academicJournals

Vol. 12(19), pp. 1646-1660, 11 May, 2017
DOI: 10.5897/AJAR2015.10545
Article Number: FEE6DF164149
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

*Full Length Research Paper*

# Response of bread wheat (*Triticum aestivum* L.) varieties to N and P fertilizer rates in Ofla district, Southern Tigray, Ethiopia

**Melesse Harfe**

Mehoni Agricultural Research Center, Ethiopian Institute of Agricultural Research, Tigray, Ethiopia.

Received 19 October, 2015; Accepted 12 November, 2015

**A field experiment was conducted during the 2006 cropping season in Ofla district in southern Tigray to assess the response of bread wheat (*Triticum aestivum* L.) varieties to nitrogen and phosphorus fertilizer rates. Factorial combinations of two wheat varieties (HAR1685 and Shehan), four N rates (0, 23, 46 and 69 kg N/ha), and four P rates (0, 10, 20 and 30 kg P/ha) were laid out in split plot design (varieties in the main plot and N-P fertilizer rates to the sub plots) with three replications. The variety HAR1685 exhibited significantly higher values for grain yield, harvest index, total N uptake, grain P uptake, N apparent recovery, and agronomic efficiency but had shorter plant height and maturity period. Shehan on the other hand, exhibited higher values for tiller number per plant, plant height, shoot dry weight at 50% flowering and at physiological maturity, biomass yield, straw yield. Application of N and P fertilizers significantly (P<0.01) influenced plant height, shoot dry weight at physiological maturity, and tiller number per plant. The variety-P-N interactions were highly significant for grain yield, biomass yield, harvest index, and straw yield. The increase and decrease in shoot dry weight at 50% flowering, grain yield, biomass yield harvest index, straw yield and available soil phosphorus at harvesting did not show a consistent trend. However, an increasing trend was observed when the rate of N increased from 0 to 69 kg N/ha. Non-significance difference due to the interaction of P and N with respect to plant height, number of tillers per plant, initial plant stand, 1000 kernels weight ,days to 50% flowering and total soil nitrogen at harvest was observed. The grain and straw N and P contents and uptakes, increased with N and P levels but the apparent recovery and agronomic efficiency of N and P fertilizers decreased with increasing N and P rates in both varieties. Grain and biomass yields were significantly and positively correlated with most of the agronomic parameters, grain N and P contents, grain N and P uptakes, and total N and P uptakes. Moreover, grain and straw N and P contents and their uptakes were strongly and positively correlated with applied N and P respectively. Even though it is one year in one location study, it can be concluded that the released variety HAR1685 had high grain yield potential, strong stems, medium plant height, heavier kernel weight, higher harvest index, and shorter maturing period and responsive to higher N and P rates. The shortcoming of the experiment was it was conducted in a single location. It should be repeated in more than one location.**

**Key words:** Bread wheat, nitrogen, phosphorous, soil, physical, chemical.

## INTRODUCTION

Wheat is one of the major cereal crops in the Ethiopian highlands that lie between latitude 6° and 16°N and longitude 35° and 42°E and is widely grown from 1500 to 3000 masl. The most suitable areas for wheat production however fall between 1900 and 2700 masl (Hailu, 1991). Wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisol areas (Amanuel et al., 2002). Among the major plant nutrients, N is the most essential for successful wheat production in most agro-ecological zones.

In Tigray Regional State, particularly in the southern part of the region, wheat is a dominant crop in the medium and highland areas. Currently, nationally released wheat varieties are introduced into the region and some of the varieties get acceptance by farmers due to their adaptability, higher yield, relatively high grain price, good bread and other food quality, and the straw for their livestock. From the wheat varieties, HAR1685 is a major one which is currently produced widely in the area particularly in Ofla district. In the area, there are also land races which are widely cultivated by farmers locally named as ‘Bani/Shehan’ and ‘Tselim Sinday’.The landrace Bani (Shehan) is a white colored which is used for making bread, ‘Kita’, porridge, and consumed as roasted and boiled.

In order to alleviate the soil fertility problem in the area, the Bureau of Agriculture and Natural Resources of the Region has introduced chemical fertilizers particularly DAP (diammonium phosphate) and urea fertilizers in each district of the zone. However the fertilizer rate which is being used by farmers is ‘blanket ‘recommendation throughout the region. Therefore, the objective of the study was to see the effect of each fertilizer rate on: (1) yield and yield components of bread wheat varieties; (2) NP concentrations in plant tissues; (3) NP uptake by bread wheat varieties; (4) fertilizer N and P recovery and use efficiency; (5) the interactions of N and P in affecting yield and yield components of bread wheat..

## MATERIALS AND METHODS

### Description of the study area

The study was conducted in Tigray Regional State in the southern zone at Ofla district (Figure 1) in the experimental field of Alamata Agricultural Research Center during 2006 cropping season (Figure 2).

Ofla district is one of the six districts of Southern Tigray zone. It is located about 620 km away from Addis Ababa to the north part of the country and about 150 km to the south of Mekelle town. The district is located on the geographic coordinates of 12°31' North latitude and 39°33' East longitude. The altitude varies between 1700 and 2800 masl and the slope ranges from 8 to 15%. Traditionally the district is classified into three agro-ecological zones, namely, *Dega*, *Waina Dega*, and *Kolla*. The *Waina Dega* covers the largest part which accounts about 42% of the total 133,300 ha while both the Dega, and *Waina Dega* cover 29% (Ofla District BoANRD, 2005). The average land holding in the district is about 0.5 ha per household and estimated total population of 132,491 (Ofla District BoANRD, 2005).

### Experimental design and procedures

Two wheat varieties (HAR1685 a released variety and Shehan local variety), four nitrogen fertilizer rates (0, 23, 46 and 69 kg N/ha) and four rates of phosphorus fertilizer (0, 10, 20 and 30 kg P/ha) were used in a 2×4×4 factorial split-plot design with three replications. The varieties were assigned to the main plot and the fertilizer combination treatments were assigned to the sub- plots.

The experimental field was prepared 3 times before planting by the conventional tillage practice. Urea and diammonium phosphate (DAP) were used for the source of N and P. The total area used in the experiment was 55.5 × 18 m (999 $m^2$). Nitrogen was applied in split doses; that is one-third at planting and two-third at mid-tillering while phosphorus was applied in full dose at planting time. The two wheat varieties were sown at the recommended seed rate of 150 kg/ha in rows by using manual row maker on July 18, 2006. The spacing between plants, rows, sub-plots, main plots, and blocks were 5, 20, 50, 100 and 150 cm, respectively.

Each sub- plot had 2 m × 3 m (6 $m^2$) gross size and 0.4 m × 3 m (1.2 $m^2$) net size. The row length was 3 m and there were 10 rows in each sub-plot. The middle two rows were used for agronomic data collection, the four rows were used for destructive sampling, and the four rows served as border.

### Data collection

#### *Soil sampling and determination of soil physical and chemical properties*

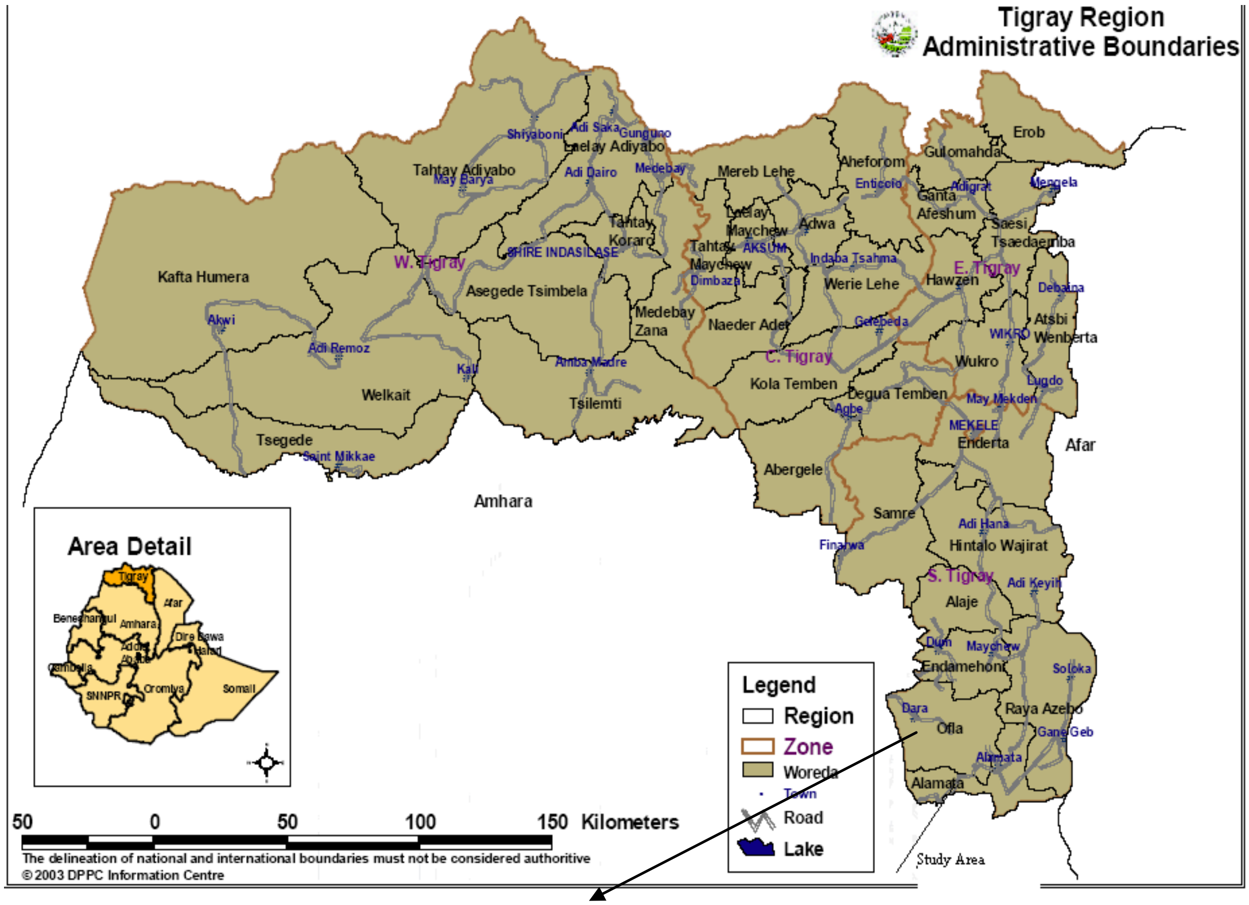
Soil samples were taken using auger from the experimental area (5 spots from each block) after final land preparation from a depth of 0-30 cm. The sub samples were composited to get a representative sample for analysis of soil texture, organic matter, pH, CEC, total nitrogen and available phosphorus. At maturity, one representative soil sample (0-30 cm depth) was taken from every plot with auger and the same treatments were composited making 32 samples for the analysis of available phosphors and total nitrogen.

Soil texture was determined using the Bouyoucos hydrometer method (Day, 1965). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter and organic carbon was determined following Walkely and Black wet oxidation method as described by Jackson (1967). Available P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen et al. (1954). Total nitrogen was determined using Kjedahl method as described by Jackson (1967).

#### *Plant sampling and analysis for nitrogen and phosphorus content*

After maturity, five non-boarder wheat plants per plot were randomly

E-mail: melesse2005@gmail.com.




**Ofla District (the study area)**

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

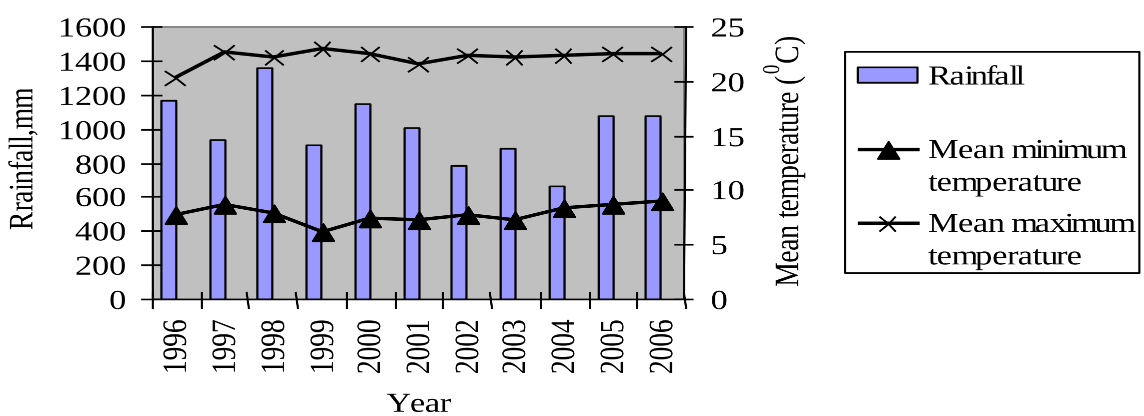



**Figure 2.** Eleven years' Annual rainfall, mean minimum and maximum temperatures in the study area (1996-2006).

taken and partitioned into grain and straw. Samples collected from each replication of a treatment were bulked to give one composite plant tissue sample. The grain and straw samples were separately air dried and oven dried at 70°C to constant weight. Before grinding, the straw samples were washed with distilled water to clean the samples from contaminants such as dust. After washing with distilled water, it was dried in oven at 70°C for 24 h. After drying, the plant tissue sample was ground and passed through 1 mm sieve for laboratory analysis.

The grain and straw contents of N and P were determined by Kjedahl method and Olsen method respectively. Sample digestion was carried out by using a fume hood. This digest was used for the

**Table 1.** Selected physical and chemical properties of the soils of the experimental site.

| pH | CEC (cmol/kg) | Total N (%) | Available P (ppm) | OM (%) | Particle size distribution (%) | | | Textural class |
|---|---|---|---|---|---|---|---|---|
| | | | | | Sand | Silt | Clay | |
| 7.04 | 44.41 | 0.134 | 19.9 | 2.23 | 36 | 33.64 | 30.36 | **Clay loam** |

analysis of both N and P. Total N and P uptake by straw and grain were calculated by multiplying N and P contents by respective straw and grain yield/ha. Total N or P uptake, by whole biomass, was calculated by summing up the N uptake and P uptake of grain and straw. Finally, applied N or P nutrient recovery was computed as the difference of the values of N or P nutrient (kg/ha) and the plant uptake values (kg/ha) as described by Pal (1991), agronomic and physiological efficiency as suggested by Mengel and Kirkby (1987, 1996).

#### *Agronomic data collection*

Days to 50% crop emergence, days to heading, days to 50% flowering, and days to 90% physiological maturity were recorded at the respective growth stage of the crop. Data were collected from the middle rows for initial plant stand at 15 days after sowing (DAS) and number of tillers per plant. Samples for shoot dry weight per 0.5 m row length at 50% flowering and at harvest were taken from the rows selected for destructive sampling. Dry matter of the shoot at 50% flowering and physiological maturity was determined by oven drying the samples at 70°C to constant weight. Yield and yield components and related traits such as plant height, 1000 kernel weight, total above-ground biomass, grain yield and harvest index were recorded during the study time. Thousand grain weight and grain yield were determined after adjusting the moisture level of grain to 12.5%. The harvest index was calculated by dividing the grain yield with total aboveground biomass.

#### Data analysis

The data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using MSTATC computer software programs. Significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984). Correlation between agronomic parameters, N and P contents and uptakes was carried out by SPSS software program.

## RESULTS AND DISCUSSION

### Selected physical and chemical properties of the soil of the experimental site

The results of the laboratory analysis of some physical and chemical properties of the soil of the experimental site are presented in Table 1. The results indicated that the experimental soil was clay loam in texture, with pH ($H_2O$) of 7.04, organic matter content of 2.23%, total N of 0.134%, available P of 19.9 mg/kg, and CEC of 44.41 cmol/ kg soil (Table 1).

Sahlemedihn (1999) ranked 0.1 to 0.2 total N of soil as low and, 3 to 5% organic matter (OM) as high and more than 5% as very high. In line with this, the OM content of the experimental soil was in the medium range and the total N is in low range. Cation exchange capacity (CEC) is an important parameter of soil; because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Sahlemedhin (1999), CEC by sodium acetate at pH 8.2 or ammonium acetate at pH 7.0 with values between 25 and 40 cmole/kg are high to medium and satisfactory for agriculture with the use of fertilizer and CEC > 40 as high to very high and needs only small amounts of lime and potassium fertilizers. Therefore, the CEC of the experimental soil (44.41 cmol/kg) was in the range of high to very high. According to Mengel and Kirkby (1996) the optimum pH range for wheat production is from 4.1 to 7.4. Thus, the pH of the experimental soil was optimum for wheat production.

### Crop phenology

More than 90% crop emergence occurred in all plots regardless of the N and P rates. Crop emergence up to 50% was recorded in all plots within eight days. This delay might be due to the delayed rainfall after planting.

The days to 50% flowering recorded significant difference ($p<0.05$) due to N rates (Appendix Table 2). As the N level increased from 0 kg/ha to 69 kg/ha, the days to 50% flowering were delayed from 67.58 to 70.04 days (Table 2). This shows higher rate of N delays flowering. This result is supported by Legesse (2004) who reported that the heading of teff was significantly influenced by applied fertilizer N rate. He indicated that N fertilization at the rate of 23 and 46 kg N/ha significantly delayed the heading stage of teff by five days as compared to the control.

There was no significant difference between the two wheat varieties and among the different P rates with respect to 50% flowering (Appendix Table 2). Similarly Legesse (2004) showed that there was no significant difference on heading stage of teff due to the application of P and its interaction with N. However, fertilizer N is reported to promote leaf growth and leaf area thereby increasing the amount of radiation intercepted and dry matter production (Russel, 1988). This might have promoted greater vegetative development for longer period of time before reproductive phase begins and hence might have caused delay in flowering.

The two varieties and N rates showed highly significant

**Table 2.** Effect of variety, P and N on some agronomic parameters

| Main effect | Variable | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variety** | **IPS** | **NTP** | **DF** | **DM** | **PH** | **SDWH** | **TKW** |
| HAR1685 | | | | | | | |
| Shehan | 415.92 | 5.84 | 71.10 | 129.60 | 103.75 | 208.76 | 40.32 |
| **SE(+)** | **2.42** | **0.06** | **0.57** | **0.52** | **0.05** | **3.35** | **0.95** |
| **LSD(0.05)** | **43.54** | **ns** | **ns** | **6.97** | **0.74** | **15.14** | **ns** |
| **N(kg/ha)** | **IPS** | **NTP** | **DF** | **DM** | **PH** | **SDWH** | **TKW** |
| 0 | 389.63 | 5.00 | 67.58 | 123.87 | 82.63 | 168.88 | 45.46 |
| 23 | 390.04 | 5.50 | 68.33 | 124.87 | 87.08 | 184.87 | 45.74 |
| 46 | 376.29 | 6.29 | 69.08 | 125.74 | 91.17 | 198.17 | 45.53 |
| 69 | 386.00 | 6.63 | 70.04 | 127.00 | 94.18 | 218.17 | 45.29 |
| **SE((+)** | **4.13** | **0.09** | **0.28** | **0.37** | **0.97** | **6.52** | **0.86** |
| **LSD(0.05)** | **ns** | **ns** | **0.80** | **1.05** | **2.74** | **18.45** | **ns** |
| **P(k/ha)** | **IPS** | **NTP** | **DF** | **DM** | **PH** | **SDWH** | **TKW** |
| 0 | 388.83 | 5.71 | 68.79 | 125.63 | 86.41 | 171.90 | 44.86 |
| 10 | 381.75 | 5.79 | 69.21 | 125.75 | 88.16 | 196.20 | 45.37 |
| 20 | 387.54 | 6.04 | 68.42 | 124.92 | 89.93 | 204.54 | 45.54 |
| 30 | 383.83 | 5.87 | 68.63 | 125.13 | 90.56 | 210.42 | 46.25 |
| SE(+) | 4.13 | 0.09 | 0.28 | 0.37 | 0.97 | 6.52 | 0.86 |
| **LSD(0.05)** | **Ns** | **Ns** | **Ns** | **Ns** | **2.74** | **18.45** | **Ns** |
| **CV(%)** | **5.25** | **7.61** | **2.01** | **1.44** | **5.34** | **16.32** | **9.31** |

IPS = Initial plant stand; NTP = Number of tillers per plant; DF = Days to 50% flowering; DM = Days to 90% physiological maturity; PH = Plant height; SDWH = Shoot dry weight at harvest; TKW = thousand kernel weight.

difference in relation to the days to 90% physiological maturity (Appendix Table 2). Table 2 indicates that the variety HAR1685 matured earlier compared to the local variety Shehan. The highest doses of N (69 kg/ha) delayed physiological maturity of the two wheat varieties. It increased the days to maturity from 123.87 to 127.00 days. Similarly Gurmessa (2002) indicated that fertilizer N beyond 46 kg/ha delayed the physiological maturity of wheat. Furthermore, Temesgen (2001) and Legesse (2004) have reported that N fertilization delayed the physiological maturity of teff. This delay might be due to extended vegetative growth instead of reproductive growth. Plants treated with N, particularly with the highest level of N, remained slightly green for longer duration while those plants without N showed yellow spike, leaf and stem indicating early physiological maturity which might have been due to depression of cytokinin synthesis or increased production of abscisic acid (ABA) under low N supply (Marshner, 1995). According to the author, amino acids are required for the synthesis of cytokinins so that cytokinin metabolism is low at low N status of the soil.

## Yield and yield components

### *Plant height*

The ANOVA table (Appendix Table 1) shows a highly significant difference between the two wheat varieties.
The local variety Shehan significantly taller than the improved variety HAR1685 (Table 2). Addis (2003) also reported that from 20 genotypes tested in four different locations of Tigray, Shehan had the highest plant height compared to HAR1685 and the other 18 genotypes. There was also highly significant (P<0.01) difference among the different rates of N and P fertilizer rates (Appendix Table 1). As the nitrogen fertilizer rate increased from 0 to 69 kg/ha, the plant height increased from 82.63 cm to 94.18 cm (Table 2). As the P rate increased from 0 to 30 kg/ha the plant height increased from 86.41 to 90.56 cm. Similarly Amsal et al. (2000) observed a positive and linear response to applied fertilizer to plant height in the central highlands of Ethiopia. Several studies in Ethiopia also exhibited dramatic plant height enhancement in response to each increment of fertilizer N doses (Zewdu et al., 1992; Tilahun et al., 1996; Damene, 2003). Many other researchers also have reported that application of higher dose of N fertilizer increased plant height (Evans et al., 1975; Hari et al., 1997; Behera, 1998). The variety-P-N interaction was found non-significant (Appendix Table 1).

### *Number of tillers per plant*

The analysis of variance showed that there was non-significant difference between the two varieties, due to N

**Table 3.** Shoot dry weight at 50 % flowering as influenced by N and P fertilizer rates.

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shoot dry weight (g/ 0.5 m) | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | **0** | **23** | **46** | **69** | **Mean** | **0** | **23** | **46** | **69** | **Mean** |
| 0 | 42.87 | 53.76 | 56.54 | 58.53 | 52.92 | 65.86 | 82.73 | 86.82 | 89.94 | 81.34 |
| 10 | 43.00 | 59.23 | 109.21 | 114.71 | 81.54 | 56.39 | 62.77 | 68.77 | 102.71 | 72.66 |
| 20 | 79.05 | 85.40 | 90.32 | 126.73 | 95.37 | 94.94 | 100.14 | 106.00 | 111.6 | 103.17 |
| 30 | 74.96 | 79.56 | 83.25 | 84.39 | 80.54 | 114.3 | 109.57 | 117.17 | 118.54 | 114.89 |
| Mean | 59.97 | 69.49 | 84.83 | 96.09 | 77.59 | 82.87 | 88.80 | 94.69 | 105.70 | 93.02 |
| Interaction | V | P | VxP | N | VxN | PxN | | VxPxN | | |
| SE(+) | 1.58 | 1.04 | 1.48 | 1.08 | 1.48 | 2.09 | 2.95 | | | |
| LSD(0.05) | ns | 2.95 | 4.17 | 2.95 | 4.17 | 5.91 | 8.35 | | | |
| CV(%) | | | | | 5.99 | | | | | |

and P rates (Appendix Table 1). However, as the N fertilizer rate increased from 0 to 69 kg/ ha, the tiller number increased from 5 to 6.63 (Table 2). In line with this several reports (Archer, 1988; Mossedeq and Smith, 1994; Ortiz- Monastrio et al., 1997; Genene, 2003) indicated greater tillering as well as higher percentage of survival of the tillers due to higher N application. Botella et al. (1993) reported that stimulation of tillering with application of N may be due to its effect on cytokinin synthesis.

### Thousand kernels weight

Non-significant difference was observed between the two wheat varieties and among the different N and P in relation to 1000 kernel weight (Appendix Table 1). However, HAR1685 had heavier 1000 kernel weight (Table 2). Gurmessa (2002) also indicated neither the main effect of N and P nor their interaction brought about significant change in 1000 grain weight. In similar other reports, Mooleki and Foster (1993), Gooding and Davies (1997), Mekonen (1985), Lemma et al. (1992) and Zewdu et al. (1992) have reported non-significant effect on 1000 kernel weight due to different doses of N fertilizers.

### *Effect of N and P on initial plant stand*

Plant stand was counted at 15 days after planting. The results revealed that there was significant difference ($P<0.01$) between HAR1685 and Shehan (Appendix Table 1). Shehan had more number of plants per four rows compared to HAR1685 (Table 2). This might be due to small seed size in Shehan which has more number of seeds per kilogram of seed compared to HAR1685. The ANOVA table indicates non-significant difference ($P<0.05$) among the P and N fertilizer rates and their interactions in terms of plant stand (Appendix Table 1).

### *Effect of applied N and P on shoot dry weight at 50% flowering*

The N rates, P rates and variety-N-P interactions showed significant ($P<0.05$) difference for shoot dry weight at 50% flowering (Appendix Table 1). As the P rates increased from 0 to 30 kg P/ha, shoot dry weight at N rates of 0, 23 and 69 kg N/ha for variety HAR1685 increased up to 20 kg P/ha and then decreased at 30 kg P/ha. At N rates of 46 kg N/ha shoot dry weight for this variety increased at 10 kg P/ha then it decreased. For variety Shehan the trend was different at all N rates (except 69 kg N/ ha); 0 kg P/ha gave high yield than 10 kg P/ha. The highest shoot dry weights at 50% flowering were found in 69-20 N-P kg/ ha interaction in HAR1685 (126.73 g/ 0.5 m) and in 30-69 P-N kg/ha interaction in Shehan (118.54 g/ 0.5 m). However, the lowest shoot dry weights at 50% flowering were observed in the interaction 0-0 N-P kg/ ha in HAR1685 (42.87 g/ 0.5 m) and in Shehan (56.39 g/ 0.5 m) in the interaction 10-0 P-N kg/ ha interaction (Table 3).

### *Shoot dry weight of wheat at harvesting*

The analysis of variance table (Appendix Table 1) shows that there were highly significant differences ($P< 0.01$) due to varieties, P rates and N rates. Shehan gave more shoot dry weight than HAR1685 (Table 2). For both N and P as the rate increased, the shoot dry weight at physiological maturity increased.

### *Effect of N and P rates on grain yield*

Appendix Table 1 indicates there was highly significant difference between the varieties, the N rates, P rates and their interactions in relation to grain yield. Table 4 shows that the highest grain yield for HAR1685 was at 0 kg P/ha

**Table 4.** Grain yield as influenced by N and P fertilizer rates.

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield (kg/ha) | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | **0** | **23** | **46** | **69** | **Mean** | **0** | **23** | **46** | **69** | **Mean** |
| 0 | 2333 | 3708 | 4596 | 4741 | 3844 | 2966 | 3114 | 3191 | 3628 | 3225 |
| 10 | 3671 | 4011 | 4266 | 4682 | 4157 | 2351 | 3227 | 3400 | 3903 | 3220 |
| 20 | 3710 | 3852 | 4109 | 4408 | 4020 | 2925 | 3181 | 3378 | 3542 | 3256 |
| 30 | 3217 | 4175 | 4258 | 4164 | 3954 | 2575 | 3501 | 3580 | 3819 | 3369 |
| Mean | 3233 | 3936 | 4307 | 4499 | 3994 | 2704 | 3256 | 3387 | 3723 | 3268 |
| Interaction | V | P | VxP | N | VxN | PxN | | VxPxN | | |
| SE(+) | 21.89 | 20.89 | 29.55 | 20.89 | 29.55 | 41.78 | 59.10 | | | |
| LSD(0.05) | 235.10 | 59.10 | 83.58 | 59.10 | 83.58 | 118.20 | 167.71 | | | |
| CV(%) | | | | | 2.82 | | | | | |

**Table 5.** Biomass yield as influenced by N and P fertilizer rates.

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Biomass yield (kg/ha) | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | **0** | **23** | **46** | **69** | **Mean** | **0** | **23** | **46** | **69** | **Mean** |
| 0 | 6967 | 10592 | 10708 | 10992 | 9815 | 9236 | 10358 | 10325 | 12017 | 10484 |
| 10 | 8375 | 9783 | 9975 | 10625 | 9689 | 8152 | 9392 | 9642 | 11517 | 9676 |
| 20 | 8675 | 10167 | 10417 | 10667 | 9982 | 9644 | 9797 | 9975 | 10525 | 9985 |
| 30 | 8049 | 9658 | 10508 | 11042 | 9814 | 8917 | 11169 | 11233 | 11233 | 10638 |
| Mean | 8016 | 10050 | 10402 | 10832 | 9825 | 8987 | 10179 | 10294 | 11323 | 10196 |
| Interaction | V | P | VxP | N | VxN | PxN | | VxPxN | | |
| SE(+) | 2.30 | 2.86 | 4.05 | 2.86 | 4.05 | 5.73 | 8.10 | | | |
| LSD(0.05) | 33.98 | 8.10 | 11.45 | 8.10 | 11.45 | 16.20 | 22.90 | | | |
| CV(%) | | | | | 0.14 | | | | | |

and 69 kg N/ha and for Shehan it was at 10 kg P/ha and 69 kg N/ ha. The increase and decrease in grain yield did not show a consistent trend. For example for HAR1685 there was yield decrement at 69 kg N/ha as P rate increased from 0 to 30 kg P/ha, but for Shehan there was fluctuation. For HAR1685 at 46 kg/ha, relatively the highest yield was obtained at the lowest P rate, but for Shehan it was vice versa.

The fertilized treatments when compared with unfertilized treatments (control), showed yield increment in both varieties. Yield increment of 1831 kg/ha (78.5%) and 853 kg/ha (28.75%) were obtained in the highest (30-69 N-P kg/ ha) interaction in both HAR1685 and in the local variety Shehan over the control respectively (Table 4). Even though there was yield increment in both varieties, higher grain yield increment was found in HAR1685 due to the interaction of 69-0 N-P kg/ ha (4741 kg/ha) and followed by 46-0 N-P kg/ha (4596 kg/ha). This indicates application of N fertilizer had significant effect on grain yield compared to P fertilizer. This might be due to high initial P content in the soil. Moreover, the highest grain yield in Shehan was recorded in 69-10 N-P kg/ha interaction which was 3903 kg/ha. In contrast to this, the lowest grain yields in HAR 1685 (2333 kg/ ha) and in Shehan (2966 kg/ha) were in 0-0 N-P kg/ ha and in 10-0 N-P kg/ha interactions respectively. It was visually observed that wheat plants in the control plots were very thin with small spike size, short and light in color whereas plants in the fertilized plots particularly in the highest N levels had thick and strong stems, green in color, large spike size. Particularly this visual difference was evident clearly in HAR1685 variety.

### *Effect of N and P rates on biomass yield of wheat*

The variety, P rates, N rates and all interactions were highly significantly different (Appendix Table 1).

**Table 6.** Harvest Index as influenced by N and P fertilizer rates

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Harvest index | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | **0** | **23** | **46** | **69** | **Mean** | **0** | **23** | **46** | **69** | **Mean** |
| 0 | 0.34 | 0.35 | 0.43 | 0.43 | 0.39 | 0.32 | 0.30 | 0.31 | 0.30 | 0.31 |
| 10 | 0.44 | 0.41 | 0.43 | 0.44 | 0.43 | 0.29 | 0.34 | 0.35 | 0.34 | 0.33 |
| 20 | 0.43 | 0.38 | 0.39 | 0.41 | 0.40 | 0.30 | 0.33 | 0.34 | 0.34 | 0.33 |
| 30 | 0.40 | 0.43 | 0.41 | 0.38 | 0.41 | 0.29 | 0.31 | 0.32 | 0.34 | 0.32 |
| Mean | 0.40 | 0.39 | 0.42 | 0.42 | 0.41 | 0.30 | 0.32 | 0.33 | 0.33 | 0.32 |
| Interaction | V | P | VxP | N | VxN | PxN | | VxPxN | | |
| SE(+) | 0.0014 | 0.002 | 0.009 | 0.002 | 0.009 | 0.0013 | 0.041 | | | |
| LSD(0.05) | 0.060 | 0.020 | 0.026 | 0.020 | 0.026 | 0.037 | 0.115 | | | |
| CV(%) | | | | | 2.60 | | | | | |

**Table 7.** Effect of N and P fertilizer rates on straw yield.

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Straw yield (kg/ha) | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | **0** | **23** | **46** | **69** | **Mean** | **0** | **23** | **46** | **69** | **Mean** |
| 0 | 4633 | 6883 | 6112 | 6251 | 5970 | 6259 | 7250 | 7134 | 8386 | 7256 |
| 10 | 4704 | 5773 | 5709 | 5944 | 5533 | 5802 | 6165 | 6241 | 7613 | 6455 |
| 20 | 4968 | 6315 | 6307 | 6258 | 5962 | 6723 | 6619 | 6597 | 6983 | 6731 |
| 30 | 4831 | 5483 | 6250 | 6878 | 5861 | 6342 | 7390 | 7651 | 7415 | 7199 |
| Mean | 4784 | 6114 | 6095 | 6333 | 5831 | 6282 | 6855 | 6906 | 7599 | 6910 |
| **Interaction** | **V** | **P** | **VxP** | **N** | **VxN** | **PxN** | **VxPxN** | | | |
| SE(+) | 20.53 | 20.95 | 29.62 | 20.95 | 20.62 | 41.89 | 59.24 | | | |
| LSD(0.05) | 537.34 | 59.25 | 83.80 | 59.25 | 83.80 | 118.50 | 167.60 | | | |
| CV(%) | | | | | 1.61 | | | | | |

Application of 69 kg N/ha gave the highest mean biomass yields in HAR1685 (10832 kg/ha) and in Shehan (11323 kg/ha). Compared to the control plots, mean biomass increment of 2816 kg/ha in HAR1685 and 2336 kg/ha in Shehan were found due to the application of 69 kg N/ha. This might be due to more plant height and number of tillers in Shehan (Table 5). The highest biomass yield for HAR1685 was at the highest P and N rates (Table 5) similar to grain yield, there was fluctuation. The only consistent trend was for HAR1685 at 0 kg N/ha to 20 kg P/ha and then decreased at 30 kg P/ha.

### *Effect of N and P on harvest index*

There was highly significant (P<0.01) difference among the variety, N rate, P rate and their interactions in relation to harvest index (Appendix Table 2). Table 6 shows that the decrease and increase in harvest index does not show any trend in any of the N and P rates. In terms of numerical comparisons, it could be said that in general harvest index of HAR1685 is higher than that of Shehan at every N and P rates.

Generally as the N and P rates increased from 0 kg/ha to 30 kg P/ha and 69 kg N/ha, the harvest indices were increased from 0.34 to 0.38 in HAR1685 and from 0.32 to 0.34 in Shehan (Table 6). The highest harvest indices were observed in 10-69 P-N kg/ ha (0.44) followed by 0-69 P-N kg/ha (0.44) in HAR1685 and in 10-46 P-N kg/ha in the local variety Shehan. The variety HAR1685 had greater mean harvest index (0.41) than Shehan (0.32). This might be due to the higher grain and straw yields in HAR1685 compared to Shehan.

### *Effect of N and P on straw yield of bread wheat*

The ANOVA (Appendix Table 2) indicates there was

**Table 8.** Available soil phosphorus as influenced by N and P fertilizer rates.

| P applied (kg/ha) | N applied (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Available soil P | | | | | | | | | |
| | HAR1685 | | | | | Shehan | | | | |
| | 0 | 23 | 46 | 69 | Mean | 0 | 23 | 46 | 69 | Mean |
| 0 | 8.48 | 9.57 | 10.59 | 9.43 | 9.62 | 8.81 | 9.64 | 8.75 | 8.95 | 9.04 |
| 10 | 11.49 | 8.63 | 9.63 | 9.56 | 9.83 | 10.68 | 11.12 | 10.52 | 10.55 | 10.72 |
| 20 | 15.57 | 11.36 | 11.44 | 13.55 | 12.98 | 11.61 | 11.80 | 12.65 | 13.37 | 12.36 |
| 30 | 16.36 | 13.81 | 12.62 | 14.62 | 14.35 | 14.64 | 13.9 | 14.82 | 16.78 | 15.04 |
| Mean | 12.97 | 10.84 | 11.07 | 11.79 | 11.67 | 11.44 | 11.62 | 11.68 | 12.41 | 11.79 |
| **Interaction** | **V** | **P** | **VxP** | **N** | **VxN** | **PxN** | **VxPxN** | | | |
| SE(+) | 0.011 | 0.047 | 0.066 | 0.047 | 0.066 | 0.094 | 0.133 | | | |
| LSD(0.05) | ns | 0.133 | 0.188 | 0.133 | 0.188 | 0.266 | 0.376 | | | |
| CV(%) | | | | | 1.44 | | | | | |

highly significant (P<0.01) difference between varieties, among N rates, P rates and their interactions with respect to straw yield. The only observable trend (Table 7) is that for HAR1685 in which at 0 kg N/ ha the straw yield increased as P rate increased from 0 to 20 kg P/ha then the straw yield decreased. In terms of numerical comparison, in general straw yield of Shehan was higher than that of HAR1685 at every N and P rates. This could help to understand farmers' preference to Shehan variety for animal feed. The mean straw yield of HAR1685 increased with increase in P up to 20 kg/ ha whereas Shehan did not show any definite trend. However mean straw yield was highest for both varieties at the highest rate of N (Table 7).

### *Effects of N and P application on available soil phosphorus at harvesting*

The analysis of variance table (Appendix Table 2) shows there was highly significant (P<0.01) difference among the P and N rates and their interactions. The decrease and increase in available soil P was not consistent (Table 8). The available soil P at harvest in HAR1685 at 0 kg P/ha increased as the N rate increased from 0 to 46 kg N/ha but at 30 kg P/ha, available soil P for same variety decreased as N increased from 0 to 46 kg ha. But such type of decrease and increase due to different rates of P and the same rate of N is not observed for Shehan.

Generally as the P and N rates increased from 0 to 30 kg P/ ha and 69 kg N/ ha, the available soil phosphorus at harvesting increased from 8.48 to 14.62 ppm in HAR 1685 and from 8.81 to 16.78 ppm in Shehan (Table 8) even though the amount is less than the available soil P at planting which was 19.9 ppm. The reduction of soil available P at harvesting compared to the initial might be due to uptake by the wheat crop and fixation in soil. The lowest available soil P at harvesting was observed in 0-0 P-N kg/ ha interactions. The highest available soil P was recorded in the interaction of 30-69 P-N kg N/ha in HAR 1685 (14.62) and in Shehan (16.78 ppm).

### *Effect of N and P application on total soil nitrogen at harvesting*

There was non-significant difference (P>0.05) in both the main and interaction effects with respect to total soil nitrogen at harvesting. The result is supported by Damene (2003) and Gurmessa (2002) who described that the values of total N content of the soil, analyzed from composite sample made per treatment tended to remain almost the same irrespective of different rates of N application.

## Crop lodging and disease incidence

In relation to crop lodging and disease/ insect pest incidence the local variety Shehan was logged almost completely except at the control treatments (data is not given). Moreover, from the visual observation this variety was highly affected by the fungal disease rust particularly the plots with the highest N level. In contrast to this the improved variety HAR-1685 did not show any lodging as well as rust infestation even at the highest N level (69 kg/ha). The highest lodging percentage in Shehan might be due to the vigorous plant height and weak stalks it possesses.

## Content, uptake, apparent fertilizer recovery and nutrient use efficiency of nitrogen and phosphorus

The grain and straw N content increased with rates of N. Maximum N content of grain were 2.2% in HAR 1685 and

**Table 9.** Nitrogen and phosphorus contents of grain and straw, uptake, apparent recovery, and N and P use efficiency at harvest in HAR1685 variety as affected by N and P fertilizers.

| Treatment (kg/ha) | Content (%) | | Uptake | | | Apparent recovery | Nutrient use efficiency | |
|---|---|---|---|---|---|---|---|---|
| | Grain | straw | Grain | Straw | Total | | Agronomic | Physiological |
| **N rates** | | | | | | | | |
| 0 | 1.65 | 0.27 | 53.36 | 12.89 | 66.25 | 122.69 | 30.66 | 0.25 |
| 23 | 2.00 | 0.26 | 78.74 | 15.73 | 94.47 | 107.65 | 23.38 | 0.22 |
| 46 | 2.20 | 0.34 | 94.76 | 21.01 | 115.77 | 51.78 | 18.36 | 0.35 |
| 69 | 1.90 | 0.26 | 85.52 | 16.46 | 101.98 | 122.69 | 30.66 | 0.25 |
| **P rates** | | | | | | | | |
| 0 | 0.083 | 0.078 | 3.19 | 4.66 | 7.85 | - | - | - |
| 10 | 0.083 | 0.100 | 3.45 | 5.53 | 8.98 | 4.94 | 31.30 | 6.34 |
| 20 | 0.085 | 0.105 | 3.42 | 6.26 | 9.68 | 3.98 | 8.80 | 2.21 |
| 30 | 0.090 | 0.116 | 3.56 | 6.82 | 10.37 | 3.66 | 3.67 | 1.00 |

**Table 10.** Nitrogen and phosphorus content of grain and straw, uptake, apparent recovery, and N and P use efficiency at harvest Shehan variety.

| Treatment (kg/ha) | Content (%) | | Uptake | | | Apparent recovery | Nutrient use efficiency | |
|---|---|---|---|---|---|---|---|---|
| | Grain | straw | Grain | Straw | Total | | Agronomic | Physiological |
| **N rates** | | | | | | | | |
| 0 | 1.80 | 0.25 | 48.66 | 15.70 | 64.36 | 1.80 | - | - |
| 23 | 1.88 | 0.28 | 61.21 | 18.95 | 80.16 | 1.88 | 68.70 | 24.02 |
| 46 | 1.88 | 0.31 | 63.67 | 21.41 | 85.08 | 1.88 | 45.04 | 14.89 |
| 69 | 1.83 | 0.32 | 68.00 | 24.07 | 91.07 | 1.83 | 40.16 | 14.79 |
| **P rates** | | | | | | | | |
| 0 | 0.070 | 0.065 | 2.26 | 4.72 | 6.97 | 0.070 | - | - |
| 10 | 0.080 | 0.088 | 2.58 | 5.68 | 8.26 | 0.080 | 5.58 | - 0.50 |
| 20 | 0.085 | 0.089 | 2.77 | 5.99 | 8.76 | 0.085 | 3.88 | 1.55 |
| 30 | 0.089 | 0.105 | 3.00 | 7.56 | 10.56 | 0.089 | 5.19 | 4.80 |

1.88% in Shehan at the fertilizer rates of 23 and 46 kg N/ha (Tables 9 and 10). Grain contained 87.3% of the total N of the crop and the remaining 12.7% was found in straw of HAR1685. However, in Shehan grain had 86.43% of the total N in the crop, and the remaining 13.57% of the total N was found in the straw. At 46 kg N/ha, grain and straw contents of N increased by 33.3 and 25.93% in HAR 1685 and 4.44 and 24% in Shehan over the control respectively. Abdoulaye and Marienville (1999) and Mekonen (2005) also reported that the grain N content and total N content were generally greater with applied N.

Nitrogen uptake of grain and straw increased with levels of N and maximum uptake was obtained at 46 kg N/ha in HAR1685 and at 69 kg N/ha in Shehan. The grain and straw uptake increased by 77.58 and 62.99% in HAR1685 in 46 kg N/ha and 39.75 and 53.3% in 69 kg N/ha in the local variety Shehan respectively. The total uptake also increased with increasing N rates in both varieties (Tables 9 and 10). The highest total N uptakes were 115.77 kg/ha in HAR1685 and 91.07 kg/ha in Shehan.

Grain and straw P contents increased with increasing of P rate in both varieties. Grain P content ranged from 0.083 to 0.09% in HAR1685 and from 0.07 to 0.0.089% in Shehan. Straw P content also ranged from 0.078 to 0.116% in HAR1685 and from 0.065 to 0.105 % in Shehan. Grain and straw P uptake increased with rate of P application in both varieties. As the P rate increased from 0 to 30 kg P/ha, the grain P uptake increased from 3.19 to 3.56 kg/ha in HAR1685 and from 2.26 to 3 kg/ha in Shehan. Moreover, the straw P uptake increased from 4.66 to 6.82 kg/ha in HAR1685 and from 4.72 to 7.56 kg/ha in Shehan. Grain P uptake was higher in HAR1685 than in Shehan but the reverse happened for straw P uptake (Tables 9 and 10).

The apparent N recovery decreased with increasing rates of N application in both varieties. As the N rate increased from 23 to 69 kg N/ha, the apparent recoveries decreased from 122.69 to 51.78% in HAR 1685 and from

**Table 11.** Correlations between some agronomic parameters

| Parameter | P | N | IPS | SDWF | SDWH | TKW | DF | DM | GY |
|---|---|---|---|---|---|---|---|---|---|
| N | 0.000 | | | | | | | | |
| IPS | -0.031 | -0.083 | | | | | | | |
| SDWF | 0.545** | 0.474** | 0.340 | | | | | | |
| SDWM | 0.415* | 0.412* | 0.537** | 0.578** | | | | | |
| TKW | 0.093 | -0.016 | -0.904** | -0.288 | -0.541** | | | | |
| DF | -0.056 | 0.351* | 0.813** | 0.406* | 0.632** | -0.910** | | | |
| DM | -0.059 | 0.253 | 0.846** | 0.390* | 0.643** | -0.955** | 0.948** | | |
| GY | 0.059 | 0.664** | -0.598** | 0.175 | -0.084 | 0.566** | -0.301 | -0.383* | |
| BY | 0.044 | 0.817** | 0.122 | 0.506** | 0.391* | -0.170 | 0.440* | 0.353* | **0.608**** |

**, * Correlation is significant at 0.01 and 0.05 level. SY = Straw yield, SP = Straw phosphorus, GP = Grain phosphorus content, SPU = Straw phosphorus uptake, GPU = Grain phosphorus uptake, TPU = Total phosphorus uptake, P = Applied phosphorus, N = Applied nitrogen, GY = Grain yield, SY = Straw yield, HI = Harvest index, BY = Biomass yield.

**Table 12.** Correlations between applied N and contents, uptake, grain yield, biomass yield, straw yield and harvest index.

| Parameters | P | N | GY | SY | SNC | GNC | SNU | GNU | TNU |
|---|---|---|---|---|---|---|---|---|---|
| GY | 0.059 | 0.664** | | | | | | | |
| SY | 0.013 | 0.554** | 0.051 | | | | | | |
| SNC | 0.284 | 0.061 | -0.042 | 0.108 | | | | | |
| GNC | -0.136 | 0.070 | 0.055 | 0.056 | 0.009 | | | | |
| SNU | 0.210 | 0.343 | 0.003 | 0.605** | 0.851** | 0.036 | | | |
| GNU | -0.074 | 0.470** | 0.669** | 0.084 | -0.029 | 0.778** | 0.026 | | |
| TNU | -0.021 | 0.535** | 0.646** | 0.226 | 0.176 | 0.759** | 0.264 | 0.971** | |
| HI | 0.055 | 0.188 | 0.780** | -0.573** | -0.089 | -0.0022 | -0.360* | 0.466** | 0.363* |
| BY | 0.054 | 0.817** | 0.601** | 0.828** | 0.057 | 0.076 | 0.481** | 0.442* | 0.541** |

**, * Correlation is significant at 0.01 and 0.05 level. SY = Straw yield, SP = Straw phosphorus, GP = Grain phosphorus content, SPU = Straw phosphorus uptake, GPU = Grain phosphorus uptake, TPU = Total phosphorus uptake, P = Applied phosphorus, N = Applied nitrogen, GY = Grain yield, SY = Straw yield, HI = Harvest index, BY = Biomass yield.

68.70 to 40.16% in Shehan (Tables 9 and 10). The maximum and the minimum apparent recoveries of N were recorded at 23 and 69 kg N/ha respectively. Furthermore, the highest P apparent recoveries were obtained at the lowest P rates in both varieties. The highest P apparent recoveries in HAR1685 (4.94) and in Shehan (5.58) were found at 23 kg P/ha.

Agronomic efficiency decreased with increasing N rate in both varieties. As the P level increased from 23 to 69 kg N/ha, the agronomic efficiency decreased from 30.66 to 18.36 in HAR 1685 and from 24.02 to 14.79 in Shehan. The highest agronomic efficiencies were observed at 23 kg N/ha both in HAR 1685(30.66) and Shehan (24.02). However, highest physiological efficiency was at the highest N rate (69 kg/ ha) in both HAR1685 (0.35) and Shehan (0.37).

The highest agronomic efficiency in HAR1685 (31.3) was recorded at application rate of 10 kg P/ha in HAR1685 and in Shehan (4.82) at 30 kg P/ha. However, the lowest agronomic efficiency of P in HAR1685 (3.67) was at 30 kg P/ha, and the lowest agronomic efficiency in Shehan (-0.5) was at the lowest P rate (10 kg P/ha). This might be due to the higher grain yield in the control than in 10 kg P/ha of Shehan variety. According to Craswell and Godwin (1984), high agronomic efficiency would be obtained if the yield increment per unit applied is high.

Highest physiological efficiency of P in HAR1685 (6.34) was obtained with the lowest P rate (10 kg P/ha) but in Shehan (40.17) it was found at the highest P rate (30 kg P/ha). Generally, physiological efficiency of P decreased in HAR1685 but increased in Shehan with application of P rates (Tables 9 and 10).

## Functional relationships between agronomic parameters and N and P contents and uptakes

The simple correlation between the agronomic parameters is given in Tables 11. The table indicates grain yield was significantly and positively correlated with applied nitrogen (r=0.664), biomass yield (r=0.608), and thousand kernel weight (r=0.566) but negatively correlated with initial plant

**Table 13.** Correlations between applied P and contents, uptake, grain yield, biomass yield, straw yield, and harvest index

| Parameters | P | N | GY | SY | SP | GP | SPU | GPU | TPU |
|---|---|---|---|---|---|---|---|---|---|
| N | 0.000 | | | | | | | | |
| GY | 0.059 | 0.664** | | | | | | | |
| SY | 0.013 | 0.554** | 0.051 | | | | | | |
| SP | 0.659** | -0.068 | 0.224 | -0.229 | | | | | |
| GP | 0.363* | 0.026 | 0.130 | -0.136 | 0.172 | | | | |
| SPU | 0.668** | 0.239 | 0.225 | 0.333 | 0.833** | 0.096 | | | |
| GPU | 0.299 | 0.458** | 0.760** | -0.045 | 0.263 | 0.735** | 0.216 | | |
| TPU | 0.671** | 0.395* | 0.517** | 0.248 | 0.788** | 0.401* | 0.902** | 0.616** | |
| BY | 0.054 | 0.807** | 0.608** | 0.828** | -0.049 | -0.037 | 0.402* | 0.389* | 0.496** |
| HI | 0.055 | 0.188 | 0.780** | -0.573** | 0.331 | 0.190 | -0.022 | 0.647** | 0.268 |

**, * Correlation is significant at 0.01 and 0.05 level. SY = Straw yield, SP = Straw phosphorus, GP = Grain phosphorus content, SPU = Straw phosphorus uptake, GPU = Grain phosphorus uptake, TPU = Total phosphorus uptake, P = Applied phosphorus, N = Applied nitrogen, GY = Grain yield, SY = Straw yield, HI = Harvest index, BY = Biomass yield.

stand (r=-0.598). The biomass yield also significantly and positively correlated with applied N (r=0.817), straw yield (r=0.828) (Table 12) and with plant height (r=0.393).

Table 11 also indicates harvest index was strongly and positively correlated with grain yield (r=0.78) but negatively correlated with straw yield (r=-0.573). The table also shows the correlation between contents of N, uptake and some agronomic parameters. It indicates that grain nitrogen uptake was correlated positively and significantly with applied N (r= 0.47), grain N content (r=0.778), and with grain yield (r=0.669) but negatively correlated with applied P(r=-0.074) and straw N content (r=-0.029).

Total N uptake was significantly and positively correlated with applied N (r=0.535), grain yield (r=0.646), grain N content (r=0.759) and grain N uptake (r= 0.971) as shown in Table 12. Moreover, the table shows that harvest index was strongly and positively correlated with grain yield (r=0.78), grain N uptake (r=0.466) and with total N uptake (r=0.363), but it had high negative correlation with straw yield (r=-0.573) and with straw N uptake (r=-0.36). The table also indicates that biomass yield was significantly and positively correlated with applied N (r=0.817), grain yield (r=0.608), straw yield (r=0.828), straw N uptake (r=0.481), grain N uptake (r= 0.442), and with total N uptake (r=0.541).

The correlation between applied P, concentrations, uptake and some agronomic parameters is indicated in Table 13. It shows that significant and positive correlations between straw P content and applied P (r=0.659), straw yield and applied N(r=0.554), straw P uptake and applied P(r=0.668). The table also indicates that grain P uptake was significantly and positively correlated with applied N(r=0.458), grain yield (r=0.0.760), and grain P content (r=0.735). Furthermore, biomass yield was correlated positively with straw P uptake (r=0.402), grain P uptake (r=0.389), and positively and significantly correlated with total P uptake (r=0.496). The harvest index was correlated strongly and positively with grain P uptake (r= 0.647).

## Conclusions

In Tigray Regional State, particularly in the Southern part of the region, wheat is a dominant crop in the medium and highland areas. In this area like other parts of Ethiopia, wheat production is adversely affected by low soil fertility, suboptimal use of mineral fertilizers in addition to diseases, weeds, and erratic rainfall distribution.

In order to alleviate the soil fertility problem in the study area, the Bureau of Agriculture and Natural Resources of Tigray has introduced chemical fertilizers in each district of the zone. However the fertilizer rate which is being used by farmers is blanket recommendation throughout the region.

Two wheat varieties (HAR1685 and Shehan /Bani), four nitrogen fertilizer rates (0, 23, 46, and 69 kg N/ha) and four rates of phosphorus fertilizers (0, 10, 20 and 30 kg P/ha) were used in a 2×4×4 factorial arranged in split-plot design with three replications. Surface soil samples (0-30 cm depth) were collected before planting and analyzed for selected physical and chemical properties. Analysis of soil samples indicated that the experimental soil was clay loam in texture, with pH ($H_2O$) of 7.04, organic matter content 2.23%, total N 0.134%, available P of 19.9 mg/kg, and CEC of 44.41 cmol/kg soil.

The analysis of variance revealed that there was highly significant differences ( P<0.01) between the two wheat varieties with respect to plant height, initial plant stand, shoot dry weight at 90% physiological maturity, grain yield, biomass yield, harvest index, and days to 90% physiological maturity. However, no significant difference was observed between the varieties in relation to tiller number per plant, days to 50% flowering, 1000 kernels weight, shoot dry weight at 50% flowering and available soil P at harvesting. The local variety Shehan was taller than the improved variety HAR-1685. With respect to initial plant stand, Shehan had more number of plants compared to HAR1685.

Application of nitrogen fertilizer affected significantly (P<0.01) plant height, shoot dry weight at physiological maturity, days to 50% flowering and days to 90% physiological maturity. As the nitrogen level increased from 0 to 69 kg/ ha, the plant height increased from 82.63 to 94.18 cm. The number of tillers per plant also increased from 5 to 6.63 when the nitrogen rate increased from 0 to 69 kg/ha. The shoot dry weight at 90% physiological maturity increased from 168.88 to 218.17 g/0.5 m with nitrogen increment from control to 69 kg/ha. The highest nitrogen application delayed days to flowering and days to maturity in both varieties. It lengthened the days to flowering from 65.5 to 67.17 days in HAR 1685 and from 69.67 to 72.92 days in Shehan. Furthermore, it increased the days to maturity from 119.75 to 123.1 days in HA 1685 and from 128 to 130 in Shehan.

Significant difference was observed among the different phosphorus fertilizer rates with respect to plant height, shoot dry weight at 90% physiological maturity. As the phosphorus rate increased from 0 to 30 kg/ha, the plant height increased from 72.21 to 74.97 cm in HAR 1685 and from 100 to 106.15 cm in Shehan. Furthermore, the shoot dry weight at 90% physiological maturity increased from 167.89 to 187.28 g/ 0.5 m in HAR1685 and from 175.02 to 233.55 g/ 0.5 m in Shehan.

The P rates, N rates and their interactions were highly significant in terms of shoot dry weight at 50% flowering, grain yield, biomass yield, harvest index, straw yield, and available soil P at harvesting. The increase and decrease in shoot dry weight at 50% flowering, grain yield, biomass yield harvest index, straw yield and available soil phosphorus at harvesting did not show a consistent trend but generally as the N rates increased from 0 to 69 kg N/ha and these parameters increased. The highest shoot dry weights at 50% flowering were found at 69-20 N-P kg/ha interaction in HAR1685 and at 30-69 P-N kg/ha interaction was in Shehan. The highest grain yield, biomass yield and harvest index were observed in the lowest P rate and at the highest N rate (69 kg N/ha). For HAR1685 grain yield was highest at 0 kg P/ha and 69 kg N/ha and for Shehan it was at 10 kg P/ha and 69 kg N/ha. The highest biomass yield was recorded at 30-69 P-N kg/ ha interaction in HAR1685 and at 0-69 P-N kg/ha interaction in Shehan. The highest harvest indices were observed in 10-69 P-N kg/ ha followed by 0- 69 P-N kg/ ha in HAR1685 and in 10-46 P-N kg/ ha in the local variety Shehan. But non-significant difference due to the interaction of P and N with respect to plant height, number of tillers per plant, initial plant stand, 1000 kernel weight, days to 50% flowering and total soil nitrogen after harvesting was observed.

The grain and straw N and P content, and uptake, increased with N and P levels but the apparent recovery and agronomic efficiency of N and P fertilizers decreased with increasing N and P rates in both varieties.

Grain yield and biomass yield were strongly and positively correlated with most of the agronomic parameters, grain N and P contents, grain N and P uptakes, and total N and P uptakes. Moreover, grain and straw N and P contents and their uptakes were strongly and positively correlated with applied N and P respectively.

From this study, it can be concluded that the improved variety HAR1685 had high grain yield potential, medium plant height, heavier kernel weight, higher harvest index, and shorter maturing period and responsive to higher N and P rates. Therefore, in Korem district, the variety HAR1685 could be preferred over the local variety Shehan. Application of N and P rates up to 30 kg P/ha and 69 kg N/ha respectively increased grain yield and most yield components of the two wheat varieties. In contrast to these, the lowest levels of P and N fertilizers (0-0 P-N kg/ ha) produced the lowest grain yield and yield components. However, the study was conducted at a single location for season; therefore, further detailed studies across locations and seasons are required to recommend agronomically optimum and economically feasible levels of N and P fertilizers for bread wheat.

## CONFLICT OF INTERESTS

The authors has not declared any conflict of interests.

### REFERENCES


Abdoulaye T, Marienville JW (1999). Nitrate reductase activity of diverse grain sorghum genotypes and its relationship to nitrogen use efficiency. Agron. J. 91:863-869.

Addis A (2003). Genotype by Environment Interaction of Bread Wheat (*Triticum aestivum* L.) Genotypes under Dryland Growing Conditions of Tigray. M.Sc. Thesis in Agriculture (Plant Breeding), Alemaya University.

Amsal T, Tanner DG, Taye T, Chanyalew M (2000). Agronomic and economic evaluation of the on-farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia. *In:* The Eleventh Regional Wheat Workshop for Eastern, Central, and Southern Africa. CIMMYT, Addis Ababa, Ethiopia.

Amanuel G, Kuhne RF, Tanner DG, Vlek PLG (2002). Recovery of 15-N labeled urea applied to wheat in the Ethiopian Highlands as affected by P fertilization. J. Agron. Crop Sci. 189:30-38.

Archer J (1988). Phosphorus. *In*: John Archer (ed.). Crop nutrition and fertilizer use. Farming Press Ltd. USA pp. 57-64.

Behera AK (1998). Response of Scented rice (*Oryza sativa*) to nitrogen under transplanted condition. Indian Agron. J. 43(1):64-67.

Botella MA, Cerda AC, Lips SH (1993). Dry matter production, yield and allocation of carbon-14 assimilate by wheat as affected by nitrogen source and salinity. Agron. J. 85(5):1044-1049.

Craswell ET, Godwin DC (1984). *In:* Mengel, K. and E.A. Kirkby, 1996. Principles of plant nutrition. Panima Publishing Corporation, New Delhi, India.

Damene D (2003). Yield response of bread wheat (*Triticum aestivum* L.) to applied levels of N and P fertilizers on Nitisol of Dawro Zone, Southwestern Ethiopia. M.Sc. Thesis in Agriculture, Alemaya University.

Day PR (1965). Hydrometer method of particle size analysis. *In*: Back, C.A. (eds.), Methods of soil analysis. American Society of Agron. J. 9(2):562-563.

Evans LT (1975). Crop physiology, Cambridge University press, London

Genene G (2003). Yield and quality response of bread wheat varieties to rate and time of nitrogen fertilizer application in Kulumsa, Southeastern Ethiopia. An M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University, Alemaya.

Gomez KA , Gomez AA (1984). Statistical analysis for agricultural research. John Willy and Sons Inc pp.120-155.

Gooding MJ, Davies WP (1997). Wheat production and utilization, systems quality and the environment, CAB international, UK

Gurmessa L (2002). Response of wheat (*Triticum aestivum*) to fertilizer N and P in Borona Zone, Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Alemaya University.

Hailu G-M (1991). Wheat production and research in Ethiopia.pp.1-15. *In* : Hailu Gebre-Mariam, Tanner, D.G., and Mengistu Hulluka (eds.) Wheat Research in Ethiopia: A Historical perspective, IAR/ CIMMYT, Addis Ababa, Ethiopia

Hari DM, Katyal SK, Ohiman SP (1997). Effect of nitrogen and seed rate in nursery on growth and yield of hybrid rice (*Oryza sativa*). Indian J. Agron. 42(2):275-277.

Jackson ML (1967). Soil chemical analysis. Practice Hall of India. New Delhi.

Lemma ZY, Tanner DG, Eyasu E (1992). The effects of nitrogen fertilizer rates and application timing on bread wheat in Bale Region of Ethiopia.. *In:* D.G. Tanner and W. Mwangi (eds.) Seventh Regional Wheat workshop for Eastern, Central, and Southern Africa. Addis Ababa, Ethiopia.

Marshner H (1995). Mineral nutrition of higher plant. 2$^{nd}$ edition. Academic Press, London. New York.

Mekonen A (2005). Response and uptake of barley (*Hordeum irregulare* L.) to different rates of Orga- P and nitrogen fertilizers on Nitisols of Gozamin district, Ethiopia, M.Sc. Thesis, Alemaya University

Mengel K, Kirkby EA (1987). Principles of Plant nutrition. International Potash Institute, Bern, Switzerland.

Mengel K, Kirkby EA (1996). Principles of Plant Nutrition, Panimo Publishing Corporation, New Delhi, India

Mossedeq F, Smith DH (1994). Time of nitrogen fertilizer application to enhance spring wheat yields in the Mediterranean climate. Agron. J. 86(2):221-226.

Mooleki SP, Foster RK (1993). Effects of N and P rates and proportional timing of N application on rainfed wheat in Zambia. Plant Soil 149:73-86.

Ofla District BoANRD (2005). Unpublished Document.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USA Circular 939:1-19

Ortiz-Monasterio JI, Sayre KD, Rajaram S, McMahon M (1997). Genetic progress in wheat and nitrogen use efficiency under four rates. Crop Sci. 37(3):898-904.

Pal UR (1991). Effects of source and rate of nitrogen and phosphorus on yield and nutrient uptake and apparent fertilizer recovery by maize in the Southern Guinea Savana. J. Agric. Sci. Technol. 1:21-24.

Russel EW (1988). Soil condition and plant growth. Eleventh edition. Bath Press, Great Britain.

Sahlemedhin S (1999). Draft guideline for regional soil testing laboratories. NFIA, Addis Abeba, Ethiopia.Temesgen K (2001). The effect of sowing date and nitrogen fertilizer on yield and yield traits of tef [ Eragrostis tef (Zucc.) Trotter ]. M.Sc. Thesis, Alemaya University.

Tilahun G, Tanner DG, Tekalign M, Getinet G (1996). Response of bread and durum wheat to source, level and timing of nitrogen fertilizer at two vertisol sites in Ethiopia. *In:* Tanner, D.G., T.Payne, and O.S., Abdalla (eds.). Proceeding of Ninth Regional Wheat Workshop for eastern, Central and South Africa. CIMMYT, Addis Ababa, Ethiopia.

Zewdu Y, Lemma Z, Tanner DG (1992). A study of several factors limiting wheat yields on farmers' fields and on station in Bale of Ethiopia. pp. 510-516. *In*: Tanner, D.G. and Mwangi W. (eds.). Proceeding of seventh regional wheat workshop for Eastern, Central and Southern Africa. CYMMYT. Addis Ababa, Ethiopia.

## APPENDIX

**Appendix Table 1**. The effect of experimental factors and their interactions on agronomic parameters

| Source of Variation | Mean Square | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PH | NTP | IPS | SDWF | SDWH | TKW | GY | BY |
| Replication | 119.7** | 0.542 | 400.6 | 116.232 | 13.936 | 31.6 | 53.02 | 3282.9** |
| Variety(V) | 21557.7** | 0.667 | 88877.5** | 5707.100 | 25306.8* | 2579.4 | 182135.7** | 47530.9** |
| Error (a) | 0.133 | 0.167 | 281.885 | 120.261 | 538.314 | 2.828 | 22733.704 | 80.907 |
| Phosphorus | 83.7* | 0.486 | 256.955 | 5973.9** | 7893.2** | 7.88 | 1559.6** | 20056.2** |
| VxP | 11.507 | 0.278 | 793.122 | 2351.7** | 3288.3 | 1.08 | 2224.7** | 16612.2** |
| Nitrogen | 605.5** | 13.125 | 981.483 | 3948.7** | 10458.3** | 0.80 | 82811.2** | 407568.2** |
| VxN | 24.8 | 0.083 | 493.760 | 271.6** | 962.8 | 1.70 | 2324.8** | 19085.4** |
| PxN | 5.7 | 0.162 | 461.538 | 694.5** | 155.8 | 0.40 | 3490.9** | 14424.9** |
| VxPxN | 8.7 | 0.287 | 630.372 | 316.6** | 60.6 | 1.20 | 5763.3** | 12581.6** |
| Error (b) | 22.5 | 0.199 | 408.905 | 26.1 | 22.8 | 11.91 | 150.8 | 160.374 |
| CV (%) | 5.34 | 7.61 | 5.25 | 5.99 | 2.48 | 7.58 | 2.82 | 1.05 |

Key: - ** and * significant different at 0.01 and 0.05 significance level respectively.
PH= Plant height, NTP= number of tillers per plant, IPS= Initial plant stand 15 days after planting, SDWF= Shoot dry weight at 50% flowering, SDWH= Shoot dry weight at harvesting.

**Appendix Table 2.** Mean Square for harvest index, Straw yield, days to 50% flowering and 90% physiological maturity and available soil phosphorus after harvesting

| Source of variation | Mean Square | | | | |
|---|---|---|---|---|---|
| | HI | SY | DF | DM | ASP |
| Replication | 0.001 | 38783.393 | 3.510 | 6.292 | 0.052 |
| Variety (V) | 0.176** | 27943940.461** | 527.34 | 1734.00** | 0.333 |
| Error(a) | 0.001 | 20225.107** | 15.594 | 12.875 | 0.005 |
| Phosphorus(P) | 0.004** | 1813243.764** | 2.71 | 3.792 | 142.478** |
| VxP | 0.001** | 462917.639** | 2.538 | 2.278 | 3.631** |
| Nitrogen (N) | 0.003** | 8687947.057** | 26.5** | 40.934** | 5.908** |
| VxN | 0.001** | 791890.644** | 3.12 | 2.278 | 7.383** |
| PxN | 0.001** | 460837.950** | 0.71 | 1.125 | 3.311** |
| VxPxN | 0.003** | 603279.908** | 0.65 | 1.435 | 3.332** |
| Error (b) | 0.001 | 10529.353 | 1.92 | 3.272 | 0.053 |
| CV (%) | 2.94 | 1.61 | 2.01 | 1.44 | 1.96 |

Key: - ** and * significant different at 0.01 and 0.05 significance level respectively.
HI= Harvest index, SY=straw yield, DF= Days to 50% flowering, DM= Days to 90 % physiological maturity, V= variety, P= phosphorus, N=nitrogen, ASP= available soil phosphorus at harvesting.