1047.67
75% Pc NPS +N	254.2	95	4078.26	1425.58	5503.84	3327	35	116445	110941.16	1297.12
100% Pc NPS +N	339.2	60	5441.96	900.37	6342.33	3114	35	108990	102647.67	994.87
100% Pc DAP +N	280	90	4577.75	1350.55	5928.3	2911	35	101885	95956.7	951.48

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus, Rec. N = Recommended Nitrogen.

4. Conclusion and Recommendations

Inappropriate crop management practices are among the key elements that contributed to the low production of wheat. Moreover, the application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. According to this study the NPS fertilizer rate based on calibrated phosphorus significantly influences the yield and yield component of wheat which is at a promising level to sustain soil fertility and tackle the problems. Therefore, the study was conducted to determine the effect of NPS fertilizer rate in relative to determined critical phosphorus for wheat in Yaya gulale District.

The analysis of variance depicted that, plant height was not significantly ($P > 0.05$) influenced by NPS fertilizer rate while spike length, biomass and grain yield was significantly ($P < 0.05$) affected by NPS fertilizer rate. The highest plant height (86.72cm), spike length (6.57cm), biomass yield (12163kg ha^{-1}) and grain yield (3327 kg ha^{-1}) of wheat were recorded from the application of 75% P-critical from NPS fertilizer rate supplemented with recommended Nitrogen whereas, the lowest value was recorded from the field without fertilizer which was significantly inferior to all other treatments. Furthermore, the economic analysis depicted that, application of NPS fertilizer at the rate of 75% P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) for the production of wheat was more economically beneficial for the districts.

Therefore, farmers could be advised to use 75 % PC from NPS fertilizer rate with recommended nitrogen for wheat production in the district. Demonstration and further scale up as well as verification at other district of similar soil type agro-ecology should be pre requisite.

Acknowledgements

We kindly thank the Oromia Agricultural Research institute for financially supporting the study. We are also grateful to Fitche Agricultural Research Center and Agricultural office of the district for facilitating the experiment.

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