Effect of Nitrogen and Phosphorus Application on Concentration and Uptake of Respective Element by Wheat *(Triticum aestivum* L.) at North Shoa, Koticho kebele, Central Highlands of Ethiopia

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Field study was conducted in 2015 cropping season in North Shoa, Central Highlands of Ethiopia. The objectives of the study were determining the N and P concentration in plant parts and their uptake by wheat. The treatment contained four level of N (0, 32, 64 and 96 kg/ha) and four level of P (0, 23, 46 and 69 kg P₂O₅/ha) which were arranged in a randomized complete block design with three replications. The source of N and P were urea and TSP, respectively. Wheat variety, Digelu, was used as a test crop. Interaction of N by P produced highly significant difference on the concentration of N and P in the grain, concentration of P in the straw, P uptake by grain and total P uptake by wheat. Similarly, highly significant differences were observed on the concentration of N and P in the grain, concentration of N and P in the straw, P uptake by the grain, and total P uptake by wheat due to main effect N and P. Nitrogen uptake by straw and grain as well as total uptake were also highly significant only due to main effect N. Phosphorus uptake was only significant due to main effect N.

**Key words:** N concentration, P concentration, straw, grain, total uptake.

**INTRODUCTION**

Wheat is one of the most important cereal crops globally and is a staple food for about one third of the world's population (Hussain *et al.*, 2002). In Ethiopia, it is grown annually on 1.68 million ha with a total production of 3.08 million tons which makes the country the largest wheat producer in sub-Saharan Africa (CSA, 2010). However, low soil fertility, especially nitrogen (N) and phosphorus (P) deficiency, is one of the major constraints limiting wheat production in Ethiopian Highlands (Tanner *et al.*, 1993; Teklu and Hailemariam, 2009).

Nitrogen is one of the most yield-limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Huber and Thompson, 2007). Use of inorganic N fertilizers has had its most substantial beneficial effect on human health by increasing the yield of field crops and nutritional quality of foods needed to meet dietary requirements and food preferences for growing world populations (Galloway and Cowling, 2002; Galloway *et al.*, 2002). Nitrogen plays a vital role in increasing the yield of a crop (Minale *et al.*, 2005). High N supply favors the conversion of carbohydrates into proteins, which in turn, promotes the formation of protoplasm (Arnon, 1972). Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components, such as nucleic acids, amino acids, enzymes, and photosynthetic pigments (Bungard *et al.*, 1999).
Phosphorus is the second most essential element for crop production and it is deficient in most soils around the world (Brady and Weil, 2002). It has been shown that adequate P enhances many aspects of plant physiology like fundamental process of photosynthesis, flowering, seed formation and maturation (Brady and Weil, 2002; Salisbury and Ross, 1992).

Nitrogen and P are considered as the most deficient nutrients in soils of Ethiopia (Asnakew et al., 1991; Anonymous, 2000). This indicates that N and P are the most yield limiting factors of cereals including wheat production.

Soil fertility status varies among adjacent farms or plots mainly due to individual farmer’s soil management practices. Productivity of the crop in the country is generally low compared to the potential of this crop. According to FAO (2002), declining of soil fertility has been identified as one of the most important constraints to limit food production in Ethiopia, in particular and in Africa in general. This low productivity can be enhanced through improved crop management practices, including application of fertilizers. Fertilizers play a pivotal role in increasing yield and improving the quality of crops. High yielding wheat varieties demand adequate nutrient supply to produce maximum grain yield (Ali and Yasin, 1991). Best experiences in some bread wheat producing areas of Ethiopia like Bale and Arsi zones showed that the yield of bread wheat can be maximized beyond 4 t/ha by using N and P fertilizers as high as 6 t/ha. 

In view of the above findings, information related to N and P fertilizer recommendation in the study area is limited. Therefore, the objectives of this research were;

- To determine N and P concentration in wheat and their uptake by grain and straw

**MATERIALS AND METHODS**

**Site Description**

The experiment was conducted in 2015 cropping season at Koticho Kebele, central highlands of Ethiopia. It is located at 2,738 m above sea level. The soil of the experimental site is slightly acidic and has high organic matter content. The soil texture of an area is clayey. Eight years data from Ethiopian Meteorological Agency (2007-2014) indicated that the area receives average annual rainfall of 1179.36 mm and has minimum and maximum temperatures of 8.29 and 20.50°C, respectively.

**Experimental Materials**

Improved variety of wheat, Digelu, released in 2005 by Kulumsa Agricultural Research Center, was used as a test crop. Nitrogen and P fertilizers were applied in the form of urea and triple super phosphate (TSP), respectively.

**Treatments and Experimental Design**

The treatments consisted of factorial combinations of four levels of N (0, 32, 64 and 96 kg/ha) and four levels of P (0, 23, 46 and 69 P₂O₅ kg/ha) arranged in RCBD with three replications. Each plot consisted of 7 rows which are 20 m apart and 3 m in length. Full dose of P (23, 46 and 69 P₂O₅ kg/ha) and half rate of N (16, 32 and 48 kg/ha) were applied to the soil at the time of sowing and the remaining half of N was applied at tillering stage.

**Plant Sampling and Laboratory Analysis**

Five plants along with their grains were taken from each treatment and placed in to separate plastic bag. It was then, labeled and transported to laboratory for further preparation. Surface contaminates, such as dust, were removed from the sample by washing it with 0.3% detergent solution. It was allowed to dry at a temperature of 60 to 70°C for 24 hours.

**Concentration of N in grain and straw (%)**

Kjeldahl procedure was used to determine total N in plant parts (straw and grain). Half gram finely ground sample was taken and placed in to digester. Then, it was digested with NaOH. Acid digest was transferred to micro-Kjeldahl flasks using distilled water. Twenty ml boric acid solution was measured and transferred to erlenmeyer flask. Two drops of indicator solution was added to it and placed under condenser to prevent loss of ammonia. Seventy five ml of 40% NaOH was poured in to distillation flasks containing digests and mixed gently. It was immediately closed and then distillation started by heating the flask. After about 80 ml had collected, receiver flask was removed. Finally, the receiver flask solution was titrated with 0.1 N H₂SO₄ from green to a pink end point and the reading of the burette was recorded.

**Concentration of P in grain and straw (%)**

Wet digestion procedure was used to determine P in plant parts (straw and grain). Twenty g ammonium molybdate was dissolved by 25 ml distilled water in a 1 L volumetric flask (solution 1). One and a quarter g of ammonium metavanadate was also dissolved in 300 ml of distilled water in a 1 L beaker (solution 2). Then, solution 2 was added to solution 1 until it reached volume of distilled water used. Five hundred ppm stock solution was obtained from this mixture and further reduced to 100 ppm P solution. From 100 ppm of the solution 10 ppm of P solution and from 10 ppm, P working standards of zero, one, two, three, four and five ppm was determined. To determine P in plant tissue, five ml of aliquote sample digest was poured in to five ml volumetric flask, 10 ml of the molybdate and
vanadate solution was added to it and kept for 10 minutes for the color to develop, finally, observance using spectrophotometer was read at a wave length of 460 nm.

**Total uptake, grain uptake and straw uptake of N**

Nitrogen uptake by plant parts was calculated by multiplying the dry weight of plant parts with their N concentration in those parts. Algebraically, it was represented as fallow;

\[
NU \text{ (kg/ha)} = \text{dry weight of grain (kg/ha) x CNG (%)}
\]

CNG- is the ratio of N accumulated in grain to dry weight of the grain
Where, NUG= N uptake by grain, CNG= concentration of N in grain.

\[
NUS \text{ (kg/ha)} = \text{dry weight of straw (kg/ha) x CNS (%)}
\]

CNS- is the ratio of N accumulated in straw to dry weight of the straw
Where, NUS= Nitrogen uptake by straw, SNC= Concentration of N in straw

\[
TNU \text{ (kg/ha)} = \text{NUG (kg/ha) + NUS (kg/ha)}
\]

Where, TNU= Total N Uptake

**Total uptake, grain uptake and straw uptake of P**

Phosphorus uptake by plant parts was calculated by multiplying the dry weight of plant parts with their P concentration in those parts. Algebraically, it was represented as fallow;

\[
PUG \text{ (kg/ha)} = \text{dry weight of grain (kg/ha) x CPG (%)}
\]

Where, PUG= Phosphorus uptake by grain, CPG= Concentration of P in grain.

\[
PUS \text{ (kg/ha)} = \text{dry weight of grain (kg/ha) x CPS (%)}
\]

Where, PUS= P uptake by straw, CPS= Concentration of P in straw

\[
TPU \text{ (kg/ha)} = \text{PUG (kg/ha) + PUS (kg/ha)}
\]

Where, TPU= Total P Uptake

**Data Analysis**

Analyses of variances for the data recorded were done using GenStat program to determine the relationship between yield and yield components due to application of N and P fertilizer rates. Least significant difference (LSD) test at 5% probability was used for mean separation when the analysis of variance indicated the presence of significant differences.

**RESULTS AND DISCUSSION**

**Soil Physico-Chemical Properties of the Experimental Site**

The soil of the study area is dominated by the clay fraction. High clay content might indicate better water and nutrient holding capacity of the soil in the study area. Soil reaction of the experimental site is moderately acidic, which is suitable range for most crops. The study area also has medium/moderate OM content and moderate total N and available P. Generally, the soil of the study area is found to be suitable for wheat production.

**Concentration of nitrogen in wheat grain**

The mean squares due to main effects and N × P interaction were highly significant (P < 0.01) for the concentration of N in wheat grains (Table 9).

Mean comparison indicated that highest N accumulation in grains (2.75%) was attained at 64/23 kg N/P$_2$O$_5$/ha, which was statistically similar with treatment combinations of 0/46 and 64/0 kg N/P$_2$O$_5$/ha. On the other hand, the lowest N accumulation was recorded for treatment combination of 0/69 kg N/P$_2$O$_5$/ha. This was also not significantly different from treatments supplied with 0/23, 32/23, 32/46, 64/46 and 96/0 kg N/P$_2$O$_5$/ha (Table 1). This implies a positive response of grain N concentration to N and P rate, which might be due to NP supply resulted in increased uptake by root which increases its concentration in plant parts. In line with this, Dash et al. 2015 reported that grain N concentration was increased with NP application. Other studies have also found increased protein at greater NP application rates. Olesen et al., 2000; Campbell et al., 1977). Moreover, Halvorson et al., (2004) have indicated that grain protein content generally increased with increasing N rate.

<p>| Table 1: Concentration of N in wheat grains (%) as affected by interaction of N and P rates |</p>
<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>P$_2$O$_5$ (Kg/ha)</th>
<th>0</th>
<th>23</th>
<th>46</th>
<th>69</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.26cd</td>
<td>2.07abc</td>
<td>2.65f</td>
<td>1.92a</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>2.39de</td>
<td>2.07abc</td>
<td>2.06abc</td>
<td>2.15bc</td>
<td>2.17</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>2.60ef</td>
<td>2.75f</td>
<td>2.00ab</td>
<td>2.38d</td>
<td>2.43</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>2.10abc</td>
<td>2.37d</td>
<td>2.13bc</td>
<td>2.22cd</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.34</td>
<td>2.32</td>
<td>2.21</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>0.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEM (±)</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letters are not significantly different (P < 0.05).
Concentration of nitrogen in straw of wheat

There were highly significant (P<0.01) differences due to main effects, but non-significant differences were observed due to N x P interaction on N concentration in straw (Table: 9).

The concentration of N in straw increased significantly with the increase in N and P2O5 application, over the control. The N concentration of straw varied from 0.31% to 0.49% due to N application. The highest straw N concentration (0.494%) due to main effect of N was observed in treatment of 96 kg N/ha. The next highest straw N concentration (0.489%) was obtained at 64 kg N/ha and both were significantly higher than 0 N application. The lowest straw N concentration (0.31%) was obtained from 0 N treatments. The straw N concentration ranged from 0.38% to 0.48% due to main effect of P. The highest N content (0.48%) was observed for 46 P2O5 kg/ha, which was statistically the same with 69 kg P2O5/ha. The lowest N concentration (0.38%) was found for treatment with 0 P2O5/ha (Table 2). This implies that concentrations of N in the wheat straw varied in relation to the amount of N and P applied to the soil. This might be due to the fact that increase in N supply resulted in increased uptake by root which increases its concentration in plant parts and increase in P level also resulted in increase in N in plant parts due to synergetic relation between the two elements. The result was in agreement with the findings of Parvez et al. (2008) who showed that maximum N concentrations in straw was 6.13 g/kg when the crop was supplied with 180 kg N/ha and the lowest N concentration (1.6 g/kg) in straw was, however, recorded for the control treatment. Raghbir et al. (2004) have also observed that N concentration of wheat grain and straw increased significantly and subsequently with increasing doses up to 40 mg P/kg soil application. Similar results were also reported by Rahman et al. (2005) and Yohannes (2014).

Concentration of P in wheat grains

The concentration of P in wheat grain was significantly (P<0.01) affected by the main effects and interactions of N and P (Table: 9).

The highest P concentration (0.66%) was recorded for N/P2O5 of 96/69 kg/ha, which was statistically different from all treatment combinations. On the other hand, the lowest P concentration in grains (0.28%) was attained at 96/46 N/P2O5 kg/ha, which was statistically identical with the control (0/0), 96/0 and 96/23 N/P2O5 kg/ha (Table 3). Plant roots having wider contact with soil are better extractors of P from the soil and feed well to above ground plant parts. This is especially true for plant with extensive root systems (Tisdale et al. 1993). It has been reported that adequate P concentration in wheat grain is 0.42 percent (PPI, 1995). Plots receiving 0/23, 32/23, 64/23, 0/46, 32/46, 64/46, 32/69, 64/69 and 96/69 kg N/P2O5 accumulated more than adequate P concentration in wheat grain. The present result revealed that grain P concentration values were higher at higher NP combination. This may probably be attributed to optimum NP supply resulted in increased P uptake by root which increases its concentration in plant parts. These results are supported by the findings of Kabir et al. (2011) who reported that the highest P concentration in wheat grain was found in the treatment fertilized with NP of 140/40 kg/ha and the lowest P value was recorded for the control treatment.
Table 4: Concentration (%) of P in wheat straw as affected by the interaction of N and P

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>P2O5 (Kg/ha)</th>
<th>0</th>
<th>23</th>
<th>46</th>
<th>69</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9.33x10⁻²b</td>
<td>17.67x10⁻²g</td>
<td>12.00x10⁻²fde</td>
<td>7.67x10⁻²a</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>11.00x10⁻³b</td>
<td>14.00x10⁻²ef</td>
<td>16.00x10⁻²fg</td>
<td>14.00x10⁻²ef</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>8.33x10⁻²ab</td>
<td>14.00x10⁻²ef</td>
<td>8.00x10⁻²ab</td>
<td>8.67x10⁻²ab</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>9.00x10⁻²abc</td>
<td>8.67x10⁻²ab</td>
<td>12.33x10⁻²de</td>
<td>8.67x10⁻²ab</td>
<td></td>
</tr>
</tbody>
</table>

LSD (5%) | 3.12x10⁻²
CV (%) | 16.70
SEM (±) | 1.08x10⁻²

Means followed by the same letters are not significantly different (P < 0.05).

Table 5: Grain, straw and total N uptake of wheat as affected by N and P rates

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>N uptake by wheat grains (%)</th>
<th>N uptake by wheat straw (%)</th>
<th>Total N uptake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>53.37a</td>
<td>9.240a</td>
<td>62.61a</td>
</tr>
<tr>
<td>32</td>
<td>54.27a</td>
<td>12.81b</td>
<td>67.08ab</td>
</tr>
<tr>
<td>64</td>
<td>64.41b</td>
<td>12.14ab</td>
<td>76.56b</td>
</tr>
<tr>
<td>96</td>
<td>72.48b</td>
<td>16.19c</td>
<td>88.67c</td>
</tr>
</tbody>
</table>

LSD (5%) | 9.24
CV (%) | 4.00
SEM (±) | 0.40

ns= non significant differences among treatment means; Means followed by the same letters with in a column for a given treatment level are not significantly different (P < 0.05).

Concentration of P in straw of wheat

The main effect of N and P as well as their interaction resulted in highly significant (P < 0.01) differences in concentration of P in wheat straw (Table 4).

The concentration of P was the highest (17.67x10⁻²%) in straws for 0/23 kg/ha N/P2O5, which was not statistically different from treatments supplied with 32 kg N and 46 kg P2O5/ha. On the other hand, lowest concentration (7.67x10⁻²%) was recorded for plots fertilized with 0 N and 69 kg P2O5/ha. However, the results obtained from treatment combinations of 64/46, 64/69, 96/69, 96/23, 96/0 and 64/0 kg/ha N/P2O5 and control (0/0) were not significantly different from the lowest value and from each other (Table 4). In agreement with this result, the findings of Kabir et al. (2011) indicated that highest P concentration in wheat straw was observed for treatments fertilized with 40/20 kg N/P/ha and the lowest P concentration in straw was found in the control treatment. Dash et al. (2015) also reported that content of P varied from 0.12% to 0.18% in straw with fertilizers containing N and P whereas skipping the P application, although the soil is rich in available P, influence its accumulation.

Nitrogen uptake by wheat grains

Nitrogen uptake by grains was significantly (P<0.01) affected by N fertilizer application. However, there was no significant effect due to P and interaction between N and P (Table 4).

The highest (72.48 kg/ha) and lowest (53.37 kg/ha) N uptake was obtained due to 96 and 0 kg N/ha, respectively. Uptake by 64 and 96 kg N/ha was significantly higher than 0 and 32 kg N/ha. Grain N uptake of wheat with 96 kg N/ha was 26.37% more than those with 0 kg N/ha. However, the result was par with the next higher level of N (64 kg N/ha). Similarly, 0 and 32 kg N/ha also did not significantly differ from each other. The result further illustrated that increased N rates resulted in increased N uptake by grains (Table 5). Since the grain is the main sink for N after anthesis, the sources of grain N are the vegetative organs which accumulate N prior to grain filling and N uptake during the grain-filling period (Cox et al., 1985). In line with this, N uptake was significantly decreased in absence of N as compared to P. Muhammad et al. (2011) and Genene (2003) obtained similar results showing that N uptake by wheat genotype was enhanced varying from 36.5 to 139.8 kg/ha as N application rate increased from 120 to 180 kg/ha.

Nitrogen uptake by wheat straw

Nitrogen uptake due to main effect of N was highly significant (P<0.01). However, there was no significant difference due to main effect of P and its interaction with N (Table 4).

Maximum N uptake by straw (16.19 kg/ha) was recorded from application of 96 kg N/ha, whereas the minimum value (9.24 kg/ha) was from 0 kg N/ha. The next highest straw N uptake was obtained at 32 kg N/ha, which was significantly higher than N concentration for the control, but
par with 64 kg N/ha (Table 5). Muhammad et al (2011) have reported that N uptake by a wheat genotype was enhanced varying from 36.5 to 139.8 kg/ha as N application rate increased from 120 to 180 kg/ha. Similarly, Yohannes (2014) reported that the uptake of N by wheat and concentration in the tissues were increased by increase in N levels.

**Total N uptake by wheat**

The main effect of N fertilizer was highly significant (P<0.01) for total N uptake. However, P application and its interaction with N did not affect this parameter (Table: 9). The range of total N uptake by wheat due to main effect of N was 62.61 to 88.67 kg/ha. The highest total N uptake (88.67 kg/ha) was recorded for 96 kg N /ha, while the lowest value (62.61 kg/ha) was found for 0 N/ha (Table 5). The result showed that total N uptake both by grain and straw was more significantly increased with increased application of N fertilizer. Osaki et al. (1992) and Shinano et al. (1994) reported that the amount of N accumulated in cereal and legume species showed a highly positive correlation with the total dry matter production at harvest. These authors further reported that N accumulation is one of the most important factors in improving yield of field crops. This may probably be due to application of N creates concentration gradients inside and outside plant system which force it to move from the soil in to plant system and then increases its uptake by plant. This result is also supported by the findings of Bereket et al. (2014) who reported that total N and P uptakes of wheat increased with increasing rates of N and P, respectively. Similar result has also been reported by Willington and Biscoe (1984) who indicated that as the N rate increases to the level of 138 kg/ha the total uptake of N by plant also increased.

**Phosphorus uptake by wheat grains**

The main effects and their interaction produced highly significant differences (<0.01) in phosphorus uptake by grains (Table: 9).

The results presented in Table 6 showed that P uptake of grains differed significantly due to different treatment combinations, with the range varied from 6.8 to 22.7 kg P₂O₅/ha. The highest P uptake (22.7 kg P₂O₅/ha) was recorded for the treatment with 96 kg N and 69 kg P₂O₅/ha, and was statistically different from the rest of treatment combinations. The lowest P uptake was recorded from control treatment (Table 6). It was found that each additional level of P along with N had increased its uptake by wheat grains. This result was also closely related to the findings of Kabir et al. (2011) who reported that the highest P uptake (8.14 kg/ha) by grain was recorded for the treatment receiving N/P of 100/30 kg/ha, whereas the lowest P uptake was recorded for the control treatment. It is also in agreement with those findings reported by Van Keulen and Stol (1991).

**Phosphorus uptake by wheat straw**

Phosphorus uptake due to main effect of N showed significant (P<0.05) difference. However, application of P and its interaction with N did not affect this parameter (Table: 9).

The highest P uptake (4.06 kg/ha) was recorded from 32 kg N/ha, which was statistically at par with the values recorded for the control and 96 kg N /ha. On the other hand, the lowest P uptake (2.42kg/ha) was recorded from 64 kg N/ha, which was also not significantly different from 96 kg N/ha. Even though total P uptake by straw of wheat was non-significant due to main effect of P, compared to the control treatment, the uptake was a little bit higher at higher P level except for 69 kg P₂O₅/ha (Table 7). In line with this, Bereket et al. (2014) indicated N and P uptakes of wheat increased with an increasing rate of respective nutrients. Similarly, Muhammad et al. (2011) also reported that uptake of both N and P was significantly affected by their respective fertilizer rates.

| **Table 6**: P uptake by wheat grain (kg/ha) as affected by interaction of N and P |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| N (kg/ha)       | P₂O₅ (Kg/ha)    | 0               | 23              | 46              | 69              | Mean            |
| 0               | 6.80a           | 11.92ef         | 12.03ef         | 7.38ab          | 9.52            |
| 32              | 7.77ab          | 11.51def        | 15.00g          | 11.13def        | 11.35            |
| 64              | 9.84b           | 11.93ef         | 13.55fg         | 15.71g          | 12.76            |
| 96              | 8.66abc         | 8.40abc         | 9.96bcde        | 22.72h          | 12.43            |
| Mean            | 8.27            | 10.94           | 12.64           | 14.34           |
| LSD (5%)        | 2.94            |                 |                 |                 |
| CV (%)          | 15.30           |                 |                 |                 |
| SEM (±)         | 1.02            |                 |                 |                 |

Means followed by the same letters are not significantly different (P < 0.05).
**Total P uptake by wheat**

The analysis of variance indicated that total P uptake (straw + grain uptake) was significantly (P<0.01) affected by N or P as well as with the interaction of N and P fertilizers (Table: 9). Total P uptake by both grain and straw ranged from 9.45 to 25.22 kg/ha. The greatest quantity of P uptake (25.22 kg/ha) was recorded for 96/69 kg N/P₂O₅/ha which was significantly different from other treatment combinations. The lowest total P uptake by wheat was recorded for the control plot, which was statistically at par with treatment combinations of 0/69, 96/46, 64/0, 96/23, 32/0 and 96/0 kg N/P₂O₅/ha (Table 8). The results further revealed that P uptake by wheat was higher at higher N and P combinations. This might probably be attributed to the fact that synergetic relation of P and N in uptake by the plant. In agreement with the present result, Kabir et al. (2011) have reported that the highest total P uptake by wheat was recorded in treatment receiving N/P of 140/40 kg/ha whereas the lowest value was recorded for the control treatment.

<table>
<thead>
<tr>
<th>Table 8: Total P uptake (kg/ha) by wheat as affected by interaction of N and P fertilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (kg/ha)</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td>64</td>
</tr>
<tr>
<td>96</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>LSD (5%)</td>
</tr>
<tr>
<td>CV (%)</td>
</tr>
<tr>
<td>SEM (±)</td>
</tr>
</tbody>
</table>

Variable means followed by the same letters are not significantly different (P < 0.05) according to LSD Tests.

<table>
<thead>
<tr>
<th>Table 9: ANOVA showing mean squares for grain and straw N and P concentration and uptake (x10⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characters (a)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
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<td>CNG</td>
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** *= highly significant (P<0.01) and significant (P<0.05) respectively, ns= non-significant; (a) = Number in parenthesis shows degree of freedom for respective source of variation; CNG= Concentration of N in wheat grain, CPG= Concentration of P in wheat grain, CNS= Concentration of N in wheat straw, CPS= Concentration of P in wheat straw, NUG= Nitrogen uptake by wheat grain, NUS= Nitrogen uptake by wheat straw, TNU= Total N uptake, TPU= Total P uptake.

**CONCLUSIONS**

Analysis of variance for N concentration revealed that there were highly significant (P < 0.01) differences among the treatment combinations for concentration of N and P in grains. Main effect of N or P also showed highly significant (P<0.01) differences for N concentration in the straw, but non-significant differences was observed due to interaction. Similarly, there were highly significant (P<0.01) differences for grain P concentration due to treatment combinations. But, non-significant difference was observed for straw P content due to interaction as well as main effect of N or P.

There were also highly significant (P<0.01) differences for total N uptake, grain N uptake and straw N uptake due to main effect of N. The main effect of P and its interaction with N had no significant difference for those parameters. Highly significant (P<0.01) differences were also observed in P uptake by wheat grain due to interaction between N and P and significant (P<0.05) difference in total P uptake by straw due to main effect of P. However, there was non-significant difference in P uptake by straw due to treatment interaction and main effect of P.

Based on the results of this study, it could be concluded that application of N fertilizer at the rate of 96 kg/ha resulted in the highest N uptake. The highest total P uptake was recorded from 96 kg N/ha by 69kg P₂O₅/ha.

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