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Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Bread wheat in Dega District, Western Oromia

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Abstract

This study was conducted to determine of NPS Fertilizer Rate Based on Calibrated Phosphorus for Bread wheat. The experiment was carried out at Dega district. The treatments contained of five (0, 25, 50, 75 and 100 %) Phosphorus critical levels (Pc) calculated from NPS fertilizer and one earlier recommended Phosphorus critical level (100% Pc) for wheat calculated from DAP fertilizer was included, which was used as check. The experiment was laid out by randomized complete block design with three replications. biomass yield was significantly ($P < 0.05$) influenced by rates of NPS on control plot and 75% Pc from NPS with recommended N from the remain treatments, whereas 25% Pc from NPS with recommended N and 50% Pc from NPS with Recommended N the result shows it was non-significance different from each other. However, at 100% Pc from NPS with recommended N and 100% Pc from DAP with recommended N also it shown non-significance influence between each other. Plant height of bread wheat was shows significantly ($P<0.05$) difference at control treatment and 25% Pc from NPS +recommended N than the other treatments. The mean grain yield of bread wheat was highly significantly ($P<0.01$) influenced by the rate of NPS. The highest grain yield (3655.60kg ha^{-1}), above ground biomass yield (14355.60kg ha^{-1}) and plant height (99.80cm) were noted at 100%Pc from NPS with recommended N and 100% Pc from DAP with recommended N respectively. However the lowest grain yield (565.30 kgha-1), above ground biomass yield (3898.60kgha^{-1}) and plant height (70.10cm) were recorded at control treatment.

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Bread wheat senate variety, economic analysis, fertilizer rate, NPS, DAP.

Introduction

Soil fertility is the status or the inherent capacity of the soil to supply nutrients to plants in adequate amounts and in suitable proportions. It may be due to some problems like water logging, saline or alkaline condition, adverse climate etc. Under these conditions, crop growth is restricted though the soil has sufficient amounts of nutrients. According to modem usage, soil fertility is the capacity of the soil to produce crops of economic value and to maintain health of the soil without deterioration (Surinder Singh Rana, 2011). For better fertility management, one should always consider what elements are needed for a particular crop and in what quantity and of the total requirements, how much is present in the soil.

Crop yields and soil fertility are generally much lower in the developing countries and there is a need for increased use of fertilizers to increase yields to produce sufficient food for the expanding populations and to maintain or improve soil fertility status (Foth and Ellis, 1997). On the other hand, crop yields in the developed world are high and agricultural soils have high fertility due to intensive use of fertilizers. According to Quinones *et al.,* (1992) stated that unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success. Moreover, using chemical fertilizers that bring more than 100% extra yield is inevitable in most cases (Kelsa *et al.,* 1992).

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and is a main food for about one third of the world's population (Hussain *et al.,* 2002). This is particularly accurate to the major food crops grown in a total grain crop area, 81.39% (10,358,890.13 hectares) was under cereals. From this wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area.

Similarly, cereals in Ethiopia contributed 87.97% about (277,638,380.98 quintals) of the grain production and the wheat 15.33% (48,380,740.91 quintals) of the grain production (CSA, 2019). 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"). Addition to that, wheat straw is commonly used as a roof thatching material, and used as a feed for animals. It accounts for about 11% of the national calorie intake (Demeke and Di Marcantonio, 2013). Low soil fertility, especially nitrogen (N) deficiency, is one of the major constraints limiting wheat production in Ethiopian highlands (Teklu and Hailemariam, 2009).

In Ethiopia, unpredictable seasonal rainfall, inadequate availability of other nutrients, nitrate leaching during the short but heavy rainy seasons, ammonia volatilization and continuous removal in the cereal mono cropping systems of the highlands are the major factors that result in inefficient use of N fertilizer (Tanner *et al.,* 1993). According to the soil fertility map prepared over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013).

Grain yield, plant height, effective tiller number/m^2 and biomass yield of bread wheat variety increase linearly with planting density and N/P2O5 fertilizer rate. Moreover, it also reported that grain yield and yield components of wheat 100% fully responded to applied nitrogen, 72.3% showed response to sulfur and 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia (Menna *et al.,* 2015). Similarly, Habtegebrial *et al.,* (2013), the optimum grain yield for two bread wheat varieties was found at 100 kg N ha^{-1} ; couple with 20 kg S ha^{-1}, beyond which the yield increase was non-significant, suggesting that higher N rates are to be avoided.

Depending upon available sulfur levels, the wheat yield can increase from 0 to 42% (De Ruiter and Martin, 2001) usually obtaining the best response with sulfur application between 10 and 20 kg ha-1 (McGrath *et al.,* 1996). Due to these, newly fertilizers such as NPS (19% N, 38% P2O5 and 7% S) are currently being used by the farmers in Ethiopia including the study area as blanket recommendation. So, the rate of NPS is not determined for Dega district. Considering this situation the rate of NPS is must for the study area. In addition to this, the amount of N in the NPS is small as compared to the requirement of bread wheat. Therefore, this research work was proposed with the following objectives to assess the effect of NPS fertilizer rates and to determine economically appropriate NPS fertilizer rate on yield and yield components of Bread wheat.

Materials and Methods

Description of the study area

Dega is located at latitude $08^0$10'41.66" to $08^0$42'45.01"N; Longitude $035^0$59'17.77" to $036^0$14'55.67"E and an altitude ranged from 1810 to 2285 meter above sea level; in BunoBedele Zone of the Oromia Regional State, Ethiopia (Fig.1). The 18 years weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August.

The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO/UNESCO, 2001) soil classification system. Its vernacular name is "*BiyyeeDiimaa*" meaning red soil.

On the average, the soil is deep and relatively highly weathered well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (MesfinAbebe, 1980).

Soil sampling and analysis

Six farmers' fields were selected purposively based on their willing and initial soil P-value. Composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O) was determined potentiometerically using glass electrode pH meter in the supernatant suspension of 1:2.5, Soil to H_2O (Van Reeuwijk and L.P., 1992). Exchangeable acidity was determined by saturated the soil samples with potassium chloride solution then filtered and titrated with sodium hydroxide as described by (17).Available Phosphorus in soil was determined by the (Olsen *et al.*, 1954) extraction method and Available Phosphorus was determined from these extracted with Spectrophotometer, (%OC) was determined by the wet oxidation method as described by (Walkley and Black, 1934). Determination of total nitrogen in soil of the samples was performed by the Kjeldahl method as described by Houba *et al.*, (1989). Cation exchange capacity (CEC) of the soil was determined from ammonium acetate, saturated samples that was subsequently replaced by Na from a percolated Sodium chloride solution after removal of extra ammonium by repeated washed with alcohol (Rowell and D. L., 1994).

Treatments, design and experimental procedures

The treatments contained of five (0, 25, 50, 75 and 100 %) P critical levels (Pc) calculated from NPS fertilizer and one earlier recommended P critical level (100% Pc) for wheat calculated from DAP fertilizer was included, which was used as check. The experiment was laid out by randomized complete block design with three replications. The test crop, wheat variety, senate was sown in a unit plot size of 3×4 m with row spacing of 20 cm apart at a rate of 150 kg ha^{-1}Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (138 kg N ha^{-1}) determined during Phosphorus calibration study for bread wheat was used. The experimental fields were prepared by using oxen plow in accordance with predictable farming practices followed by the farming community in the area where, the fields were tilled four times. Full amount of phosphorous as per the treatment and half of N was applied at sowing time. The remaining one-half of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding throughout the period of the trial. All other recommended agronomic management practices disease and insect pest control was done. Finally, plant height, grain and biomass yields were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Economic analysis

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of NPS, DAP,UREA, the cost of labor required for the application of fertilizer, and cost for trashing were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 kg-^{1}), DAP (1997.00ETB 100 kg-^{1}), UREA (1394.00ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of bread wheat trashing (1 ETB kg$^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during fertilizer application for some plots of each treatment were recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Bread wheat grain yield was valued at an average field price of 25 ETB kg^{-1}. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, bread wheat grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit was also calculated as per standard manual (CIMMYT, 1988).

Results and Discussion

A field experiment was carried out during 2023 cropping season to study determination of NPS fertilizer rate based on calibrated phosphorus for bread wheat in Dega district. Record of the data collected from the field and laboratory analyses were subjected to statistical analysis and the results obtained are presented and discussed in the following sections.

Selected Soil Chemical properties before planting

The pH of soils of study site value was ranges 4.68 to 5.23 indicate strongly acidic so the results agreed with Tekalign (Tekalign Tadese, 1991) and FAO (2006). Available phosphorus ranges 0.38 to 1.76ppm was shows very low (FAO, 2006). Total nitrogen 0.18% to 0.28% also shows low to medium as mentioned (FAO, 2006). The soil organic carbon contained about 2.15% to 2.95%

which shows low according to Gedefa *et al.,* (2018) and FAO (2006). Also, the cation exchange capacity (CEC) of the soil was ranges from 28.20 to 33.00 $cmol_e$/kg which indicate high (FAO, 2006; Landon, 1991) (Table 1).

Yield and yield components of bread wheat

The major agronomic parameters and yield components measured for this study include plant height, grain yield, and total above ground biomass yield were analyzed. The main effects of NPS fertilizer rate highly significant with phosphorus critical and requirement factors.

Plant Height (cm)

Plant height of bread wheat was shows significantly ($P<0.05$) difference at control plot (unfertile plot) and 25% Pc from NPS +Rec (Table 2) than the other treatments. However the other treatments not shows significance difference between them, but it shows as fertilizer rate increase the plant height of bread wheat also increases. Maximum plant height (99.80cm) was attained from the combined effect of 100%Pc from DAP and Recommended N, whereas the minimum plant height (70.10 cm) from the unfertilized plot (Table 2). Similarly, Menna *et al.,* (2015) stated that plant height, of bread wheat variety increase linearly with planting density and N/P2O5 fertilizer rate. This finding also, agreed with Tigist *et al.,* (2021), who noted that a successive increase of NPS and KCl fertilizers attributed to the gradual increase in the plant height of wheat.

Above Ground Biomass

Total above-ground biomass of the crop was significantly ($P < 0.05$) affected by rates of NPS on control plot and 75% Pc from NPS with Recommended N from the remain treatments, whereas 25% Pc from NPS with Recommended N and 50% Pc from NPS with Recommended N the result shows it was non-significance different from each other. Again at 100% Pc from NPS with Recommended N and 100% Pc from DAP with Recommended N also it shown non-significance influence between each other.

Highest dry biomass yield (14355.60kg ha^{-1}) was obtained from the treated by 100% Pc from DAP with recommended N. (Table 2), while unfertilized (control) plots recorded the lowest biomass (3898.60kgha^{-1}). Total above-ground biomass showed an increment due to the increase of NPS rate increase. These results linked with Tigist *et al.,* (2021) the above-ground biomass has shown an increasing trend with an increasing amount of fertilizer rates.

Grain yield (kgha^{-1})

The mean grain yield of bread wheat was highly significantly ($P<0.01$) influenced by the rate of NPS fertilizer. The highest grain yield (3655.60 kg ha-1 and 3494.40 kg ha-1) were obtained in response to application of 100% Pc from NPS and 100% Pc from DAP fertilizers, respectively. Whereas the lowest grains yield (565.30 kg ha-1) was obtained in response to control (unfertile) (Table 2). These result shows as fertilizer of NPS rate increase the grain yield of bread wheat also increases. These finding also agreed with Abdurahman *et al.,* (2021) and Ishete and Tana (2019) who stated that increasing the rate of blended NPS fertilizer increased grain yield of bread wheat.

Economic analysis

The economic analysis of bread wheat in relation to nutrient management practices is presented in (Table 3). For a treatment to be considered as valuable to farmers, between 50 and 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in table 3, the partial budget and dominance analysis showed that the highest net benefit 65991.00 Birr ha^{-1} was gained in the treatment that was treated by 100%Pc from NPS kg ha^{-1} with recommended N, whereas the lowest net benefit 10175.25 Birr ha^{-1} was obtained in the control treatment. In overall, the economic analysis showing that, a farmer's investment of one Birr in 100%Pc from NPS kg ha^{-1} with recommended N ha^{-1} on bread wheat earns the one Birr and gives an additional 3.6381 Birr. Based on the results obtained on the effects of different fertilizing rates in bread wheat, the following conclusions may be drawn. The analysis of variance showed that biomass yield was significantly ($P < 0.05$) influenced by rates of NPS on control plot and 75% Pc from NPS with recommended N from the remain treatments, whereas 25% Pc from NPS with recommended N and 50% Pc from NPS with Recommended N the result shows it was non-significance different from each other. Again at 100% Pc from NPS with recommended N and 100% Pc from DAP with recommended N also it shown non-significance influence between each other. Plant height of bread wheat was shows significantly ($P<0.05$) difference at control plot (unfertile treatment) and 25% Pc from NPS +Rec than the other treatments.

Table.1 Soil data before planting

Sites	pH (H2O)	Exch.A (cmol $^{(+)}$/kg soil)	Av. P (ppm)	OC (%)	TN (%)	CEC (cmol (+)/kg soil)
1	5.23	0.64	1.19	2.28	0.20	31.80
2	5.15	0.48	0.93	2.83	0.26	30.00
3	5.30	0.24	0.38	2.63	0.25	28.20
4	4.68	0.24	0.74	2.73	0.27	31.00
5	5.20	0.16	1.43	2.15	0.18	32.60
6	5.20	0.24	1.76	2.95	0.28	33.00

OC= Organic, TN= Total Nitrogen, CEC= Cation Exchange Capacity, P= Phosphorus

Table.2 Mean plant height, bio mass yield and grain yield of bread wheat

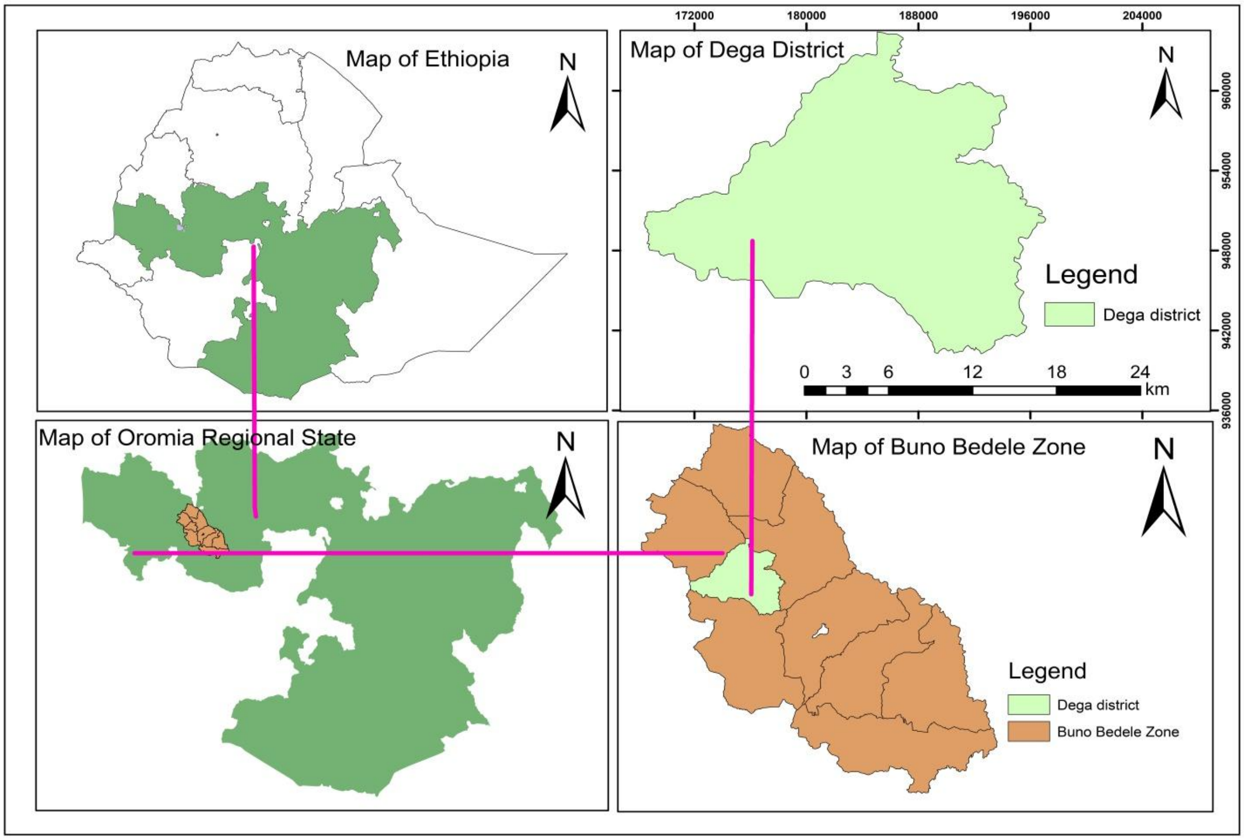
Treatments	PLH (cm)	BMY (kgha^{-1})	GY (kgha^{-1})
Without fertilizer	70.10^{c}	3898.60^{d}	565.30^{e}
25% Pc from NPS +Rec N	94.20^{b}	5658.30^{c}	1629.20^{d}
50% Pc from NPS +Rec N	96.70^{ab}	6718.10^{c}	2419.40^{c}
75% Pc from NPS +Rec N	99.70^{a}	11200.00^{b}	3205.60^{b}
100% Pc from NPS+Rec N	98.60^{a}	13922.20^{a}	3655.60^{a}
100% Pc from DAP+Rec N	99.80^{a}	14355.60^{a}	3494.40^{ab}
Mean	93.20	9292.10	2494.90
CV (%)	6.80	26.36	17.66
LSD	4.20	1620.40	324.52

Table.3 Partial budget analysis for treatment applied for bread wheat

Treatments	Av.GY (Kgha^{-1})	Adj.GY (Kgha^{-1})	TVC Birr	Gross benefit Birr	Net benefit Birr	MRR%
Without fertilizer	565.30	508.77	2544.00	12719.25	10175.25	399.97
25% Pc from NPS+Rec N	1629.20	1466.28	6632.00	36657.00	30025.00	485.56
50% Pc from NPS+Rec N	2419.40	2177.46	11878.00	54436.50	42558.50	238.92
75% Pc from NPS+Rec N	3205.60	2885.04	14077.00	72126.00	58049.00	704.43
100%Pc from NPS+Rec N	3655.60	3290.04	16260.00	82251.00	65991.00	363.81
100%Pc from DAP+Rec N	3494.40	3144.96	17128.00	78624.00	61496.00	D

Adj.GY=Adjusted Grain Yield, Av.GY=Average Grain Yield. TVC= Total Variable Cost

Fig.1 Map of the study area



However the other treatments not shows significance difference between them. The mean grain yield of bread wheat was highly significantly ($P<0.01$) influenced by the rate of NPS fertilizer. The highest grain yield (3655.60 kg ha^{-1} and 3494.40 kg ha^{-1}) were obtained in response to application of 100% Pc from NPS and 100% Pc from DAP fertilizers, respectively.

Whereas the lowest grains yield (565.30 kg ha^{-1}) was obtained in response to control (unfertile treatment). General the results shows as fertilizer of NPS rate increase the plant height, above ground biomass, and grain yield of bread wheat also increases.

The economic analysis revealed that for a treatment to be considered valuable to farmers (100% marginal rate of return), application of 100%Pc from NPS ha^{-1} with recommended N ha^{-1} fertilization are profitable and recommended for farmers in terms of net benefit for the study area.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Author Contribution Statement

The authors confirm contribution to this research paper as follows accordingly the number given for them: study concept writing up to data interpretation of the results as full manuscript Bati Dube[1*], design and data analyzing Dagne Chomdessa[2*] and data collection and financial support Gedefa Sori[3*]. Addition to that all authors reviewed the results and approved the final version of the manuscript.

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