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Determination of NPS Fertilizer Rates Based on Calibrated Phosphorus for Bread Wheat (*Triticum aestivum L.*) Production in Horo District, Western Oromia Region

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Abstract: The purpose of this study was to establish the optimum NPS rate based on calibrated phosphors for bread wheat productivity in Horo District. NPS fertilizer based on the critical levels of P and optimum N fertilizer determined for the district to determine the economically optimum levels of NPS. The treatments consist of 100% Pc from DAP and recommended N fertilizer and 100%, 75%, 50%, 25% Pc from NPS fertilizer with recommended N fertilizer and control (no fertilizer application) on a bread wheat, with seed rate of 150 kg ha^{-1}. The two years (2020-2021) analysis of variance showed that biomass yield of bread wheat was highly significantly affected by the rate of NPS. The highest grain yield (5028.30 kg ha^{-1}) and biomass yield (11455.4 kg ha^{-1}) were obtained in response to the application of 100% of Pc from NPS + Rec. N, whereas the lowest grain yield (2882.2 kg ha^{-1}) and biomass yield (8144.3 kg ha^{-1}) were obtained from control treatment, respectively. The highest net benefit of 53247.4 Birr ha^{-1} was obtained from 100% of Pc from NPS with optimum N fertilizer application. Based on the findings of this study, 100% of Pc from NPS plus suggested nitrogen fertilizer was selected as the best and resulted in the highest yields of bread wheat production in Horo district, according to both agronomic data and partial budget analysis. Therefore, the technology's verification and demonstration for popularization should be continued.

Keywords: NPS, Bread Wheat, Optimum Fertilizer

1. Introduction

Wheat is an important staple food crop all over the world [1]. Ethiopia is one of the largest wheat producers in Sub-Saharan Africa and approximately 80% of the wheat area is planted to bread wheat [2]. Even though, the current wheat production is inadequate to fill Ethiopia's needs [3] due to low soil fertility and soil management practices. According to the report of Food and Agricultural organization, global wheat production in 2018 was estimated at 734 million tons from a total of 214 million hectares area harvested; with average yield of 3425 kg ha^{-1}.

One of the main obstacles to achieving food security and poverty reduction in Ethiopia is improving agricultural output. The assessment of the spatial variability of soil parameters across the field is necessary when applying agricultural inputs based on site-specific requirements of soils and crops [4-6]. One apparent strategy is to boost fertilizer application and encourage appropriate agronomic practices to maximize productivity, given that soil fertility is one of the main issues.

In Ethiopia, 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 [7]. Phosphorous is the most yield limiting of soil-supplied elements, and soil P tends to decline when soils are used for agriculture [8].

Soil analyses and site-specific studies indicated that elements such as K, S, Ca, Mg, and micronutrients (e.g. Cu, Mn, B, Mo, and Zn) were becoming depleted and deficiency symptoms were observed in major crops in different parts of the country [9, 10].

As a result, Ethiopia has started using NPS fertilizer as a compound fertilizer to increase agricultural production and address plant nutrient deficits for crop development. Additionally, there has already been some practice using and applying the newly introduced fertilizer in the form of NPS rather than DAP. However, the rate and reaction of the NPS fertilizer trial are not done in line with the types of crops and soil. Therefore, this study was conducted to determine optimum NPS fertilizer rate for bread wheat production in Horo District.

2. Materials and Methods

2.1. Description of the Study Area

Horo is situated at latitude: 1,042,726N to 1,091,814N; Longitude 270,000E to 316,199E and an altitude ranging from 1449-3147 m above sea level; in Horo-Guduru Wollega Zone of the Oromia regional state, Ethiopia (Figure 1). The terrain is generally undulating to rolling plains. The area is characterized by a mono-modal rainfall pattern. The mean monthly rainfall ranges from 12.8 to 343.8 mm, and mean monthly temperature is 17.23 to 22.9°C. The major soil types are generally described as Nitisols [11].

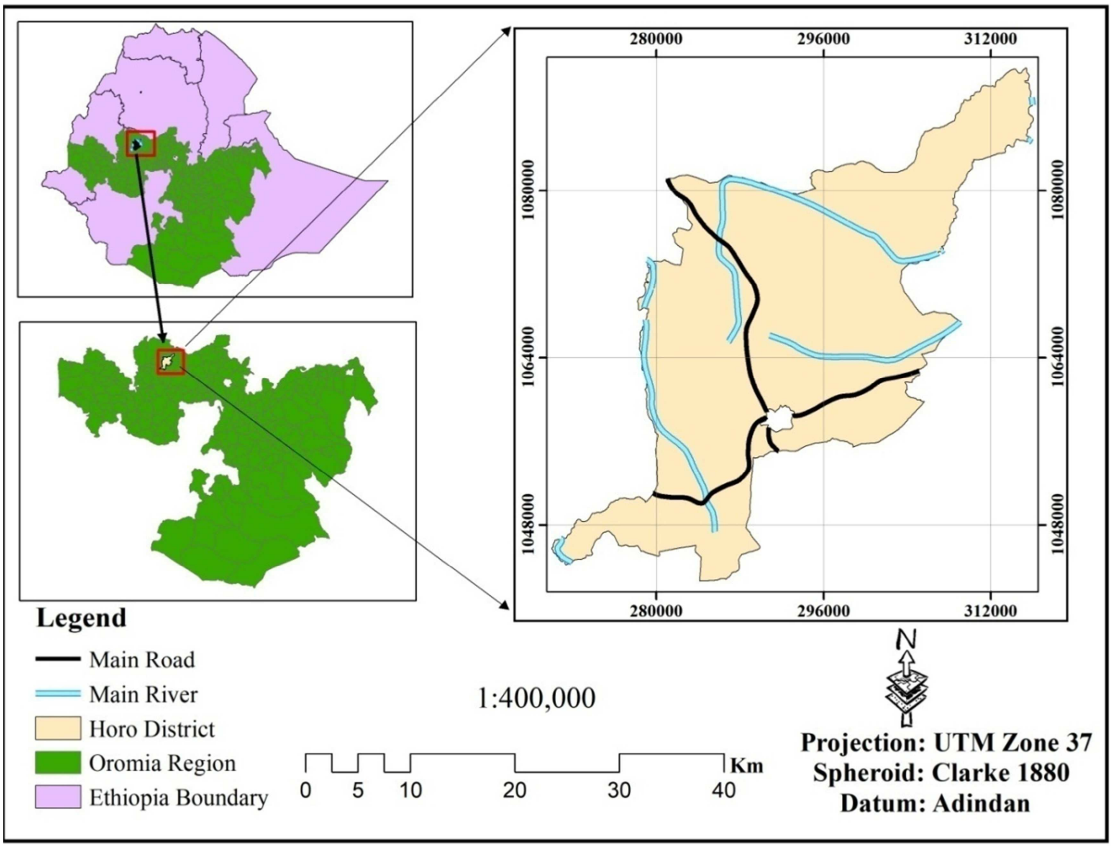

Figure 1. *Location map of Horo District, Oromia, Ethiopia.*

2.2. Treatments, Experimental Design and Procedures

The study was conducted on farmers' fields across Horo District of Horo Guduru Wollega Zone during the main cropping seasons of 2019/20-2020/21. Twelve farmers were selected purposively based on their willing, wealthy and initial soil P-value. Improved bread wheat variety Liban was used at 150 kg/ha seeds rate with 20 cm inter row spacing. Phosphorus fertilizer rate was given according to the formula developed, P (kg/ha) = (P critical-P initial)* Prf. Urea and DAP were used as the source of N and P, respectively. For verification purpose the experiment was laid out in randomized complete block design that was replicated. It is aimed to determine the NPS rate based on phosphorus critical level for hybrid bread wheat variety. Before planting date, composite soil samples were collected and analyzed to determine initial soil P for phosphorus fertilizer to be applied. Phosphorus fertilizer recommendation rate were calculated according to the formula.

$$P\ (kg/ha) = (P_{critical} - P_{initial}) * Prf.$$

This recommendation was compared with *farmers practice (blanket recommendation) and control*.

2.3. Treatments

Six treatments within the experiment were arranged in randomized complete block design with three replications.

T1 = 100% of P critical from DAP + recommended nitrogen

T2 = 100% of P critical from NPS + recommended nitrogen

T3 =75% of P critical from NPS + recommended nitrogen

T4 =50% of P critical from NPS + recommended nitrogen

T5 =25% of P critical from NPS + recommended nitrogen

T6 = Control (without fertilizers)

Recommended N (46 kg N/ha) determined in the area for bread wheat production was used. The gross plot size (3m × 4m) received DAP and an NPS fertilizer at planting time. Nitrogen was applied at 30 days after planting in the form of urea.

2.4. Data Collection

Agronomic data: Date of planting, number of tiller, plant height, number of seeds per spike, spike length, biomass, grain yield and thousand kernel weight.

2.5. Soil Sample Collection

Composite soil samples were collected randomly from each field following a zigzag fashion from 0 to 20 cm depth before planting/application of fertilizer using an auger. The composite soil sample was air dried, crushed with wooden pestle and mortar to pass through a 2mm sieve size for the analysis chemical properties.

2.6. Data Analysis

Microsoft Excel was used to manage the data and properly document it. The reliability of the data was managed using a frequent monitoring and evaluation technique. One-way analysis of variance (ANOVA) was used with SAS software for Windows version 9.1 to analyze the experiment's data. The significant difference between the treatment means was examined using the Least Significant Difference test (LSD).

2.7. Economic Analysis

The average yield was adjusted downwards by 10 percent to reflect the difference between the experimental plot yield and the yield farmers was expected from the same treatment. The average open market price (Birr kg^{-1}) for different crops and the official prices of N and P fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MARR) should be 100% [12], which is suggested to be realistic. To use the marginal rate of return (MRR) as basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) should be 100%. This will enable to make farmer recommendations from marginal analysis.

$$MRR = \frac{Net\ income\ fertilized\ field - Net\ income\ unfertilized\ field}{Total\ variable\ cost\ from\ fertilized\ application}$$

Marginal rate of return (MRR) was calculated both farmer practice and soil test Total variable cost, was a cost incurred due to application of P fertilizer (both but in separate of Soil test based P calibration result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred are the same for all treatments. Gross income is obtained by multiplying mean grain yield (kg/ha) of each treatment by the price of one kg of the grain. *Net income* is calculated by subtracting the total variable cost from the gross income.

3. Result and Discussion

3.1. Soil pH and Available Phosphorus

The soil reaction of the experimental sites before planting ranged from 4.56-5.26 (Table 1). Accordingly, the soils were strongly to extremely acidic in reaction. FAO [13] reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Mengel, K. et al. [14] reported optimum pH range of 4.1 to 7.4 for wheat production. The soils of all sites were strongly acidic based on Bruce, R. C. and Rayment, G. E. [15] soil pH classification system. A similar finding was reported for the site.

Moreover, all the sites contained very low available P (1.56–9.96ppm) on the basis of the article [16] ratings. This might be attributed to fixation of P in acid soils. Besides, the availability of P in most soils of Ethiopia continuously decline by the impacts of abundant crop harvest, land management practices and soil erosion [17-20]. Variation in available P content of the sites could be due to differences in strength of acidity, organic matter content, rocks, and amount of residual p-fertilizers found in the soils. The exchangeable acidity (Al + H), on the other hand, varied between 0.42 and 3.50 $cmol_c\ kg^{-1}$ for soils with pH values 5.5 and its mean value was 1.55 $cmol_c\ kg^{-1}$ soil.

Table 1. *Selected chemical properties of the soil of the experimental sites before sowing.*

Sites	pH (H_2O)	Av. P (ppm)	Ex. Acidity ($cmol_c$(+)/Kg)
1	4.92	3.49	2.71
2	5.02	6.04	2.18
3	5.17	5.61	0.83
4	4.92	3.49	1.66
5	5.18	4.24	0.88
6	5.26	4.20	0.42
7	4.97	9.96	0.98
8	4.70	2.22	3.50
9	4.84	9.18	0.56
10	4.56	3.56	2.91
11	5.06	2.28	0.51
12	4.77	1.56	1.45

3.2. Plant Height

The application of NPS fertilizer had a highly significant (P 0.01) impact on plant height (Table 2). Application of 100% of PC from NPS + Rec. N resulted in the maximum plant height (83.5 cm), which was recorded. The Control plant (without fertilizers) had the lowest plant height measured at 65.7 cm. The increased plant height at the highest level of NPS fertilizer supplemented with supplemental nitrogen rates could be attributed to an increasingly adequate supply of nitrogen, phosphorus, and sulphur nutrients, which contributed to better vegetative development, which in turn resulted in more mutual shading and inter-nodal extension. Nitrogen is considered as one of the major limiting nutrients in plant growth and adequate supply of it promotes the formation of chlorophyll which in turn resulted in higher photosynthetic activity, vigorous vegetative growth and taller plants. P is required for shoot and root development where metabolism is high and cell division is rapid. Similarly, sulfur in NPS fertilizer promotes formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth and taller plants [21].

3.3. Spike Length and Seed Per Spike

The result revealed that fertilizer showed spike length and seed per spike not significantly ($p<0.05$) affected by the application of different rates of NPS fertilizers and optimum N. The effect of fertilizer showed that the highest number of seed per spike (44.15) was recorded from 50% of Pc from NPS plus recommended N fertilizer rate (Table 2). The highest number of spike length was recorded from 100% of Pc from NPS plus recommended N fertilizer application. The lowest spike length and seed per spike was obtained from the control (without application of fertilizer) (Table 2).

3.4. Grain Yield and Above Ground Biomass

The mean grain yield of wheat was significantly ($P<0.05$) affected by the NPS fertilizer application and optimum nitrogen fertilizer application (Table 2). The highest grain yield (5028.30 kg ha^{-1}) was obtained by the application of 100% of Pc from NPS + Rec. N, which was not statistically different from application of 100% of Pc from DAP + Rec. N, whereas the lowest (2882.2 kg ha^{-1}) grain yield was obtained from control treatment (Table 2). Similarly, Temesgen Chimdessa and Chalsissa Takele [17] found that soil test crop response based P application had a significant effect on bread wheat grain yield at the same District than blanket fertilizer application.

The mean biomass yield of bread wheat was highly significantly affected by the effect of NPS and optimum N fertilizer rates (Table 2). Biomass yield increased as the rate of NPS increased from zero to the highest rate of application. Maximum (11455.4 kg ha^{-1}) biomass yield was obtained at application of 100% of Pc from NPS with optimum recommended N fertilizer, whereas the lowest (8144.3 kg ha^{-1}) biomass yield was recorded by control plot (Table 2). The result is consistent with the author [22] who found that maximum application of NPS (200 kg ha^{-1}) and 92 kg ha^{-1} N application increased biomass yield of bread wheat.

Table 2. *Effect of NPS fertilizer and optimum N fertilizer on yield and yield components of bread wheat in Horo district during 2021-2022 main cropping seasons.*

Treatments	Parameters				
	Grain yield (kg/ha)	Above ground dry biomass (kg/ha)	Plant Height (cm)	Spike Length (cm)	Seeds perSpike (No)
Control (without fertilizers)	2882.2^{c}	8144.3^{e}	65.7^{d}	6.32	36.30
25% of Pc from NPS + Rec. N	3637.4^{bc}	9109.7^{d}	76.3^{c}	7.71	42.60
50% of Pc from NPS + Rec. N	3950.10^{ac}	9590.2^{cd}	76.9^{bc}	7.69	44.15
75% of Pc from NPS + Rec. N	4226.70^{ab}	10055.1^{bc}	80.5^{ab}	7.83	42.85
100% of Pc from NPS + Rec. N	5028.30^{a}	11455.4^{a}	83.3^{a}	7.98	43.30
100% of Pc from DAP + Rec. N	4547.10^{a}	10447.9^{b}	80.6^{ab}	7.96	42.00
Significance	**	***	***	NS	NS
LSD $_{(5\%)}$	1131.60	740.68	4.0047	1.86	8.50
CV (%)	11.43	3.09	2.92	10.05	8.30

3.5. Partial Budget Analysis

The highest net benefit of (53247.4) Birr ha^{-1} was obtained from 100% of Pc from NPS with optimum N fertilizer application. However, the lowest net benefits of (32748.9) Birr ha^{-1} were obtained from the recorded from the treatment without fertilizers (Table 3).

Table 3. *Economic analysis for Bread wheat production in Horo District.*

Treatments	ADGY (qt/h)	GFB (ETB/h)	FC (birr/h)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control (without Pfertilizers)	23.9	35856.5	0.0	3107.6	32748.9	
25% of Pc from NPS + Rec. N	32.5	48809.6	2387.7	6617.8	42191.8	269.0
50% of Pc from NPS + Rec. N	33.8	50756.3	3219.7	7618.5	43137.8	94.5
75% of Pc from NPS + Rec. N	35.8	53718.9	4259.6	8915.3	44803.6	128.5
100% of Pc from NPS + Rec. N	43.0	64518.5	5679.5	11271.1	53247.4	358.4
100% of Pc from DAP + Rec. N	38.1	57084.9	6094.1	11041.4	46043.4	3136.5

4. Conclusion and Recommendation

In Ethiopia, the blanket recommendations that are presently in use were issued several years ago, which may not be suitable for the current production. Since the spatial and temporal fertility variations in soils were not considered, farmers have been applying the same P fertilizer rate to their fields regardless of soil fertility differences. The treatment consisted of 100% of P critical from DAP, 100% of P critical from NPS, 75% of P critical from NPS, 50% of P critical from NPS, 25% of P critical from NPS, control and recommended N fertilizer. Based on the results of this study, both agronomic data and partial budget analysis 100% of Pc from NPS plus recommended nitrogen fertilizer was chosen as the best and led to the maximum yield and yield components of bread wheat production in Horo district. Therefore, verifying and demonstrating of the technology for popularization should be followed up.

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References

[1] Mathpal B., Srivastava P. C., and Shankhdhar, S. C., 2015. Zinc enrichment in wheat genotypes under various methods of zinc application. *Plant, Soil and Environment*, 61 (4): 171-175.

[2] Assefa M, Johnson MRS, Nyambilila A, and Tekalign M., 2015. Wheat Response to Applied Nitrogen, Sulfur, and Phosphorous in three Representative Areas of the Central Highlands of Ethiopia. *In J Plant Soil Science* 8 (5): 1-11.

[3] Minot Nicholas, James Warner, Solomon Lemma, Leulsegged K., Abate G., and Shahidur Rashid. 2015. The Wheat Supply Chain in Ethiopia: Patterns, trends, and policy options. International Food Policy Research Institute (IFPRI) Washington, DC.

[4] Fraisse, C. W., Sudduth, K. A., Kitchen, N. R., Fridgen, J. J., 1999. Use of Unsupervised Clustering Algorithms for Delineating within Colfield Management Zones," ASAE Paper 993043. ASAE, Ontario, Canada.

[5] Hatfield, J. L., 2000. Precision agriculture and environmental quality: challenges for research and education. In: *Proceedings of a National Workshop "Precision Agriculture and the Environment: Research Priorities of the Nation*", March 1999, Ames, IA.

[6] Wang, Y., Zhang, X., Huang, C., 2009. Spatial variability of soil total nitrogen and soil total phosphorus under different land uses in a small watershed on the Loess Plateau, China. *Geoderma* 150, 141–149.

[7] Agegnehu, G. and Bekele, T., 2005. On-farm integrated soil fertility management in wheat on Nitisols of central Ethiopian highlands. *Ethiopian Journal of Natural Resources*, 7 (2), pp. 141-155.

[8] David, M. E. and J. T. David, 2012. Modeling an improvement in phosphorous utilization in Tropical Agriculture. *Journal of Sustainable Agriculture*, 36: 18-35.

[9] Asgelil D, Taye B, Yesuf A. 2007. The status of Micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major Maize, Wheat, Teff and Citrus growing areas of Ethiopia. In: Proceedings of Agricultural Research Fund, pp 77-96.

[10] Ayalew A; Boke S; Haile W. 2010. Review of soil and water technologies: case of Southern Nations Nationalities and Peoples Regional State (SNNPRS) (Unpublished).

[11] FAO (Food and Agricultural Organization of the United Nations). 1990. Soil resources of Ethiopia.

[12] CIMMYT (International Maize and Wheat Improvement Center). 1998. From agronomic data to farmer recommendations*: An economic workbook*. CIMMYT, Mexico.

[13] FAO (Food and Agriculture Organization), 2000. *Fertilizers and their use 4th ed*. International fertilizer industry association, FAO, Rome, Italy.

[14] Mengel, K. and Kirkby, E. A. 1996. *Principles of Plant Nutrition*. Panimo Publishing Corporation, New Delhi, India.

[15] Bruce, R. C. and Rayment, G. E. 1982. Soil testing and some soil test interpretations used by the Queensland Department of Primary Industries. Bulletin QB 8 (2004), Indooroopilly, Queensland.

[16] Karltun, E., Lemenih, M., and Motuma T., 2013. Comparing farmers' perception of soilfertility change with soil properties and crop performance in Beseku, Ethiopia. *Land Degrad. Dev.* 24, 228–235.

[17] Temesgen Chimdessa and Chalsissa Takele. 2020. Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat *(Triticum Aestivum L.)* Production in Horo District, Oromia Regional State, Ethiopia. *Advances in Biochemistry*. Vol. 8, No. 3, 2020, pp. 52-56. doi: 10.11648/j.ab.20200803.12.

[18] Dawit, S., Fritzsche, F., Tekalign, M., Lehmann, J., and Zech, W., 2002. Phosphorus formsand dynamics as influenced by land use changes in the sub-humid Ethiopian highlands. *Geoderma* 105, 21–48.

[19] Birhanu, I., Muktar, M., and Kibebew, K., 2016. Impact of deforestation and subsequent cultivation on soil fertility in Komto, Western Ethiopia. *J. Soil Sci. Environ. Manage*. 7, 212–221.

[20] Bereket A., Tadesse A., Kibret, K., and Melese, A., 2018. Phosphorous status and adsorption characteristics of acid soils from Cheha and Dinsho districts, southern highlands of Ethiopia. *Environ. Syst. Res.* 7, 17.

[21] Rao, S., Singh, K. K., Ali, M., 2001. Sulfur: A key nutrient for higher pulse production. Fert. News, 46 (10): 37-50.

[22] Tagesse Abera, Ketema Belete, Tamado Tana. 2018. Effect of Blended NPS Fertilizer Supplemente with Nitrogen on Yield Components and Yield of Bread Wheat (Triticum aestivum L.), Journal of Natural Sciences Research, Vol. 8, No. 11.