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Research Article

Effects of NPS Fertilizer Rate on Yield and Yield Components of Bread Wheat Production in Degem District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Productivity of wheat was low due to depleted soil fertility and the blanket use of fertilizers. Fertilizer is the most vital input, contributing significantly to final wheat yields although wheat yields have long been low due to a lack of soil test-based site-specific fertilizer recommendations. This study aimed to determine an economically appropriate rate of NPS fertilizer based on calibrated Phosphorus for bread wheat production in the Degem district. The experiments laid out in randomized complete block design (RCBD) with three replications. The treatments were based on already determined Phosphorous critical and requirement factors and consisted of 100% Pc from TSP fertilizer, 25%, 50%, 75%, and 100% Pc from NPS fertilizer and control (without fertilizer). The phosphorus requirement factor (Pf) (5.85), phosphorus critical (Pc) (22 ppm), and optimum nitrogen optimum nitrogen (92 kg ha^{-1}) were used from previous studies. Improved bread wheat variety senete was used at 150 kg/ ha seeds rate. The results of a statistical analysis of variance demonstrated that NPS fertilizer rates based on calibrated phosphorus had significant effects on bread wheat production. Partial budget analysis shows the maximum net benefit (101,570.65 Birr ha^{-1}) with an acceptable marginal rate of return (MRR) (932’52 %) through the application of 75% of Pc from NPS with optimum nitrogen fertilizer use. Consequently, 75% Pc from NPS should be used in the Degem district for bread wheat production, with the optimum nitrogen. Thus, further scaled-up and demonstration of the technologies for bread wheat production in the Degem district.

Keywords

Blanket Application, Optimum N, Nps Fertilizer Rate, Phosphorous Critical (Pc), Phosphorus Requirement Factor (Pf), Soil Test Based

1. Introduction

Wheat is grown and consumed worldwide, making it an important staple food crop, both in terms of caloric and nutritional content [12]. Ethiopia is one of the largest wheat producers in sub-Saharan Africa and approximately 80% of the wheat area is devoted to bread wheat [3, 10]. The national average productivity of wheat (2.7 tone ha^{-1}) [8] is still lower than the world’s average (3.4 tone ha^{-1}) [10]. However, soil fertility decline (nutrient deficiencies), poor crop management, unbalanced fertilization, disease prevalence, and lack of sustainable soil management practices are important fac-

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tors in reducing wheat yields. Low soil fertility, especially nitrogen (N) deficiency, is one of the main constraints limiting wheat production in the Ethiopian highlands [16]. The soil test reported for wheat fields in the Central Ethiopian highlands showed deficiencies in N, P, S, Zn, Mo, and B contents [11].

Phosphorus is the element supplied by soil that limits yield the most, and soil phosphorus tends to reduce when land is under continuous cultivation and other factors like fixation [9]. Therefore, low phosphorus availability constitutes a major problem for the sustainable improvement of cereal crop yields. To improve soil nutrient deficiencies, Ethiopia has started using NPS as a compound fertilizer to increase agricultural production and address crop nutrient deficiencies for crop growth [5].

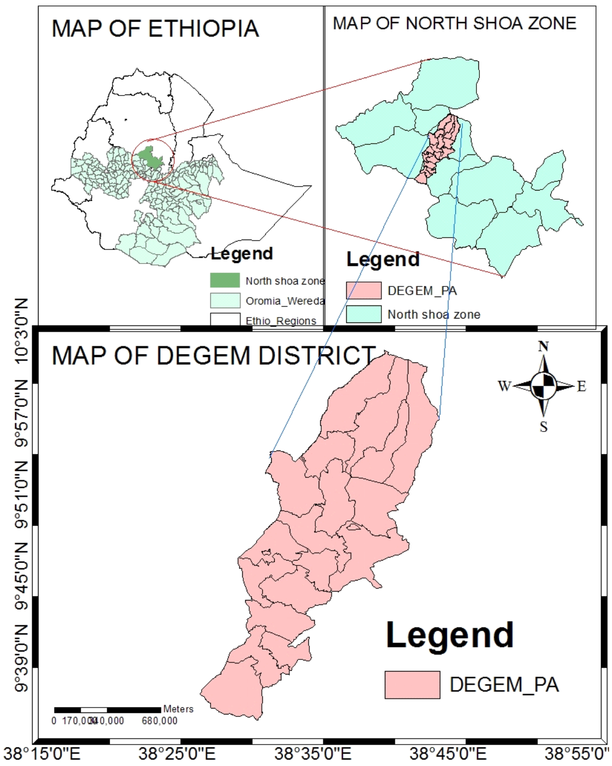
Blanket fertilization recommendations do not consider soil type; plant response; and agroecology. Currently, site-specific soil test-based crop response phosphorus calibration studies get good attention. This move from blanket recommendations led to diversification and the abandonment of DAP and urea, which were long the only imported fertilizers for cereal crops [2]. New fertilizers such as NPS (19% N, 38% P_2O_5, and 7% S) are currently being used by Ethiopian farmers, including in the study area. In addition to the newly introduced NPS fertilizer practiced by the farmers, the amount of N in NPS is low compared to the needs of bread wheat.

Fitche Agricultural Research Center conducted a research to determine critical phosphorus concentration and phosphorus requirement factors for bread wheat in Degem district using TSP fertilizer. However, NPS fertilizer rates and response have not yet been adjusted to the critical phosphorus level (Pc) determined during the phosphorus calibration process. Thus, based on the determined optimum N (92 $kgha^{-1}$), Pc (22 ppm) and Pf (5.85), optimum NPS fertilizer rate determination was carried out in the study area with the objectives; to determine NPS fertilizer rate in relative to determined P-critical for bread wheat and to estimate the economically feasible NPS fertilizer rate for higher yield of bread wheat in Degem district.

2. Material and Methods

2.1. Description of the Study Area

Degem district which is located in North Shewa Zone of Oromia Regional Sate in the central highlands of Ethiopia. The district is located at 124 km of the capital Addis Ababa in the Northwest direction. The district is located between 9°34'0" to 10°03'0" North and 38°29'0" to 38°44'0" East and at an average elevation of 2878 m.a.s.l. The long-term mean annual rainfall was 1150 mm that with mean maximum and minimum temperatures of 22 ℃ and 15 ℃, respectively.



Source: Spatial analysis tool of ArcGIS10.3

***Figure 1**. Maps of the study area.*

2.2. Site Selection, Soil Sampling and Analysis Methods

The study was conducted on farmers' fields across previous calibrations done in the Degem district. Nine farmer's fields were selected purposively based on their willingness to handle the experimental fields and initial soil P-value. Improved bread wheat variety senete was used at 150 kg/ ha seeds rate.

Soil samples were taken at 0-20 cm soil depth using an Auger sampler. Then collected soil samples air-dried, ground with a mortar and pestle sieved 2 mm sieve for further analysis in the laboratory [10]. The pH-H_2O: determined using pH meter. Available phosphorous was determined using spectrophotometer [14].

2.3. Experimental Design and Treatments

A total of six treatments within the experiment were arranged in a randomized complete block design with three replications on plot size 3 m x 4 m (12 m^2). The recommended Nitrogen (92 kg ha^{-1}), Pc = 22 ppm and Pf = 5.85 for bread wheat production in Degem district was used to calculate the rate of phosphorus fertilizer to be applied P = (Pc - Pi)* Pf. The treatments were based on already determined phosphorous critical (Pc) and requirement factor (Pf) as follows:

Table 1. *Experimental Treatments.*

No	Treatments	Fertilizer source	Kg N ha^{-1}
T1=	Control	-	0
T2=	25% Pc	NPS	92
T3=	50% Pc	NPS	92
T4=	75% Pc	NPS	92
T5=	100% Pc	NPS	92
T6=	100% Pc	TSP	92

$$\text{Rate of P applied (kg/ha)} = (\text{Pc-Pi})*\text{Pf}$$

Where Pc: Critical phosphorus concentration Pi: Initial available P Pf: Phosphorus requirement factor which was derived from the calibration study.

2.4. Data Collection

The agronomic data of bread wheat such as plant height, spike length, biomass, grain yield and economic data were collected.

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 5% significant level.

2.6. Economic Analysis

Partial budget analysis was done using CIMMYT to identify economic feasibility among the treatments [6]. The average grain yield was adjusted by ten percent (10%) to reduce the exaggeration of grain yield when the small plot was converted to a hectare basis.

3. Result and Discussions

3.1. Soil Reaction (PH) and Available Phosphorus of Experimental Field

The soil pH (H_2O) of the study area was moderately acidic with the value ranged from 5.56 to 5.72 according to the ratings suggested by [15] (Table 2). The available phosphorus content of soils was very low to medium with the value ranged from 4.68 to 11.21 ppm according to the rating given by [7].

Table 2. *Soil pH and Available Phosphorus of experimental field.*

Site	Soil pH	Available Phosphorus
1	5.59	10.21
2	5.72	5.73
3	5.66	4.68
4	5.72	6.89
5	5.71	6.57
6	5.63	4.73
7	5.59	4.78
8	5.60	11.21
9	5.56	4.78
Mean	5.64	6.62
SD	0.06	2.47

Where: SD = Standard Deviation, CV = Coefficient of variation
Source of data: Field Experiment

3.2. Yield Components Responses of Bread Wheat Production to Fertilizer Rates

The result of analysis of variance showed that plant height was very highly significantly ($P < 0.05$) affected by the NPS fertilizer rate. Plant height increased with an increased up to optimum NPS fertilizer rate based on calibrated phosphorus supplemented with Nitrogen fertilizer (Urea). In conformity with this result [13, 1, 2, 17, 18] reported that increased application of balanced fertilizer significantly increased plant height of wheat. The effect of NPS fertilizer was very highly significantly ($P < 0.05$)) influences spike length. Increasing fertilizer application up to 75% PC from NPS showed increasing tendency of spike length with optimum nitrogen fertilizer. These results agree with [1, 9] 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 3. *Effects of NPS Fertilizer rate and recommended Nitrogen on yield components of bread wheat.*

Treatments	PH (cm)	SL (cm)
Control	65.25^{e}	4.95^{e}
25% Pc-NPS	84.75^{d}	5.94^{d}
50% Pc-NPS	89.72^{c}	6.36^{c}
75% Pc -NPS	96.81^{a}	7.50^{a}
100% Pc- NPS	93.55^{b}	6.94^{b}
100% Pc- TSP	90.36^{bc}	6.53^{c}

Treatments	PH (cm)	SL (cm)
$LSD_{0.05}$	3.21	0.21
CV (%)	6.9	6.20

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
Source of data: Field Experiment

Table 4. *Effects of NPS Fertilizer rate and recommended Nitrogen on biomass and grain yield of bread wheat.*

Treatments	Biomass yield-(kg ha^{-1})	Grain yield (kg ha^{-1})
Control	3860 ^{e}	1422 ^{c}
25% Pc-NPS	6125 ^{d}	2930 ^{b}
50% Pc-NPS	8064 ^{c}	3338 ^{b}
75% Pc -NPS	9898 ^{a}	4173 ^{a}
100% Pc- NPS	8984 ^{b}	3959 ^{a}
100% Pc- TSP	7437 ^{c}	3299 ^{b}
$LSD_{0.05}$	682.743	419
CV (%)	17.2	24.5

Means with the same letter in columns are not significantly different at 5% level of significance's, CV=Coefficient of variation, LSD=Least Significance Difference.
Source of data: Field Experiment

3.3. Biomass and Grain Yield Responses of Bread Wheat Production to Fertilizer Rates

The analysis of variance revealed that the effect of NPS fertilizer was very highly significant ($P < 0.05$)) affect the biomass and grain yield depending on the rate of NPS fertilizer applied (Table 4). The highest biomass (9898 kg ha^{-1}) and grain yield (4173 kg ha^{-1}) was obtained at an application of 75% P-critical from NPS fertilizer with recommended Nitrogen and the lowest biomass yield of (3860 kg ha^{-1}) and grain yield (1422 kg ha^{-1}) was registered from the control plot (Table 4). The result is consistent with that of [4, 9, 19] who reported increased in biomass yield of bread wheat with increased application of balanced fertilizers with nitrogen. As well as this result agrees with [2, 17, 19] who reported that, the maximum grain yield of bread wheat was recorded at the highest application of blended fertilizer.

3.4. Partial Budget Analysis

The maximum net benefit (101,570.65 ETB ha^{-1}) with an acceptable MRR was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (36,972 ETB ha^{-1}) was obtained from the unfertilized treatment (Table 5). Therefore, 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 application rates and can be recommended for farmers of the study area and other areas with similar agro-ecological conditions.

Table 5. *Partial budget analysis for bread wheat production under different rates of NPS fertilizer and optimum N fertilizer application.*

Treatments	Variable Input (Kg ha^{-1})		Unit price (ETB)		TVC	Output (Kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	TSP/NPS	Urea	TSP/NPS	Urea						
Control	0	0	0	0	0	1422	26	36972	36972.00	
25% Pc-NPS	439.24	28.12	16.35	15.01	7603.15	3299	26	85774	78170.85	541.87
50% Pc-NPS	445.53	14.65	16.04	15.01	7367.70	3959	26	102934	95566.30	795.29
75% Pc -NPS	398.78	35.29	16.04	15.01	6927.35	4173	26	108498	101570.65	932.52
100% Pc- NPS	265.85	90.19	16.04	15.01	5618.64	3338	26	86788	81169.36	786.62
100% Pc- TSP	132.93	159.51	16.04	15.01	4526.27	2930	26	76180	71653.73	766.23

Where: ETB = Ethiopian Birr, TVC = Total Variable Cost, MRR = Marginal Rate of Return, PC = Critical phosphorus
Source of data: Field Experiment

4. Conclusion and Recommendations

The blanket applications without considering the nutrient deficiency, soil type, and crop production limiting factors are issued several years ago, currently not affordable for the current wheat production. The application of 75 % of Pc from NPS with recommended N produced the maximum grain yield (4173 kg ha^{-1}), while the control plot produced the lowest grain yield (1422 kg ha^{-1}). The maximum net benefit (101,570.65 ETB ha^{-1}) with an acceptable MRR was obtained from the application of 75% Pc from NPS with recommended nitrogen, whereas the least net benefit (36,972 ETB ha^{-1}) was obtained from the unfertilized treatment.

Therefore, NPS fertilizer at the rate of 75 % P-critical in NPS fertilizer with recommended Nitrogen fertilizer (92 kg N ha^{-1}) to replace blanket recommendations based on determined critical phosphorus for bread wheat production in the district was more economically profitable application rates and can be recommended for farmers of the study area and other areas with similar agro-ecological conditions. Thus, further scaled-up and demonstration of the technologies for bread wheat production in Degem district.

Abbreviations

Pc	Critical Phosphorus Concentration
Pi	Initial Available P
Pf	Phosphorus Requirement Factor
SD	Standard Deviation
CV	Coefficient of Variation
PH	Plant Height
SL	Spike Length
LSD	Least Significance Difference
ETB	Ethiopian Birr
TVC	Total Variable Cost
MRR	Marginal Rate of Return

Author Contributions

Abera Donis: Conceptualization, Formal Analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Dereje Girma: Data curation, Formal Analysis, Supervision, Validation, Visualization

Dejene Getahun: Data curation, Supervision, Writing – original draft

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Tadele Geremu: Writing – original draft

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Conflicts of Interest

The authors declare no conflicts of interest.

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