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Effect of Nitrogen and Phosphorus Fertilizers on Yield Components and Yield of Bread Wheat (Triticum aestivum L.) in Lemo District, Hadiya Zone, Southern Ethiopia

Tagesse Abera*

Department of Plant Science, Faculty of Agronomy and Agricultural Sciences,University of Wachemo, Hossana, Ethiopia

***Corresponding author:** Tagesse Abera, Department of Plant Science, Faculty of Agronomy and Agricultural Sciences, University of Wachemo, Hossana, Ethiopia, Tel: +125912422196, E-mail: tages9696@gmail.com

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Abstract

Wheat is one of Ethiopia's most important agricultural crops. However, the crop's production is limited, owing to low soil fertility issues. As a result, this study was carried out to evaluate the effects of nitrogen and phosphorus fertilizers, as well as to determine the most economically viable fertilizer rate for increasing bread wheat production. The experiment included five nitrogen (N) fertilizer levels (0, 23, 46, 69, and 92 kg N ha^{-1}) and three phosphorus (P) fertilizer levels (100, 150, and 200 kg ha^{-1}) fertilizers, as well as a control. Randomized Complete Block Design in factorial arrangement with three replication was used. Except for days to heading, grain filling period, AGB, and 1000-kernels weight, the interaction of N with P rate showed a significant effect on all parameters. The application of 92 kg N ha^{-1} with 200 kg P ha^{-1} resulted in the maximum grain yield (6832 kg ha^{-1}) and harvest index (40 %). The application of 46 kg N ha^{-1}+ 200 kg P ha^{-1} obtained the highest net return (1284.8 %), according to the results of the economic study. Finally, the study's findings revealed that combining 46 kg N ha^{-1} with 200 kg P ha^{-1}increased bread wheat output while maintaining an acceptable economic benefit. But, the experiment was approved out only in one location for one cropping season, so further studies at different locations for several years or seasons should be conducted in the study area and economically feasible levels of N and P fertilization should be analyzed before giving a conclusive recommendation.

Keywords: N fertilizer: P fertilizer; bread wheat; grain yield

Introduction

Bread wheat (*Triticum aestivum* L.) is one of the most widely grown and most consumed food crops all over the world [1]. The crop is one of the most important cereal crops globally and is a staple food for about one third of the world's population [2]. Among many wheat plants, only three species are commercially important. These are bread wheat (*Triticum aestivum)*, durum wheat (*Triticum durum)* and emmer wheat (*Triticum compactum)* [3].

Ethiopia is the second major wheat producer in sub-Saharan Africa, after South Africa [4]. But, the Ethiopia government is required to import wheat ever year because of high demand than supply [5]. Nutritionally, bread wheat grain is high in carbohydrates: whole grain wheat flour contains crudely 70% carbohydrate, 11.5% protein (varying from 8-15%), 2% fat, 2% fibre, 1.5% ash, and 13% water [6]. Low soil fertility and inefficient mineral fertilizer application, as well as illnesses, weeds, irregular rainfall in lower altitude zones, and waterlogging in Vertisols areas, all have a negative impact on wheat production in the country [7]. The most critical elements limiting wheat development and output in Ethiopia are nitrogen and phosphorus. NP fertilizers have been used in the majority of bread wheat fertilizer experiments. The *Woreda's* Office of Agricultural and Natural Resources has introduced chemical fertilizer Triple Super Phosphate (TSP), which comprises nutrients 46 percent P_2O_5 and urea (46 percent N) fertilizers, to alleviate the area's soil fertility problem. The NP fertilizer rate applied by farmers, on the other hand, is based on a blanket guideline (100 kg ha^{-1}) in the Distinct. This NP fertilizer may or may not be sufficient to suit the area's crop requirements. Thus, it is vital to conduct site specific study on the response of one of the common varieties with the newly introduced blended fertilizer in combination with nitrogen fertilizer that will help farmers to increase the yield of the crop.This study was conductedto assess the effect ofnitrogen and phosphorus fertilizers on yield components and yield and to assessment the economically feasible N and P rate for higher yield of bread wheat.

Materials and Methods

Area Description

During the 2016 main cropping season, the experiment was done on the experimental field of Wachamo University's plant science department in Limo district, southern Ethiopia.

The project is located on geographic coordinates of 7⁰ 14' to 7⁰ 45' N latitude and 37⁰ 50' to 37⁰ 50' E longitudes, about 232 km of Addis Ababa and at an altitude of 2106 meters above sea level. The total annual precipitation is 1320 mm, with minimum and maximum temperatures at 12° and 24° C., respectively. The area's rainfall has a bimodal distribution pattern, with the main rainy season (*Meher*) falling between June and September and the short rainy season (*Belg*) falling between late February and early April. Wheat is harvested from June through September, which is the main growing season.

Experimental Materials

The test crop was a bread wheat variety called *Danda'a*, which was issued by Kulumsa Agricultural Research Centre in 2010 [8]. As a source of nutrients, urea (46 percent nitrogen) and TSP (46 percent P_2O_5) fertilizers were employed.

Soil Sampling and Analysis

Before sowing, the composite soil sample was analyzed for the determination of soil texture, soil pH, organic carbon, total nitrogen, available phosphorus and cation exchange capacity (CEC) analysis using standard laboratory procedures.

Treatments, Experimental Design:

The treatment includes five nitrogen levels (0, 23, 46, 69, and 92 kg ha^{-1}) and three P values (46, 69, and 92 kg ha^{-1}) as well as a control (Table 1). The experiment was set up in a factorial randomized complete block design (RCBD) with three replications.

Management of the Experiment

The experimental plots were fixed to ten rows, each spaced 20cm wide. Between center lines and plots, a 1m and 0.5m spacing was maintained, respectively. Drilling has been used to sow seeds at a seed rate of 125 kg ha^{-1} in an area size of 3 m x 2 m (6 m^2). Fertilizers have been used in keeping with the treatments. One-third N was applied in the form of urea at sowing time, and the full rate of blended NPS was applied as per the treatment.

At the mid-tillering crop stage, the remaining two-thirds of N was side dressed. The data on growth and yield metrics was collected in the middle eight rows. The outermost one row from each side of a plot was regarded a boundary, as was 25 cm out of each side of the rows, resulting in a net plot size of 2.5 m x 1.6 m.

Data collection and evaluation parameters

Days to 50% heading: Days to heading was recorded as the number of days from the date of sowing till spikes emerged in 50% of the plants in each net plot.

Days to 90% physiological maturity: Days to maturity was recorded as the number of days from date of sowing till in 90% of the plants changed their green color to yellowish, in each plot.

Grain filling period: was determined the number of days from anthesis to physiological maturity, *i.e.* the number of days to maturity minus the number of days to heading.

Plant height (cm): Plant height was measured from the soil surface to the tip of a spike (awns excluded) of 10 plants, randomly taken 5 plants each from two 0.5 m row length in net plot area at physiological maturity

Total number of tillers: Total tillers were counted from two randomly taken rows of 0.5 m in length from the net plot area at physiological maturity.

Number of productive tillers: The number of productive tillers bearing spikes was counted at physiological maturity by counting all spikes from two randomly taken rows of 0.5 m in length from the net plot area.

Number of kernels per spike: Number of kernels per spike was determined from the ten randomly sampled spikes from the net plot.

Thousand kernels weight (g): It was determined based on the weight of 1000 kernels sampled from the grain yields used to determine of each treatment, using an electric seed counter, weighing with an electronic balance and adjusted to 12.5% moisture level.

Aboveground dry biomass yield: The plants in the net plot area were harvested at ground level, sun dried for about 10 days until constant weight attained and weighed to obtain the total biomass yield and expressed in kg ha^{-1}.

Grain yield: The grain yield was taken by harvesting and threshing the grain yield from net plot area and converted to kg ha^{-1}.

The yield was adjusted to 12.5% moisture.

Grain yield (kg ha^{-1}) at 12.5% moisture base = Yield obtained (kg ha^{-1}) x (100-%MC)/(100 - 12.5)
Where, MC= grain moisture content.

Harvest Index (HI): It was calculated as the ratio of grain yield per to the aboveground dry biomass yield per plot expressed as a percentage.

$$\text{HI (\%)} = \frac{\text{Grain yield / plot}}{\text{Above ground dry biomass / plot}} \times 100$$

Data Analysis

According to the experimental design test GenStat 15thedition software, the results were subjected to analysis of variance (ANOVA) [9]. Duncan's multiple range tests were used to distinguish the significant differences between treatment means at a 5% level of significance.

Results and Discussion

Soil Properties before Planting

Table 1 shows the physical and chemical parameters of the soil in the experimental field. The experimental site's soil texture class is silt loam. The soil in the experimental field has a slightly acidic pH (6.3), low total N (0.157%), very low available phosphorus (2.2 mg kg^{-1}), and medium CEC (22.56 Cmol kg^{-1}). It also has low organic carbon content (1.86%), indicating that it has low N supplying potential to plants because organic matter content is often used as an index of N. From the results of soil analysis it can be depicted both nitrogen and phosphorus may be yield limiting for wheat production in the area.

Crop Phenology and Plant Height

Days to heading and grain filling periods were significantly affected (P< 0.01) by both primary effects of nitrogen and phosphorus rates. The interaction effect, on the other hand, had no effect on the bread wheat's days to 50 percent heading grain filling duration. This result is consistent with [10]. [11] Findings from (2000) back up the current finding. The major effects of phosphorus, nitrogen, and the interaction effect all had a highly significant (P < 0.01) impact on days to physiological maturity and plant height. The conclusion is consistent with [12] findings, as well as [13]. [14] Conclusions are also supported by this research (2007).

Table 1: Soil properties of the experimental site

Physical properties	Content	Rating
Soil texture:		
Sand (%)	28	
Silt (%)	49	
Clay (%)	22	
Textural class		Silt loam
Chemical properties		
pH (1:2.5 H_2O)	6.3	Slightly acidic
Organic carbon (%)	1.86	Low
TN (%)	0.157	Low
Available P (mg/kg)	2.2	Very low
CEC Cmol kg^{-1}) of soil	22.56	Medium

Yield Components and Yield

The main effect of N and P fertilizer rates on total and productive number of tillers was very significant (P< 0.01), and the interaction was significant (P< 0.05). The findings of [15] back up these conclusions (2014). The primary impacts of N and P fertilizer rates on both aboveground dry biomass and thousand kernels weight were extremely significant (P < 0.01).The interaction impact, on the other hand, was not significant. [16], as well as [14] research; support these conclusions (2007). The main effects of both nitrogen and phosphorus fertilizers, as well as the interactions of N x P, had a significant (P < 0.01) impact on the grain yield of bread wheat, according to analysis of variance (Table 5). The result is supported by data [17]; [14].

The best grain yield was obtained with 92 N and 92 kg P kg ha^{-1}, but the rate of 46 kg N ha^{-1} with 92 kg P ha^{-1} was not statistically different. The main effects of N and P rates, as well as the interaction, had a highly significant (P < 0.01) effect on harvest index, whereas the interaction had a significant (P < 0.05) effect on harvest index. The findings of [18] by support this idea (2001).

Table 2: Main Effect of N and P on some parameter of bread wheat

N (kg ha^{-1})	**DH**	**GFP**	**TKW(g)**	**AGB**	
0	63.00^{d}	29.67^{c}	45.17^{c}	15567^{b}	
23	64.00^{c}	30.67^{b}	45.62^{c}	16585^{a}	
46	65.44^{b}	30.5^{6}	47.30^{b}	16822^{a}	
69	67.22^{b}	30.78^{b}	48.53^{ab}	16728^{a}	
92	70.22^{a}	33.33^{a}	49.93^{a}	16855^{a}	
LSD (0.05)	1.301	2.065	1.529	719.1	
P (kg)					
100	65.58^{b}	29.17^{c}	45.65^{b}	16130^{b}	
150	66.25^{b}	31.50^{b}	46.75^{a}	16275^{b}	
200	68.33^{a}	33.33^{a}	47.77^{a}	17129^{a}	
LSD (0.05)	1.126	1.788	1.184	557.0	
CV (%)	2.0	6.7	6.3	4.5	
Treated × Control					
LSD (0/05)	2.057	2.629	4.800		2868.255
CV(%)	0.9	2.6	3.2		6.9

N= nitrogen; P = phosphorus; DH=Days to 50% heading; GFP= Grain filling period; TKW=Thousand kernels weight; AGB=Above ground biomass; CV= coefficient of variance; LSD= Least Significant Difference at 5% level

Table 3: The Interaction Effect of nitrogen with phosphorus on days to 90%physiological maturity and plant height of bread wheat

N (kg ha^{-1})	P (kg ha^{-1})					
	90% PM					
	PH					
	100	150	200	100	150	200
0	86.33^{i}	91.33^{hi}	90.33^{gh}	74.87^{j}	83.60^{h}	81.07^{i}
23	88.00^{g}	95.67^{cdef}	96.67^{bcde}	84.52^{hg}	85.23^{gh}	92.40^{d}
46	94.00^{f}	95.33^{def}	98.00^{bc}	86.63^{fg}	89.53^{e}	97.17^{c}
69	95.00^{ef}	97.67^{bcd}	98.33^{b}	88.23^{ef}	94.67^{cd}	102.50^{b}
92	95.67^{cdef}	99.00^{b}	101.33^{a}	92.53^{d}	96.60^{c}	106.27^{a}
Treated mean		95.58 A			90.39A	
Control mean		89.33B			63.53B	
N × P LSD (0.05) 1.458		Treated ×Control 1.339		N×P LSD (0.05) 2.455	Treated ×Control 16.4	
CV (%) 0.9		0.4		CV (%) 1.6	6.1	

N= nitrogen; P = phosphorus; PM= Physiological maturity; PH= Plant height; CV= coefficient of variance; LSD= Least Significant Difference at 5% level

Table 4: The Interaction Effect of nitrogen with phosphorusfertilizers on total number of tillers and productive number of tillers of bread wheat

N (kg ha^{-1})	P (kg ha^{-1})					
	TNT				PNT	
	100	150	200	100	150	200
0	4316667^{g}	4166667^{g}	6300000^{bcd}	3666667^{g}	3986000^{fg}	5961333^{bc}
23	4533333^{fg}	5700000^{cde}	5083333^{efg}	4368667^{efg}	5435833^{bcd}	4880000^{def}
46	5450000^{def}	5650000de	6400000^{bcd}	5138333^{cde}	5388833^{cde}	6082333^{bc}
69	5433333^{def}	6000000^{bcde}	6816667^{ab}	5180333^{cde}	5718667^{bcd}	6432333^{ab}
92	5633333de	6766667^{abc}	7600000^{a}	5331667^{cde}	6449333^{ab}	7105000^{a}
Treated mean		5757778A			5478311A	
Control mean		3316667B			2466667B	
N×P LSD (0.05) 966593.5		Treated ×Control 2174158		N×P LSD (0.05) 926598.7	Treated ×Control 1638732.5	
CV (%) 10.1		12.3		CV (%) 10.2	12.3	

N= nitrogen; P = phosphorus; TNT= Total number of tillers; PNT= Productive number of tillers; CV= coefficient of variance; LSD= Least Significant Difference at5% level

Table 5: The Interaction Effect of Effect of nitrogen with phosphorus fertilizers on grain yield and harvest index of bread wheat

N (kg ha^{-1})	P (kg ha^{-1})					
	GY(kg ha^{-1})				HI (%)	
	100	150	200	100	150	200
0	4050^{e}	5172^{cd}	5232^{bcd}	0.284^{c}	0.323^{bc}	0.319^{bc}
23	4581de	5533^{bc}	5288^{bcd}	0.283^{c}	0.335^{bc}	0.318^{bc}
46	5180^{cd}	5199^{bcd}	6810^{a}	0.316^{bc}	0.321^{bc}	0.377^{ab}
69	5290^{bcd}	5506^{bc}	5983^{b}	0.319^{bc}	0.333^{bc}	0.349^{ab}
92	5396^{bc}	5453^{bc}	6832^{a}	0.324^{bc}	0.325^{bc}	0.400^{a}
Treated mean		5417A			0.33A	
Control mean		2093B			0.28B	
N×P LSD (0.05) 683.1		Treated ×Control 1347.5		N×P LSD (0.05) 0.034	Treated ×Control 0.043	
CV (%) 7.5		8.4		CV (%) 6.3	4.0	

N= nitrogen; P = phosphorus; GY= Grain yield; HI= Harvest index; CV= coefficient of variance; LSD= Least Significant Difference at 5% level

Partial Budget Analysis

The partial budget analysis revealed that combining 200 kg P ha^{-1} fertilizer with 46 kg N ha^{-1} application yielded the highest net benefit with an acceptable MRR. The net benefit of using enhanced bread wheat at rates of 200 kg P ha^{-1} and 46 kg N ha^{-1} was shown to be greater than the benefit of applying P and N at the blanket recommended rates (100 kg P ha^{-1} and 100 kg N ha^{-1}). As a result, the net positive benefit derived by applying 200 kg P ha^{-1} + 46 kg N ha^{-1} to bread wheat is economically profitable, and farmers in the research area and other places with similar agro-ecological circumstances can use these application rates.

Table 6: Marginal analysis of bread wheat yield as influenced by N with P fertilizer rates

P (kg ha^{-1})	N (kg ha^{-1})	Average Yield (kg ha^{-1})	Adjusted Yield (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0	0	2093	1883.7	11302.2	0	11302.2	0
100	0	4050	3645	21870	1822	20048	480
100	23	4581	4122.9	24737.4	2415.5	22321.9	383.13
100	46	5180	4662	27972	3009	24963	445
100	69	5290	4761	28566	3602.5	24963.5	0.084
100	92	5396	4856.4	29138.4	4196	24942.4	D
150	0	5172	4654.8	27928.8	2608	25320.8	D
150	23	5533	4979.7	29878.2	3201.5	26676.7	228.45
150	46	5199	4679.1	28074.6	3795	24279.6	D
150	69	5506	4955.4	29732.4	4388.5	25343.9	179.32
150	92	5453	4907.7	29446.2	4982	24464.2	D
200	0	5232	4708.8	28252.8	3394	24858.8	D
200	23	5288	4759.2	28555.2	3987.5	24567.7	D
200	46	6810	6129	36774	4581	32193	1284.8
200	69	5983	5384.7	32308.2	5174.5	27133.7	D
200	92	6832	6148.8	36892.8	5768	31124.8	672.46

P = phosphorus; N= nitrogen; ETB= Ethiopian Birr; GB= Gross benefit; TVC = Total variable cost; NB = Net benefit; D=Dominated treatment's, MRR = Marginal rate of return

Conclusion and Recommendation

The primary yield-limiting elements in cereal production, especially wheat in Ethiopia, are nitrogen and phosphorus. Despite some information on the effect of nitrogen and phosphorus fertilizers on wheat productivity, a full study in silt loam soil, such as the case of Lemo distinct, is lacking. The main effects of N, P, and interactions of N x P were significant for all parameters in this experiment; however, the interaction impact of the two components was not significant for days to 50% heading, grain filling duration, thousand kernels weight, and aboveground dry biomass. The feasible way to addressing the problem of limited bread wheat production in the research area is to use higher N fertilizer with higher P rates. In general, using 46 kg N ha^{-1} with 200 kg P ha^{-1} resulted in the highest grain yields as well as the optimum economic benefit or profitability. As a result, this treatment can be recommended to improve bread wheat yield in the study area's silt loam soil.

Author contribution

Author_Tagesse A.: Initiating the research proposal, preparing the proposal, officialdata analysis, writing original draft preparation, editing and writing the manuscript.

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Data availability:- The datasets analyzed during the current study are collected from the experimental fieldbased on each parameters procedure.

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