**Determination of Nitrogen and Phosphorus Fertilizer Rates and its Nutrient Uptake for Yield of Breadwheat at Debark and Wogera, Ethiopia**

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# **ABSTRACT**

In Ethiopia, nitrogen (N) and phosphorus (P) are the two primary nutrients limiting bread wheat yields. However, optimal N and P rates for wheat production in Northern Gondar, specifically in Debark and Wogera districts, were not well established. This research aimed to determine the best NP fertilizer rates, their economic feasibility, and agronomic efficiency for bread wheat. The study was conducted in 2023/24 main season using the Alidero variety, with a factorial design of four N levels (115, 161, 207, and 253 kg ha-1) and three P2O5 levels (46, 69, and 92 kg ha-1), plus a control treatment (0 N, 0 P2O5). Experiments laid in RCB design with three replications on two farmers' fields. Data were analyzed using SAS software. Results showed that N rates significantly affected growth and yield (*p<0.01*), while biomass and tiller number were significantly influenced by the interaction of NP rates (*p<0.05*). The highest grain yield (4952 kg ha-1) was achieved at the rate of 161 kg N ha-1. The maximum dry biomass yield of 14986 kg ha-1 occurred at 161 N/46 P2O5 kg ha-1. Nitrogen uptake peaked at 130.06 kg ha-1 by 161 kg N ha-1. Economic analysis indicated that the NP combination of 161/46 kg ha-1 yielded at marginal rate of return of 660% and a maximum net benefit of 313,460 ETB ha-1. The application of 161/46 N and P2O5 kg ha-1 is recommended for bread wheat production in Wogera, Debark districts, and similar agroecological areas.

**Keywords:**  Above ground dry biomass, Grain yield, Nitrogen, Nutrient uptake, Phosphorus

**1. INTRODUCTION**

Agriculture in Ethiopia is the basis of the country’s economy; however, its production and food systems are facing challenges due to a fast-growing population and increasing soil fertility depletion (Bouteska *et al.,* 2024). Currently, governmental and non-governmental organizations in Ethiopia have given special attention to the agricultural sector, which plays a leading role in the economic development of the country (Desta *et al.,* 2022).

The effectiveness of fertilizer application and targeting specific niches in responding to a specific soil fertility problem and its positive economic return (Tamene *et al.,* 2017). Thus, efforts to increase crop productivity through fertilizer application and to narrow the yield gaps in smallholder farming require stratified fertilizer management in agricultural lands (Degaga *et al*., 2022).

Nitrogen is an essential element of all the amino acids in plant structures, which are the building blocks of plant proteins and enzymes. It is important in the growth and development of vital plant tissues and cell membranes, chlorophyll, proteins, and enzymes necessary for plant growth and photosynthesis. (Luo *et al*., 2018).

Phosphorus is the second most essential element for crop production to achieve maximum yield production of wheat. It involves the energy processes to enhance root development and strengthening of straw and affects flowering, fruiting, seed formation, and crop maturation (Kedir *et al.,* 2021).

Ethiopia is the second largest wheat (*Triticum aestivum* L.) producer in sub-Saharan Africa. It ranks fourth after *Tef* (*Eragrostis tef* (Zucc) Totter), Maize (*Zea mays*), and Sorghum (*Sorghum bicolor L.*) in area coverage (CSA, 2019). In Amhara region yield and area coverage of wheat production is 554661.74 hectares, total production of 1404707.48 tons, and yield productivity of 2.53 t ha-1 (CSA, 2018). In Ethiopia, wheat is one of the major staple food security crops and has great nutritional value and contains starch (60-90%), protein (11-16.5%), and fat (1.5-2%) and its straw is good source for animal feed (Ashamo *et al.,* 2012).

However, lack of optimal use of production inputs, especially nitrogen and phosphorus deficiency, are the major problems for wheat production in Ethiopian highlands (Alambo *et al.,* 2022). Specifically there was limited research conducted concerning NP fertilizer rates in the study areas such as Debark and Wogera. Therefore, the study was initiated to determine the rates of NP fertilizers, agronomic use efficiency and uptake of NP on yield and yield components of bread wheat at Debark and Wogera districts, and to determine the economic feasibility of NP fertilizer rates for smallholder farmers in the study area

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# **2. MATERIALS AND METHODS**

## 2.1 Description of Study Area

The experiment was conducted during 2023/24 main season at Debark and Wogera districts of North Gondar zone, in the Amhara Region, Ethiopia. Debark district is located at 37.500 to 38.166 N longitude and 12.83 to 13.50 latitude and an altitude of 2751 meters above sea level. Whereas Wogera is located at 37.500 to 38.166 longitude and 12.500 to 13.33 latitude and an altitude of 2793 meters above sea level (Figure 1). The dominant soil type in these areas was Cambisols (FAO, 2015).

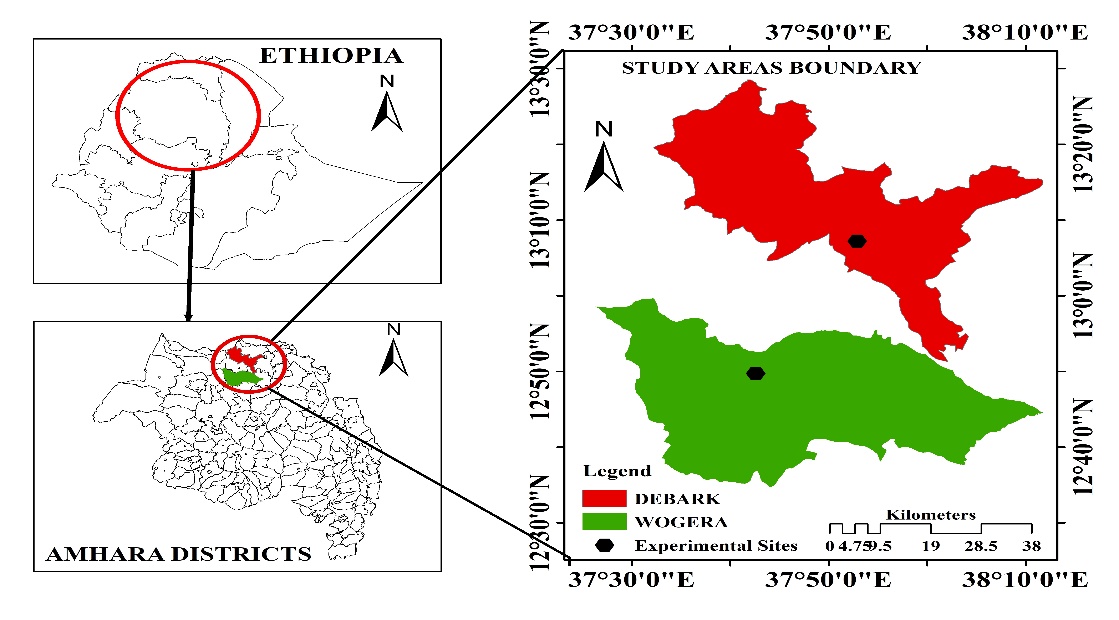


Figure 1. Map of the study area

### **2.2. Climatic Condition**

Both Wogera and Debark districts have tepid to cool moist highland agro-ecology. The minimum and maximum temperatures of the study site at Wogera was 4.70c and 29.40c, and annual rainfall 1185 mm last five years ago. The minimum and maximum temperature for Debark also, 4.710c and 23.60c and annual rainfall 1019 mm last five years ago.

Figure 2: Average monthly rainfall and mean maximum and minimum temperature at Wogera from 2014 –2023 growing period.

Source: <https://gisweb.ciat.cgiar.org>

Figure 3: Average monthly rainfall and mean maximum and minimum temperature at Debark from 2014 – 2022 growing period.

Source: <https://gisweb.ciat.cgiar.org>

In general, from both districts in the main rainy season (July, August, and September) rainfall contributed the highest percentage of rainfall in the region (Dereje *et al.,* 2012). The maximum and minimum temperatures generally higher from March to December.

### **2.3 Planting materials and experimental design**

The adapted and recommended variety of wheatwas *Alidero.* The Completed factorial arrangement of four levels of N (115, 161, 207, and 253 kg ha-1) and three levels of P2O5 (46, 69, and 92 kg ha-1) and (0) at a satellite plot in a randomized complete block design (RCBD) with three replications was used. The experiment had 13 treatments (Table 1) and applied on two farmers’ fields. Gross plot size was 3 m \* 2.5 m (7.5 m2) and net plot size was 2.6 m \*2 m (5.2 m2). Spacing of 20 cm, 1 m, and 1.5 m between rows, plots, and blocks respectively were kept. Triple Super Phosphate (TSP) (46% P2O5) used as a source of phosphorus and urea (46% N) used as a source of nitrogen. All phosphorus fertilizer doss were added at the time of planting. Whereas application of urea was 1/3 of N added at planting 1/3 of N at the tiller stage, and the remaining 1/3 of N at the booting stage.

Table 1: Treatment combination of Nitrogen and phosphorus

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatments | Nitrogen kg ha-1 | P2O5 kg ha-1 | Treatments | Nitrogen kg ha-1 | P2O5 kg ha-1 |
| T1 | 0 | 0 | T8 | 207 | 46 |
| T2 | 115 | 46 | T9 | 207 | 69 |
| T3 | 115 | 69 | T10 | 207 | 92 |
| T4 | 115 | 92 | T11 | 253 | 46 |
| T5 | 161 | 46 | T12 | 253 | 69 |
| T6 | 161 | 69 | T13 | 253 | 92 |
| T7 | 161 | 92 |  |  |  |

### **2.4. Soil sampling and analysis**

Composite soil samples were collected from the experimental sites before planting at depth of 20 cm. Collected soil samples taken to soil laboratory to determine soil texture, soil pH, Organic carbon, total nitrogen, available phosphorus, Cation exchange capacity (CEC) and exchangeable base values.

### **2.5 Plant sampling method**

Grain and straw samples collected from each net plot during trashed and dried at 70 °C until recorded constant weight. The dried samples were milled, and the grain and straw NP content of the plant samples were determined using the micro-Kjeldahl and Olsen methods respectively as stated by the American Association of Cereal Chemists (AACC) (2000). To measure agronomic efficiency (AE) as showed Eq.1. The NP uptake of grain and straw were calculate by multiplying the grain or straw yield (kgha-1) by the NP concentration in (%) of grain and straw on each treatment as shown eq.2.

AE= GYF (kg) – GYU (kg) /quantity of applied fertilizer (kg) ---------eq. 1

**Note: -** AE = Agronomic Efficiency (kg kg-1), GYF = grain yield of fertilized crop, GYU= grain yield of unfertilized crop

NP = uptake of grain or straw (kg ha-1) = Yield of grain or straw (kg ha-1) \* NP concentration of grain or straw (%) x 10-2 -----------------eq.2

**2.6 Collected data**

### 2.6.1 Agronomic data

Days to heading date: days to spike heading was determined as the number of days taken from the date of planting to the date of 50% heading of the plants from each plot by visual observation.

Days to 90% physiological maturity: Days to physiological, maturity were determined as the number of days from planting to the date when 90% of the peduncle turned yellow in straw color. It was recorded when no green color remained on glumes and peduncles of the plants, i.e. when grains are difficult to break with a thumbnail.

Plant height (cm): Plant heights were measured above soil surface to the tip of the spike excluded awns randomly 10 plants selected from the net plot at maturity.

Spike length (cm): measured from the bottom of the spike to the tip of the spike excluding the awns of 10 randomly tagged plants randomly selected from the entire net plot.

Number of effective tillers: Determined from the 0.5 m length of two rows counted at emergency from the net plot and counted again at physiological maturity. Then the number of plants at physiological maturity minus the number of plants at emergency divided by counted number of plants at the emergency

Thousand seed weight (gm): It was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using an electronic seed counter and weighing with a sensitive balance. Then, the weight of seed was adjusted to 12.5% standard moisture content.

Aboveground dry biomass (kg ha-1): It was determined from plants harvested from the net plot area after sun drying to a constant weight and converted to kg per hectare.

Grain yield (kg ha-1): Grain yield was taken by harvesting the biomass yield from the net plot with a sack to prevent wastage during trashing. After trashing yield weighted in kg per plot by using a sensitive balance then converted to kgha-1 and adjusted by standard moisture content of cereal crops at 12.5%. Adjusted grain yield was calculated kg ha-1 by using equation 3 as follows. AGY= actual yield (kg ha-1) \* (100 – MC (%)/ (100 – 12.5) -------eq .3

Note: - AGY= Adjusted Grain Yield, MC= moisture content of actual yield

Harvest index (%): It is the ratio of grain to total shoot dry matter and is a measure of reproductive efficiency. It calculated by dividing grain yield by the aboveground dry biomass yield and multiplied by 100.

### 2.6.2 **Economic analysis**

Economic analysis was performed using CIMMYT’s (1988) methodology. Average prices for wheat grain, wheat straw were considered for benefit. Whereas fertilizer cost, labor for application, and cost of transport were considered in Ethiopian birr (ETB) costs. Gross return was the value of the two products, i.e. wheat grain, and straw for various treatments estimated at the farm get price. Wheat grain and Straw yields were adjusted 10% downwards that assuming farmers would obtain yields 10% lower than those obtained in this experiment would. The price of fertilizer was urea and NPS (39.40 ETB kg-1 and 39.65 ETB kg-1), respectively and labor cost for transport and urea split application was 3.95 ET Birr kg-1. The average local market price of wheat grain and straw was 70.00 and 2.00 ETB kg-1 respectively.

The dominance analysis and marginal rate of return (MRR) were calculated to select the best economically and biologically feasible treatment as shown.

NR= TR – TVC

TR= AGY x Price of the wheat grain +farm gate price of straw

TVC= Cost of N fertilizer + Cost of P fertilizer + cost of N application and cost transport

AGY= GY – (UGY x 10%)

*Note:* -MRR =marginal rate of return, ▲NR =change of net return, ▲VC= change of variable cost, TVC= total variable cost, TR=total revenue, AGY=adjusted grain yield by 10% downwards, GY=actual grain yield, UGY=unadjusted grain yield

## 2.7 Statistical Analysis

Analysis for collected parameters subjected to statistical analysis software (SAS) version 9.4 using the General linear model (GLM) procedure. Mean comparison among treatments done by least significance difference (LSD) at 5% confidence level.

# **3. RESULTS AND DISCUSSION**

3.1. Physicochemical properties of Soil

Physicochemical properties of soil at Wogera and Debark sites had a clay loam and clay textural class respectively (Table 2) (Bouyoucos, 1951). Soil pH results considered as slightly acidic according to a rating by Sahlemedhin and Taye (2000), which are generally suitable for most crops. Soil pH from 6.0 to 7.5 is the acceptable range for wheat production in Ethiopia (Takala B., 2019). Available phosphorus was medium according to Cottenie (1980) rating. Organic carbon and total nitrogen was moderate according to Debele B., (1980). Cation exchange capacity (CEC) ranged under high level according to Debele B., (1980). In general, both sites have higher CEC, which is favorable for crop production (Tolosa S., 2012).

Table 2: Soil physicochemical properties at Wogera and Debark districts

|  |  |  |  |
| --- | --- | --- | --- |
| Soil physicochemical properties | Unit | Amount |  |
| Wogera | Debark |
| PH |  | 6.23 | 6.47 |
| Cation exchange capacity | Cmol (+)/Kg soil | 61.48 | 50.204 |
| Available P | Mgkg-1 | 11.49 | 13.58 |
| Total nitrogen | % | 0.189 | 0.169 |
| Organic carbon | % | 1.94 | 1.99 |
| Texture class |  | clay loam | Clay |

## 3.2 Crop Phenology and Growth Parameters

### **3.2.1 Days to heading**

Days to 50% heading was significantly (*p* < 0.001) affected by the main effects of N-rate while there was no significant difference for the application of phosphorus rates. Increasing N fertilizer rates from 115 to 253 kg ha-1 extended the number of days to 50% heading from 71 to 75 days (Table 3). Days to heading showed an increasing tendency with rising N rates. That related to the increased N rates and its effect in extending vegetative growth and hence prolonging days to heading. On the other hand, the use of low N fertilizer rates for wheat production shortens the intervals between the growth phases due to the accessibility of inadequate nutrients. The current finding is in line with the studies of Godebo *et al*. (2021) who reported that, days to heading showed an increasing trend with increasing N fertilizer rates from 0 to 69 kg ha-1.

### **3.2.2 Days to 90% maturity**

The results showed that the main effects of the N fertilizer rate were highly significant (*p* < 0.001) on days to 90% physiological maturity. However, applying P has no significant difference on days to 90% physiological maturity. Conversely, the interaction effects of the N and P did not significantly affect days to 90% physiological maturity. The shortest date recorded (122) days on the plot, which received 115 kg ha⁻¹ of nitrogen, while the longest dates 126 days were observed at 207 kg ha⁻¹ nitrogen rates, respectively (Table 3). In contrast, the control plots matured earlier at 118 days. That might be attribute to the role of nitrogen in enhancing vegetative growth, thereby delaying maturity. These results align with the study by Kabato *et al*. (2022), which reported that applying 55.2% NP fertilizers delayed the maturity of wheat, whereas control levels led to earlier maturity. Similarly, Haileselassie *et al*. (2014) found that the highest doses of nitrogen delayed physiological maturity due to increased nitrogen uptake, which promotes high photosynthetic activity and extends the vegetative growth period.

### **3.2.3 Plant height**

The analysis of variance shows that plant height was significantly (*p* < 0.01) affected by application of Nitrogen rates. However, the application of phosphorus and the interaction of NP fertilizers had no significant effect on the growth of plant height. The highest plant height was recorded from plots where, at N rates of 161 and 253 kg ha-1 received (103 cm) equally. Whereas the shortest was recorded on, control plots 89 cm (Table 3). The significant plant height difference due to different N rates might indicate that nitrogen is essential for increased cell division and elongation. The finding in line with the result of Hordofa *et al.* (2022) stated that increasing nitrogen rates increases the plant height up to the optimal level of N, and balanced and adequate soil nutrient management is important practice.

### **3.2.4 Spike length**

The application of Nitrogen and phosphorus fertilizer rates did not significantly affect individuals or their interaction with spike length. However, there was a significant difference as compared to the control plot (Table 3). This finding is in line with Dugassa *et al*. (2019) who reported that spike length is insignificant due to different rates of N and P, which may probably spike length, is sensitive to environmental and genetic factors.

Table 3: Effect of NP fertilizers on the mean value of crop phenology and growth parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N  ka-1 | HD | MD | PH | SPL |
| 115 | 71c | 122c | 100b | 10.1 |
| 161 | 72c | 124b | 103a | 10.3 |
| 207 | 74b | 126a | 102ab | 10.1 |
| 253 | 75a | 126a | 103a | 10.4 |
| LSD (5%) | 1 | 1 | 1.8 | 0.3 |
| Sig. | \*\* | \*\* | \* | ns |
| P2O5 kg ha-1 |  |  |  |  |
| 46 | 73 | 124 | 102 | 10.2 |
| 69 | 73 | 124 | 101 | 10.4 |
| 92 | 72 | 124 | 102 | 10.1 |
| LSD (5%) | 1 | 0 | 2 | 0.3 |
| Sig. | ns | ns | ns | ns |
| CV (%) | 2.58 | 0.47 | 2.66 | 4.71 |
| Control (0,0) | 66 | 118 | 89 | 8.4 |

**NB:** *\*\* = highly significant at P<0.01, \* = significant at P<0.05, ns = non-significant, CV = coefficient of variance, HD = 50% heading date,LSD = least significant difference, MD = 90% maturity date, N = nitrogen, P2O5 = phosphorus, PH = plant height (cm), SPL = spike length (cm).*

## 3.3 Yield and Yield Related Components

### **3.3.1 Number of effective tillers**

An effective number of tillers per plant was significantly influenced (*p* < 0.01) by the interaction effect of N\*P application rates. The maximum effective number of tillers per plant recorded was 4.62 and 3.95 from the plots, which received 161/69, 115/69, and 115/92 N P2O5 kg ha-1 equally. While the lowest number of effective tillers was from the control plots (2.2 in number) (Table 4). This finding is supported by Haileselassie *et al.* (2014) who reported that nitrogen and phosphorus application increased significantly the number of effective tillers per plant. According to Gebremedhin T., (2019) number of effective tillers per plants were significantly affected by various levels of phosphorous and nitrogen fertilizers, and the highest number of effective tillers per plant (nine tillers) was recorded when 150 N kg ha-1 and 92 kg ha-1 P2O5 was applied.

### **3.3.2 Aboveground dry biomass**

Aboveground dry biomass was significantly (*p* < 0.05) influenced by the interaction effect of nitrogen and phosphorus rates. The maximum and minimum yield of biomass (14984 kg ha-1) and (6194 kg ha-1) was recorded from plots, which received 161 /46 N P2O5 kg ha-1 and control plots respectively (Table 4). That might related to nitrogen and phosphorus role in accelerating plant vegetative growth and the increase plant height and tiller number could increase biomass production.

This finding is supported by Kabato *et al.* (2022) the highest biological yield (9.84 ton ha-1) was achieved combined application of the NP (55.2%: 46%) while the lower yield (5.74 ton ha-1) was recorded at the control level. However, the finding contradicts with Dugassa *et al.* (2019) who stated that N and P's interaction effect was insignificant on the yield of biomass and he concluded that the application of only 96 kg N ha-1 fertilizer is advisable. Conversely, the current finding is not in line with Haileselassie *et al*. (2014) who stated that yields of wheat straw insignificantly due to the interaction effect of NP fertilization.

Table 4 : Interaction effect of NP fertilizers on the number of tillers and dry biomass

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N kgha-1 | P2O5 kg ha-1 | | | | | |
| Effective tiller number | | | Above-ground Dry biomass (kg ha-1) | | |
| 46 | 69 | 92 | 46 | 69 | 92 |
| 115 | 3.02d | 3.95ab | 3.95ab | 13140ab | 12472b | 12356b |
| 161 | 3.08d | 4.62a | 3.88bc | 14984a | 12719ab | 13091ab |
| 207 | 3.48bcd | 3.62dcb | 3.48bcd | 13131ab | 13489ab | 14124ab |
| 253 | 3.48bcd | 3.08d | 3.22cd | 14658ab | 13366ab | 13367ab |
| LSD (5%) | 0.72 | | |  | 2351 |  |
| CV (%) | 17.36 | | |  | 7.7 |  |
| Control plot(0,0) | 2.2 | | |  | 6194 |  |

### **NB:** *CV = coefficient of variance, LSD = least significant difference, N=nitrogen, P2O5 = phosphorus*

### 3**.3.3 Thousand seed weight**

The analysis of variance showed that thousand seed weight of bread wheat was significantly (*p* < 0.05) influenced by different rates of nitrogen fertilizer. The highest and the lowest thousand seed weight obtained 43.9 gm and 41.5 gm at the plots, which received 115 N kg ha-1 and 253 kg N ha-1 respectively (Table 5). Thousand seed weight was consequently reduced with increasing nitrogen rates. The current study is similar to Asargew *et al.* (2014) who stated that thousand seed weights responded only to the application of nitrogen and reduced with increasing of N.

### 3.3.5 **Grain yield**

The result of the analysis of variance showed that the grain yield of bread wheat was significantly (*p* < 0.05) affected by different rates of nitrogen fertilizer. The maximum and minimum grain yield (4952 kg ha-1) and (2196 kg ha-1) was obtained on plots that received 161 kg N ha-1 and control plot respectively (Table 5).The application of N above 161 kg ha-1 has no significant difference on the yield. That indicates the optimum grain yield has already attained at the rate of 161 kg N ha-1. The study is supported by the report of Belete *et al. (* 2018) who stated that the highest grain yield of wheat was recorded (5457.6 and 5324.55 ) kg ha-1 up to N rate of 240 kg ha-1 and above this have not significant difference. He also concluded that the increase in wheat yield with increasing N rates up to adequate levels of N and above these rates, the grain yields become decreased. However, the result disagree with the study of Menamo and Nebyou (2016), who conclude that the highest mean yield of 63.96 quintals was recorded from the interaction of 50 /150 N and P2O5 kg ha-1 fertilizers.

Table 5, Effect of NP on the mean value of Bread wheat yield and yield components

|  |  |  |  |
| --- | --- | --- | --- |
| N (kg ha-1) | GY( kg ha-1) | TSW (gm) | HI (%) |
| 115 | 4590b | 43.9a | 36.1 |
| 161 | 4952a | 42.7b | 36.7 |
| 207 | 4699ab | 41.9c | 34.6 |
| 253 | 4850ab | 41.5c | 35.2 |
| LSD (5%) | 273 | 1.1 | 2.0 |
| Sig. | \* | \*\* | ns |
| P2O5 kg ha-1 |  |  |  |
| 46 | 4769 | 42.3 | 34.3b |
| 69 | 4863 | 42.7 | 37.3a |
| 92 | 4686 | 42.6 | 35.4b |
| LSD (5%) | 236 | 1.0 | 1.8 |
| Sig. | ns | ns | \*\* |
| CV (%) | 8.56 | 3.97 | 8.58 |
| Satellite plot (0,0) | 2196 | 42.2 | 28.2 |
| *NB: \*\* = highly significant at P<0.01, \* = significant at P<0.05, ns = non-significant,CV = coefficient of variance, GY = Grain yield (kg ha-1), HI = harvest index,* LSD = *least significant difference, N = nitrogen, TSW = thousand seed weight (gm)* | | | |

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### 3**.3.4 Harvest index**

The analysis of variance indicated that the harvest index of bread wheat was significantly (*p* < 0.01) influenced by different rates of phosphorus fertilizer. The application of phosphorous rates increased from 46 to 69 kg ha-1 P2O5, harvest index showed an increase from 34.3 to 37.3 % then, it decreased above 69 kg ha-1 P2O5. The highest and lowest harvest indexes 37.3 % and 28.2% obtained on plots, that received 69 kg ha-1 P2O5 and control plots respectively (Table 5). The results contradict Gebremedhin T., (2019) findings who stated that the harvesting index of wheat not affected significantly by the application of phosphorous fertilizer rates from (0 to 115 kg ha-1 P2O5) and the maximum harvesting index (49.03%) was recorded control plots.

## 3.4 Nutrient Use Efficiency

### **3.4.1 Agronomic N efficiency**

The agronomic efficiency of N (AEN) was significantly (*p* < 0.01) influenced by the application of N. The application of 115 kg ha−1 N produced the maximum AEN (20.92 kg grain per kg N) whereas the lowest AEN (10.54 kg grain per kg N) was recorded at high N rate of 253 kg ha−1 (Table 6). The study showed that AEN increases up to 115 kg N ha−1 and above this rate of N, it was reduced. This result is in line with Wogenie and Anjulo (2017) who reported that the highest AEN was obtain at lower rate of nitrogen. Similarly, Godebo *et al.* (2021) conclude that at the lower rate of N, the wheat plant utilized most of the supplied N for grain yield production, however at a high rate of N, efficiency of N decreased. Likewise, Haileselassie *et al.* (2014) reported that the agronomic efficiency of wheat decreases with increasing N rates.

### **3.4.2 Agronomic P efficiency**

The agronomic efficiency of phosphorus (AEP) was significantly (*p* < 0.05) influenced by the main effect of N and P but their interaction was not significant. The maximum AEP (43.54 and 56.19 kg kg−1) were recorded from the rate of 161 kg N ha−1 and 46 kg P2O5 ha−1 although, the lowest one is 37.47 and 27.19 kg kg−1 from 115 kg N and 92 kg P2O5 ha−1 respectively. The result showed that the agronomic P efficiency decreases with the increasing rate of NP rates after supplying 161 and 46 kg ha−1 respectively (Table 6). The result of the study is adjacent to the findings of Dobocha *et al*. (2019) who indicated that the agronomic efficiency of P was 50.48 kg kg−1 at the rate of 46 kg ha-1 nitrogen.

### **3.4.3 Nitrogen uptake in grain and straw**

The analysis of variance indicated that nitrogen uptake by the grain (GNU) was significantly (*p* < 0.05) influenced by the rate of N. While P rates and their interaction were not significant. Whereas, N uptake of straw (SNU) was significantly (*p* < 0.05) affected by the main effect of NP.

The maximum and the minimum values of nitrogen uptake by the grain (GNU) were (130.06 and 43.08) kg ha−1 recorded from the rates of 161 kg N ha−1, and control plots respectively. The application of N rates above 161 kg N ha-1 has not significant difference within N rates. The grain yield was found to have higher content of N than straw. The result in line with Daba A., (2017) reported that, the highest amount of nitrogen uptake by grain (104.9 kg ha-1) was recorded at the rate of 120 kg N ha-1.

The maximum value of N uptake by straw were (46.35 and 45.11) kg ha-1 at the rate of 207/46 N P2O5 and the minimum value was recorded at control plot (Table 6). Other authors Assen and Debele, (2000) was reported that nitrogen uptake significantly increased in straw with increasing N rates.

### **3.4.4 Phosphorus uptake in grain and straw**

The analysis of variance showed that phosphorus in grain uptake (GPU) was not significantly affected by the application of NP and their interaction; while the main effects of N had significant (*p* < 0.05) effects on straw p uptake (SPU). The maximum (12.91 kg ha-1) and minimum (4.09 kg ha-1) uptake of P in straw was observed at the rate of 207 kg ha-1 N and control plots respectively (Table 6). The result indicated that the amount of nitrogen uptake by the grain is higher than straw. The straw yield of wheat found to have higher content of nitrogen than phosphorus. The finding is in line with Godebo *et al*. (2021) who concluded that the grain yield has a higher content of N and P than straw.

Table 6: Nutrient uptake and agronomic use efficiency

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Nitrogen  kg ha-1 | GNU  Kg ha-1 | SNU  Kg ha-1 | GPU  Kg ha-1 | SPU  Kg ha-1 | AEN  kg kg-1 | AEP  kg kg-1 |
| 115 | 112.96b | 34.16b | 16.43 | 7.95b | 20.92a | 37.47b |
| 161 | 130.06a | 33.30b | 15.76 | 9.34b | 17.19b | 43.54a |
| 207 | 128.39ab | 46.35a | 16.21 | 12.91a | 12.15c | 39.68ab |
| 253 | 133.30a | 42.23ab | 16.42 | 9.91ab | 10.54d | 42.26a |
| LSD (5%) | 16.9 | 9.6 | 6.7 | 3.1 | 1.07 | 3.96 |
| Sig. | \* | \* | ns | \* | \* | \* |
| P2O5 kg ha-1 |  |  |  |  |  |  |
| 46 | 128.92 | 45.11a | 14.56 | 9.04 | 15.05 | 56.19a |
| 69 | 133.80 | 38.33ab | 14.55 | 10.86 | 15.74 | 38.82b |
| 92 | 123.31 | 33.58b | 19.50 | 10.17 | 14.80 | 27.19c |
| LSD | 14.6 | 8.3 | 5.9 | 2.7 | 0.92 | 3.43 |
| Sig. | ns | \* | ns | ns | ns | \* |
| CV (%) | 10.3 | 19.4 | 32.8 | 24.7 | 10.46 | 14.46 |
| (0,0) | 43.08 | 19.78 | 8.44 | 4.09 |  |  |
| ***NB:*** *\*\* = highly significant at P<0.01, \* = significant at P<0.05, ns = non-significant, AEN= agronomic efficiency of nitrogen, AEP = agronomic efficiency of phosphorus, CV = coefficient of variance, GNU = grain nitrogen uptake, GPU = grain phosphorus uptake, LSD = least significant difference, SNU = straw nitrogen uptake, SPU = straw phosphorus uptake*  **4. Partial Budget Analysis** | | | | | | |

The Dominance analysis indicated that treatments were produced lower net benefits were not significant for investment. These treatments dominated and dropped from competition and were marked “D” (Table 7). These un-dominated treatments were 161/46, 115/69, and 115/46 kg ha-1 NP combination gave net benefits of 313,460.00 ETB, 295,061.00 ETB, and 284,437.00 ETB and acceptable marginal rate of return range of 660%, 760% and 1060%, respectively. The maximum net benefit of 313,460 ETB ha-1 with an acceptable MRR of 660% was recorded due to the application of 161/46 N and P2O5 kg ha-1.

According to CIMMYT (1988), the recommendation is not necessarily based on the highest (MRR) rather, it based on the lowest cost, the highest net benefit with acceptable MRR. This finding also, in line with Asargew *et al*. (2014) who recommended 276 N and 90 P2O5 kg ha-1 to get maximum yield and economic advantage based on maximum net benefit of 22,120.6 ETB ha-1 with acceptable MRR. Therefore the rates of 161/46 kg ha-1 N and P2O5 gave the highest grain yield (4,468 kg ha-1), provided the highest net benefit and within the acceptable MRR (660%).

Table 7: Dominance Analysis and marginal rate of return of NP on grain yield and straw yield

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NP fertilizer | | AGY(kgha-1) | ASY  (kg-1) | Total  GB(ETB) | TVC  (ETB) | NB  (ETB) | DA | MB(ETB) | MC(ETB) | MRR % |
| N(kg ha-1) | P2O5(kg ha-1) |
| 0 | 0 | 1976 | 3598 | 145544.4 | 0.00 | 145544.4 |  |  |  |  |
| 115 | 46 | 4029 | 7797 | 297601.2 | 13164 | 284437.2 | 138892 | 138892.5 | 13164.3 | 1060 |
| 115 | 69 | 4219 | 7156 | 309625.2 | 14564 | 295061.2 | 10624 | 10624.2 | 1399.8 | 760 |
| 115 | 92 | 4144 | 7126 | 304347.8 | 15964 | 288383.8 | D |  |  |  |
| 161 | 46 | 4468 | 9017 | 330809.9 | 17350 | 313459.9 | 25076 | 18398.6 | 2786.1 | 660 |
| 161 | 69 | 4486 | 6961 | 327932.5 | 18750 | 309182.5 | D |  |  |  |
| 161 | 92 | 4416 | 7366 | 323853.8 | 20150 | 303703.8 | D |  |  |  |
| 207 | 46 | 4207 | 7611 | 309696.8 | 21536 | 288160.8 | D |  |  |  |
| 207 | 69 | 4441 | 7700 | 326241.0 | 22936 | 303305.0 | D |  |  |  |
| 207 | 92 | 4041 | 8671 | 300193.2 | 24336 | 275857.2 | D |  |  |  |
| 253 | 46 | 4465 | 8577 | 329685.1 | 25722 | 303963.1 | D |  |  |  |
| 253 | 69 | 4361 | 7668 | 320634.5 | 27122 | 293512.5 | D |  |  |  |
| 253 | 92 | 4270 | 7760 | 314424.4 | 28522 | 285902.4 | D |  |  |  |

**NB***: AGY = Adjusted grain yield kg ha-1, ASTRY = Adjusted straw yield (kg ha-1*)*, DA = Dominance analysis, D = Dominated, GB = gross benefit in Ethiopian Birr, NB = Net benefit, NP = nitrogen and phosphorus combination (Kg ha-1), TVC = Total variable cost.*

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# **5. CONCLUSION AND RECOMMENDATION**

Based on the analysis of variance results, the application of nitrogen rates generally affected crop phenological and growth parameters. Concerning yield and yield components, N rates significantly affect grain yield, and thousand seed weight. The productive tiller number and dry biomass were significantly (*p* < 0.05) influenced by the interaction effects of N and P2O5 rates.

The maximum and the minimum grain yield was obtained at the rate of 161 and 0 N application and dry biomass yield was obtained at the rate of 46 kg ha-1 and 0 P2O5 respectively. The agronomic efficiency of nitrogen (AEN) was significantly influenced by nitrogen rates, with the highest value recorded at 115 kg ha−1 N. The agronomic efficiency of phosphorus (AEP) influenced by NP application, with the highest value recorded at 161 /46 kg N and P2O5 ha−1. In terms of NP uptake in grain and straw, the analysis variance showed that, nitrogen uptake by the grain significantly influenced by the N rates.

The combination of 161/46 N and P2O5 kg ha-1 was recorded high net benefits and an acceptable range of MRR. Therefore, the application of 161 kg ha-1 N and 46 kg ha-1 P2O5 is biologically as well as economically feasible and recommended in the study area.

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# **6. REFERENCES**

Alambo, M., Meskele, M., Gessese, M. K., Wachamo, E. W., Melo, B. Y., Lakore, Z. S., Wassie, A. S., Haile, W. T., Kassie, F. C. (2022). Performance evaluation of Ethiopian bread wheat (*Triticum aestivum* L.) genotypes in Southern Ethiopia. *Journal of Advances in Agriculture*, 2022, Article 1338082. https://doi.org/10.1155/2022/1338082

American Association of Cereal Chemists (AACC). 2000. Approved Methods of the American Association Cereal Chemists, American Association of Cereal Chemists, Inc., St. Paul.

Asargew, F., Yayeh, B., Omer, B. (2014). Influence of N and P fertilizer rate on the yield and yield components of bread wheat in Northwestern Ethiopia. *Journal of Biology, Agriculture, and Healthcare*, 4 (15).

Ashamo, M., Mulualem, T., Goa, Y. (2012). Participatory on-farm evaluation of improved bread wheat technologies in some districts of southern Ethiopia. *Ethiopian Journal of Agricultural Sciences,* 85-90.

Assen, Y., Debele, D. (2000). The effect of rate and time of nitrogen application on its uptake by bread wheat varieties and soil characteristics on farmers’ fields in *Ethiopia Journal of Natural Resources Management;* 2(2), 137–150.

Ayalew, D., Tesfaye, K., Mamo, G., Yitaferu, B., Bayu, W. (2012). Variability of rainfall and its current trend in Amhara region, Ethiopia. \**African Journal of Agricultural Research*, 7\*(10), 1475–1486. <https://doi.org/10.5897/ajar11.698>

Belete, F., Dechassa, N., Molla, A., Tana, T. (2018). Effect of nitrogen fertilizer rates on grain yield and nitrogen uptake and use efficiency of bread wheat (*Triticum aestivum* L.) varieties on Vertisols of central highlands of Ethiopia. *Journal of Agriculture and Food Security*, 7(1), 1–12. https://doi.org/10.1186/s40066-018-0231-z

Bouteska, A., Sharif, T., Bhuiyan, F., Z. A., M. (2024). Impacts of the changing climate on agricultural productivity and food security: Evidence from Ethiopia. *Journal of Cleaner Production,* 449(February), 141793. https://doi.org/10.1016/j.jclepro.2024.141793

Bouyoucos, G. S. (1951). Recalibration of the hydrometer methods for making mechanical analysis of soil. *Agronomy Journal*, 43, 434-438. https://doi.org/10.2134/agronj1951.00021962004300090005x

Central Statistical Agency (CSA). (2018). Agricultural sample survey series, 2017/18: Report on area and production for major crops (private holdings, main season) (Statistical Bulletin No. 586). Central Statistical Agency of Ethiopia, Addis Ababa, Ethiopia.

Central Statistical Agency (CSA). (2019). Report on area, production, and yield of crops for private peasant holdings for main crop season 2012–2013 Addis Ababa: CSA.

CIMMYT. (1988). Maize production in developing countries: A technology development and transfer perspective. Mexico City.

Cottenie, A. (1980). Soil and plant testing as a basis of fertilizer recommendations (No. 38/2).

Daba, N. A. (2017). Influence of nitrogen fertilizer application on grain yield, nitrogen uptake efficiency, and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) cultivars in Eastern Ethiopia. *Journal of Agricultural Science*, 9(7), 202. https://doi.org/10.5539/jas.v9n7p202

Debele, B. (1980). The physicochemical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Degaga, B., Abera, T., Habtamu, A. (2022). Effect of nitrogen application time on phenology, growth, yield, and economic feasibility of bread wheat (*Triticum aestivum* L.) varieties in Ambo District of Western Ethiopia. Oromia Agricultural Inputs Regulatory Authority, 22(2), 112–118. https://doi.org/10.5829/idosi.aejaes.2022.112.118

Desta, G., Amede, T., Gashaw, T., Legesse, G., Agegnehu, G., Mekonnen, K., Whitbread, A. (2022). Sorghum yield response to NPKS and NPZn nutrients along sorghum-growing landscapes. Experimental Agriculture, 58(1), 1–16. https://doi.org/10.1017/S0014479722000072

Dobocha, D., Abera, G., Worku, W. (2019). Grain quality and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) varieties in response to nitrogen fertilizer in Arsi highlands, southeastern Ethiopia. Journal of Agricultural Science, 1544-1552.

Dugassa, A., Belete, K., Shimbir, T. (2019). Response of wheat (*Triticum aestivum* L.) to different rates of nitrogen and phosphorus at Fiche-Salale, highlands of Ethiopia. International Journal of Plant Breeding and Crop Science, 6(1), 474–480.

Food and Agriculture Organization. (2015). World reference base for soil resources 2014: International soil classification system for naming soils and creating legends for soil maps (World Soil Resources Reports No. 106). Rome, Italy: Author. <http://www.fao.org/3/i3794en/I3794en.pdf>

Gebremedhin, T. (2019). Response of bread wheat (*Triticum aestivum* L.) yield and yield components to different levels of phosphorus in Gozamen District, East Gojjam. *Journal of Agriculture, Forestry and Fisheries*, 8(1), 23-30. https://doi.org/10.11648/j.aff.20190801.14

Godebo, T., Laekemariam, F., Loha, G. (2021). Nutrient uptake, use efficiency, and productivity of bread wheat (*Triticum aestivum* L.) as affected by nitrogen and potassium fertilizer in Keddida Gamela. *Environmental Systems Research*, 10(12). https://doi.org/10.1186/s40068-020-00210-4

Haileselassie, B., Habte, D., Haileselassie, M., Gebremeskel, G. (2014). Effects of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat (*Triticum aestivum* L.) on the sandy soils of Hawzen District, Northern Ethiopia. *Journal of Agriculture, Forestry and Fisheries,* 3(3), 189–198. https://doi.org/10.11648/j.aff.20140303.1

Hordofa, M., Mekuria, R., Kebede, K. (2022). Effect of NPS-B blended fertilizer and nitrogen application on bread wheat yield and economic profitability on Nitisols of Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, 8(1), 28–37. https://doi.org/10.20431/2454-9479.0801004

Kabato, W., Ergudo, T., Mutum, L., Tibor, J., Zontan, M. (2022). Response of wheat to combined application of nitrogen and phosphorus along with compost. *Journal of Crop Science and Biotechnology,* 25(5), 557–564. <https://doi.org/10.1007/s12892-022-00151-7>

Kedir, M., Kufa, T., Dume, B. (2021). Assessment of soil chemical properties and coffee leaf analysis in Goma Woreda of Oromia Region. *Journal of* *Agriculture, Forestry, and Fisheries*, 10(3), 93-101. https://doi.org/10.11648/j.aff.20211003.13

Luo, Z., Liu, H., Li, W., Zhao, Q., Dai, J., Tian, L., Dong, H. (2018). Effects of reduced nitrogen rate on cotton yield and nitrogen use efficiency as mediated by application mode or plant density. *Field Crops Research,* 218, 150-157. https://doi.org/10.1016/j.fcr.2017.12.012

Menamo, M., Nebyou, M. (2016). The effect of application of different rates of NP fertilizers on yield and yield attributes of bread wheat in Chancha District. *Journal of Natural Sciences Research*, 6(5), 63–66.

Sahlemedhin, S., Taye, B. (2000). Procedures for soil and plant analysis (Technical Paper No. 74). National Soil Research Center, NFIA.

Takala, B. (2019). Soil acidity and its management options in western Ethiopia. *Journal of Environment and Earth Science,* 9(10), 2224-3216

Tamene, L., Amede, T., Schulz, J. K., Degfie, T., Steffen, S. (2017). A review of soil fertility management and crop response to fertilizer application in Ethiopia: Towards the development of site-and context-specific fertilizer recommendation.

Tolosa, S. (2012). Effects of inorganic fertilizer types and sowing methods on variable seed rates on yield and yield components of teff in Ada’a Woreda, central Ethiopia (*Master’s thesis*). Haramaya University

Wogene, S., Anjulo, A. (2017). Response of bread wheat varieties to different levels of nitrogen at Doyogena, Southern Ethiopia. *International Journal of Science and Research*, 7(2), 452-459.