Response of Wheat (*Triticum aestivum* L.) to Different Rates of Nitrogen and Phosphorus at Fiche-Salale, Highlands of Ethiopia

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In Ethiopia, wheat is being cultivated on about 1.51 million hectares, delivering 3.3 million tons of grain yields. However, productivity of this crop is low compared to its potential due to many factors among which N and P play a vital role. Field study was conducted in 2014 crop season at Fiche-Salale with the objective of determining the optimum rates of N and P fertilizer for wheat production. The treatments consist factorial combination of 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 replicated three times in a randomized complete block design. Wheat variety, Digelu, was used as a test crop. The result of the study indicated that grain and biological yields were significantly affected only due to main effect N. The highest (3284 kg/ha) and lowest (2383 kg/ha) grain yield was obtained from application of 96 kg N/ha and 0 kg N/ha, respectively. Similarly, the highest (6611.00 kg/ha) and lowest (5145.00 kg/ha) biological yield was obtained from 96 kg N/ha and 64 kg N/ha, respectively. The highest MRR was also attained at 96 kg N/ha (6998.80%). Hence, 96 kg N/ha is profitable for the area.

Key words: biomass yield, grain yield, fertilizer rate, wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important large-acre crop which is growing on more acres globally than any other crop. It is a staple food for about one third of the world’s population (Hussain and Shah, 2002). In Ethiopia, it is being cultivated on about 1.51 million ha, delivering about 3.3 million tons of grain yields which make the country the largest wheat producer in sub Saharan Africa (CSA, 2013) and the 2nd in Africa after South Africa (Demeke and Di Marcantonio, 2013). However, the Ethiopian government is forced to import wheat every year because of higher demand than supply.

Nitrogen (N) and phosphorus (P) are considered as the most deficient nutrients in soils of Ethiopia, including North Shoa zone of Oromia National Regional State (Asnakew *et al.*, 1991; Anonymous, 2000). Similarly, FAO (2002) reported that declining 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 is true in the highlands of Ethiopia specifically due to high human population pressure, intensification in land use, inadequate soil and water conservation measures, expansion of cropping marginal lands and poor soil management. This low productivity can be enhanced through improved crop management practices, including application of fertilizers. High yielding wheat varieties demand adequate nutrient supply to produce maximum grain yield (Ali and Yasin, 1991). Determining the optimum rate of N and P fertilizer rate is the key to maximize the economic yields. Best experiences in some bread wheat producing areas of Ethiopia like Bale and Arsi zones showed the yield of bread wheat can be maximized beyond 4 t/ha by using N and P fertilizers integrated with other better crop management options DZARC (1989).

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In view of the above findings, information related to N and P fertilizer recommendation in Fiche-Selale area is limited. Therefore, the objective of this research was to investigate the effect of N and P rates on yield and yield components of bread wheat and find economically appropriate rates of N and P fertilizer rates for the study area.

MATERIALS AND METHODS

Site Description

The experiment was conducted in 2014 cropping season at Fiche (Selale), central highlands of Ethiopia, which is 112 km away from Addis Ababa in northern direction on the way to Gojam. It is located between latitude and longitude of 9°48’N and 38°44’E and 9.800°N and 38.733°E, respectively, and 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 is grouped as a clay type. Data from Ethiopian Meteorological Agency (EMA) indicated that the area receives average annual rainfall of 1179.36mm and has maximum and minimum temperatures of 8.29 and 20.50 °C, respectively (EMA, 2007-2014). There is no site specific recommendation of fertilizer in an area. However, farmers use blanket recommendation of 100 kg urea and 100 kg DAP/ha fertilizer which contained 64kg N and 46kg P₂O₅

Experimental Materials

Improved variety of wheat, Digelu, released by Kulumsa Agricultural Research Center in 2005, was used as a test crop. N and P fertilizers were applied in the form of urea (46% N) and triple super phosphate (46% P₂O₅), 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 20cm apart and 3m in length. Full dose of P and half dose of N were applied to the soil at the time of sowing and the remaining half dose of N was applied at tillering stage. The control in this experiment is the combination which contained 0 N by 0 P₂O₅.

Data Collection

Crop phenology

- Days to 50% heading: recorded when 50% of the plants on the plots produced head from the date of sowing.
- Days to 50% maturity: Recorded after 50% of the plants on the plots reached maturity stage from the date of sowing.

Growth parameter

- Plant height (cm): At maturity, five plants were taken at random from five central rows and their heights were measured from the base of the plant to tip of the spike using meter tape. Finally, average value was taken as height of a plant.
- Spike length (cm): At maturity, five plants were taken at random from five central rows and their spike length was measured from the base of the spike to its tip using meter tape. Finally, average value was taken as length of spike of a plant.

Yield and yield components

- Number of effective tillers per square meter: After heading, the number of tillers that produced heads were counted for the five central rows by using 0.5mx0.5m quadrant and subsequently converted in to tillers per square meter.
- Number of seeds per spike: Five plants were randomly selected from five central rows of a plot at maturity. The number of seeds in each spike was counted after threshing with hand. The average values were taken as number of kernels per spike.
- Thousand-Grain weight (gm): 1000 grains were counted at random from each treatment after the grain had attained a moisture content of 12%. Its weight was measured using sensitive balance.
- Above ground dry biomass (kg/ha): The entire five central rows were harvested at maturity and placed in to sacks. After it was allowed to dry in the sun, its weight was measured by using Salter balance (manufactured in 2012) and subsequently converted in to kg/ha.
- Grain yield (kg/ha): Sun-dried biomass was threshed in the sack using stick. Only grain weight was taken after cleaning and the grain yield was subsequently converted in to Kg/ha.

Soil Sampling and Analysis

- Soil sample was taken from up to 30cm before planting from the entire field to assess the chemical properties of the soil like soil pH, organic carbon, N and P.
- Collected samples were dried for five days under shade to prevent volatilization losses of N. After the samples were dried, clods and large aggregates were crushed and mixed. Then the crushed material was further ground using pestle and mortar to pass 2 mm sieve.
- Sedimentation technique was used to determine soil texture.
- Determination of soil pH was done using Potentiometric method was used to determine the pH of the soil.
- Walkley and Black (1934) method was used to determine organic matter content of the soil while Determination of total N in the soil (%) was made by Kjeldahl method (source) and Olsen et al. (1954) method was used for estimating available soil P.
Economic Analysis

The cost of 100 kg urea (1160 birr), DAP (1552 birr) and wheat grain price of 1600 birr per 100 kg used for the benefit analysis. Marginal rate of return was calculated as change of benefit divided by change of cost as described by CIMMYT (1988). The yield adjustment used was 90% of the actual yield.

\[
\text{MRR} (%) = \frac{\Delta \text{NR}}{\Delta \text{TVC}} \times 100
\]

Where, MRR= marginal rate of return, \( \Delta \text{NR} \) = change in net revenue, \( \Delta \text{TVC} \) = change in total variable cost.

\[
\text{NR} = \text{TR} - \text{TVC}
\]

Where, TR= Total revenue, TVC = total variable cost.

\[
\text{TVC} = \text{Cost of N fertilizer} + \text{Cost of P fertilizer}
\]

Where, AGY= Adjusted grain yield

\[
\text{AGY} = \text{GY} - (\text{UGY} \times 10\%)
\]

Where, GY= Grain yield, UGY= unadjusted grain yield.

Data Analysis

Analyses of variances for recorded data 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 results indicated that texture of the soil in the study area is dominated by the clay fraction. On the basis of particle size distribution, the soil contains 16% sand, 18% silt, and 66% clay (Table 1). According to the soil textural class determination triangle, soil of the study area was found to be clayey. High clay content might indicate better water and nutrient holding capacity of the soil in the study area. According to Tekalign (1991), soil reaction (pH) of the experimental site is moderately acidic (i.e., between 5.3-5.9), which is suitable range for most crops. The pH of most agricultural soils is generally in the range of 4 to 9 (Fageria et al., 1990). The study area, as described by Tekalign (1991), has medium/moderate OM content (between 2.59 - 5.17%) and high total N (between 0.12 - 0.25%). Soil available P as determined by Cottenie (1980) was low (5 – 9 mg/kg soil). Since P availability is determined by pH of the soil and the soil of this area is in a suitable range of pH for the availability of P, it can be concluded that the soil of this area is naturally poor in P. Generally, the soil of the study area was found to be suitable for wheat production.

Table 1: Selected physico-chemical properties of the experimental soil before planting

<table>
<thead>
<tr>
<th>Physical property</th>
<th>chemical property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture (%)</td>
<td>Textural class</td>
</tr>
<tr>
<td>Sand</td>
<td>Silt</td>
</tr>
<tr>
<td>16.00</td>
<td>18.00</td>
</tr>
<tr>
<td>pH</td>
<td>OM (%)</td>
</tr>
<tr>
<td>Available N (%)</td>
<td>Total P (ppm)</td>
</tr>
</tbody>
</table>

Effect of N and P on Wheat Phenology

Days to 50% heading and Maturity

Analysis of variance indicated that days to 50% heading was significantly (P<0.05) effected by N rate while P and N x P interaction showed a non significant effect on both days to 50% heading as well as 50% maturity. Days to 50% maturity was also not significantly affected due to application of N fertilizer.

The longest days to 50% heading (86.58) was observed for the higher N rate (64 kg N/ha), whereas the lowest value (83.17) was recorded for the control treatment (Table 2). Except for 96kg N/ha, which is par with 64 kg N/ha, increment in N rate from control to 64kg/ha resulted in delayed heading. Nitrogen rate of 96kg/ha and 64kg/ha were significantly different from the control. However, 32, 64 and 96 kg N/ha were not significantly different from each other. Similarly, the control and 32kg N/ha were statistically identical. Nitrogen applied at a rate of 32, 64 and 96 kg/ha delayed the date to 50% heading by 0.5, 3.41 and 3.16 days, respectively, compared to the control. This may probably be attributed to excess N supply causes higher photosynthetic activities, vigorous growth, delayed heading & maturity (Mengel and Kirkby, 1996). Accordingly, Cock and Ellis (1992) have also reported that N fertilizer application had a significant effect on days to heading.

Table 2: Phenological parameters as affected by N and P rates

<table>
<thead>
<tr>
<th>N (Kg/ha)</th>
<th>Days to 50% heading</th>
<th>Days to 50% maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>83.17a</td>
<td>156.75</td>
</tr>
<tr>
<td>32</td>
<td>83.67ab</td>
<td>157.83</td>
</tr>
<tr>
<td>64</td>
<td>86.58b</td>
<td>158.50</td>
</tr>
<tr>
<td>96</td>
<td>86.33b</td>
<td>158.67</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>2.95</td>
<td>NS</td>
</tr>
<tr>
<td>CV%</td>
<td>4.20</td>
<td>2.90</td>
</tr>
<tr>
<td>SEM (+)</td>
<td>1.02</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Where, NS = non-significant. Variable means followed by the same letters with in a column are not significantly different (P < 0.05).
Growth Parameter

Plant height

Plant height was affected significantly (P<0.01) due to main effect of N and N x P (P<0.05) due. But, non significant differences were observed to main of effect Phosphorus.

Plots received 96 kg N and 46 kg P₂O₅/ha produced the highest plant height (101.33 cm). In contrast to this, the shortest plant height (84.67 cm) was recorded from the control plot. All treatments were significantly different from the control, except treatments containing N/P₂O₅ of 0/46, 64/23 and 64/69 kg/ha (Table 3). This may probably be due to N supply causes higher photosynthetic activities, vigorous growth (Mengel and Kirkby, 1996). Phosphorus has also significant effect on dry matter yield and individual plant characteristics like height, number of leaves and leaf area (Ayoub et al., 2002). Pervez et al. (2009) have reported significant increase in plant height of wheat with application of N. At the same time, adequate P enhances many physiological processes and the fundamental processes of photosynthesis, thus, helping in plant growth (Brady and Weil, 2002). The result is also in accordance with the findings of Kausar et al. (1993), Ayoub et al. (1994), Maqsood et al. (1999) and Khan et al., (2009) who reported that plant height increased significantly with increasing level of NP.

Table 3: Plant height (cm) as affected by interaction of N and P rates

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>P₂O₅ (kg/ha)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>84.67</td>
</tr>
<tr>
<td>23</td>
<td>46</td>
<td>92.20</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>100.80</td>
</tr>
<tr>
<td>69</td>
<td>96</td>
<td>98.33</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>94.00</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td></td>
<td>7.45</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>4.70</td>
</tr>
<tr>
<td>SEM (±)</td>
<td></td>
<td>2.56</td>
</tr>
</tbody>
</table>

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

Spike length

Non-significant differences were observed on spike length due to N, P and the interaction of N and P. This may probably due to the fact that spike length is controlled less by environmental factor while more by genetic factor. Similar result was reported by J. Abdollahi Gharekand et al. (2012).

Yield and Yield Components

Number of effective tillers per square meter

The interaction of N x P fertilizers was significantly (p<0.01) affect the number of effective tillers/m²; however, main effect of N and P have no significant on effective tillers/m². The result indicated that highest effective number of tillers (636/m²) was observed when 96 kg N/ha and 46 kg P₂O₅/ha were applied. On the other hand, the lowest number of tillers (313/m²) was produced from control treatment (Table 4). The results also revealed that tiller number was high under higher NP combinations. The probable reason for this might be due to the fact that NP supply played a significant role in plant growth and development, increase in number of grains per spike, number of fertile tillers and grain yield. Nitrogen has positive effect on cytokinin synthesis which stimulates formation of new tillers (Botella et al. 1993) while P plays significant role in preventing abortion of formed tillers. This result agrees with the findings of Prystupa et al. (2004), who reported that number of productive tillers/plant was significantly affected by NP fertilizer application.

Table 4: Interaction effect of N and P fertilizer rate on Number of effective tillers/ m² of wheat

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>P₂O₅ (kg/ha)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>313.00</td>
</tr>
<tr>
<td>23</td>
<td>46</td>
<td>508.00</td>
</tr>
<tr>
<td>64</td>
<td>32</td>
<td>669.00</td>
</tr>
<tr>
<td>69</td>
<td>96</td>
<td>479.00</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>467.25</td>
</tr>
<tr>
<td>LSD (%)</td>
<td></td>
<td>153.90</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>19.20</td>
</tr>
<tr>
<td>SEM (±)</td>
<td></td>
<td>53.30</td>
</tr>
</tbody>
</table>

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

Number of seeds per spike

Phosphorus and interaction of N x P fertilizers had highly significant (P < 0.01) effect on the number of seeds per spike, but effect due to main effect N was non-significant. The highest number of seeds per spike (73.87) was recorded for 64/46 kg N/P₂O₅/ha, which was also not significantly different from 96/0 and 0/23 kg N/P₂O₅/ha, which had produced 69.67 and 69.00 seeds per spike, respectively, while the lowest value (52.67) was recorded for the control treatment (Table 5). This may probably have attributed to N increases dry matter production and P have also positive effect on number of seed produced per plant. In line with this, Ali et al. (2002) reported that highest number of seeds per spike was obtained from application of 150/90 kg/ha N/P. These results are also in accordance with Kadry et al., (1984) and Diliba et al., (1988).

Thousand kernel weight

The analysis of variance showed that the main effects of N and P fertilizer application and their interaction had non-significant effect on thousand kernel weight. Thousand kernel weights is an important yield determining component and reported to be a genetic character that is influenced least by environmental factors (Ashraf et al., 1999).
**Table 5**: Interaction effects of N and P rates on number of seeds per spike of wheat

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>P2O5 (kg/ha)</th>
<th>P2O5 (kg/ha)</th>
<th>P2O5 (kg/ha)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>62.67a</td>
<td>39.00efg</td>
<td>61.00bcd</td>
<td>64.07cdef 61.69</td>
</tr>
<tr>
<td>32</td>
<td>58.33abc</td>
<td>66.33def</td>
<td>56.33def</td>
<td>59.93bcd 52.73</td>
</tr>
<tr>
<td>64</td>
<td>56.67cdef</td>
<td>55.47ab</td>
<td>73.87g</td>
<td>61.60bcd 53.90</td>
</tr>
<tr>
<td>96</td>
<td>59.67tg</td>
<td>52.33bcede</td>
<td>61.80bcd</td>
<td>61.60bcd 53.85</td>
</tr>
<tr>
<td>Mean</td>
<td>61.34</td>
<td>53.28</td>
<td>65.75</td>
<td>61.80</td>
</tr>
</tbody>
</table>

LSD (5%) = 9.99
CV (%) = 8.60
SEM (±) = 2.42

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

**Above ground biomass yield**

Biomass production was significantly (P<0.01) influenced due to application of N. However, the interaction effect of N and P was not significant on total biomass yield. Similarly, the main effect of P was not significant.

The highest total biomass (6611 kg/ha) was recorded from application of 96 kg/ha N and it was significantly different from the total biomass obtained from other levels (Table 6). This may probably due to N effect on vegetative growth of plants, especially at higher doses. Better growth and higher straw yield with an increase in N level enhance the vegetative growth of plants (Ma et al., 2004). This result is in line with the finding of Khan et al. (2000) who obtained maximum biological yield from plots treated with 285 kg N per hectare.

**Grain yield**

Application of N had significant (P<0.01) effect on the grain yield; however, the main effect of P as well as its interaction with N did not significantly affect this parameter. The highest grain yield (3284 kg/ha) was obtained due to application of 96 kg N/ha, whereas the lowest value (2383 kg/ha) was recorded from the control treatment. Except the highest level of N, the rest were not significantly different from the control, although there was slight increment in yield with increasing N level. Generally, grain yield increased as the amount of N increased from the control to the highest level of 96 kg/ha (Table 6). This might be due to the ability of N to determine photosynthetic capacity of the crop, and the increased seed number per unit area (Ellen and Spiertz, 1980). This result is also supported by the findings of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980). This result is also supported by the finding of many previous workers (Hailu (1991); Tanner and Spiertz, 1980).

**Economic Analysis**

The partial budget analysis (Table 7) showed that highest net benefit of 44868.60 birr/ha was obtained from the treatment that received 96 kg N/ha. On the other hand, the lowest net benefits of 34315.20 birr/ha was obtained from the treatment that was fertilized with 0 kg N/ha. For a treatment to be considered as worthwhile to farmers, between 50 and 100% marginal rate of return (MRR) is the minimum acceptable rate of return (CIMMYT 1988). The highest MRR (6759.17%) in this case was recorded for 96/0 kg N/ha. The next higher MRR (319.61%) was recorded for the treatment with 32 kg N/ha. There was also other treatment that had scored MRR beyond 100%, but were by far lower than 96 kg N/ha rate. Therefore, application of 96 kg N/ha is profitable and recommended for farmers in Fiche and other areas with similar agro-ecological conditions.
CONCLUSIONS AND RECOMMENDATION

Based on the results of this study, it could be concluded that application of N fertilizer at the rate of 96 kg/ha is advisable since grain yield and biological yields are the most important economic parts used by the farmers. Partial budget analysis also supports this recommendation. However, similar studies are further needed at various locations using different varieties of wheat to provide conclusive recommendations.

ACKNOWLEDGMENTS

I would like to thank Salale University for financial support until I complete this paper. I would also like to acknowledge Grar Jarso Woreda Agricultural office for providing me experimental site and Debre Birhan Agricultural Research Center for its support in laboratory analysis. Without their passionate participation and input, this study could not have been successfully completed.

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Accepted 12 December 2018


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