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RESEARCH ARTICLE

# Estimating Growth and Yield Related Traits of Wheat Genotypes under Variable Nitrogen Application in Semi-Arid Conditions

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**ABSTRACT**
The current study was conducted at Agronomic Research Area of the University of Agriculture, Faisalabad during 2008-09 and 2009–10 growing seasons, to investigate the grain yield and yield components of ten new wheat cultivars under variable nitrogen (N) levels. Each year, the crop was sown on 12$^{th}$ November with four N levels ($N_1$= 0 kg ha$^{-1}$, $N_2$= 55 kg ha$^{-1}$, $N_3$=110 kg ha$^{-1}$, $N_4$= 220 kg ha$^{-1}$) and ten cultivars (Faisalabad-2008, Lasani-2008, Miraj-2008, Sahar-2006, Shafaq-2006, GA-2002, Bakkhar-2001, Inqlab-91, Chakwal-50 and Chakwal-97). Split Plot Design was used keeping N levels in main plots and cultivars in subplots with three replications. The results showed that increasing levels of N significantly increased plant height, total dry matter, number of productive tillers, number of grains per spike, 1000-grain weight, grain yield and harvest index. Grain yield was 2670, 3140, 3480 and 4370 kg ha$^{-1}$ in the respective nitrogen treatments. The application of N @ 220 kg ha$^{-1}$ in cultivar Faisalabad-2008 resulted in higher yield under irrigated semi-arid conditions of the Punjab.

## INTRODUCTION

In Pakistan, wheat is grown throughout the country ranging from 23 $^o$N to 37 $^o$N, from 61 $^o$E to 76 $^o$E. The wheat producing area is largely arid and semi-arid. At present wheat is grown on an area of 9042 thousand hectares and total wheat production of the country is 23 million tons with an average yield of 2714 kg ha$^{-1}$ (GOP, 2012). Increase in cropping intensity and introduction of high yielding cultivars have caused considerable drain of Nitrogen and crops showed a positive response to added nitrogen in the soil (Ali et al., 2004). Yield and yield components of high yielding varieties generally increase by increasing level of N (Ibrahim et al., 2010). N application increased seed development (grain filling rate and duration), which ultimately produced highest grain weight (Waraich et al., 2007). Various N rates (0, 100, 150, 200 kg ha$^{-1}$) had significant effect on biological yield but 200 kg N ha$^{-1}$ produced maximum biological yield (Hussain et al., 2006). Nitrogen occupies a conspicuous place in plant metabolism and it also increases the grain yield in cereals. In addition to the formation of proteins, N is an integral part of chlorophyll, which is the primary absorber of light energy for photosynthesis. An-adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth and dark green color, and its supply influences the utilization of carbohydrates. Recent research demonstrates that N is beneficial at certain growth stages for some genotypes of corn, sorghum, soybeans, wheat and barley, further, its application at post-silking or during grain filling is required to maximize grain yields (Havlin, 1999). Therefore, judicious use of nitrogenous fertilizers is of prime importance for farm profitability and environmental protection from pollution. Nitrogen plays an imperative role in maximization the crop yields (Massignam et al., 2009) and improves the yield as well as quality of all crops (Dreccer et al., 2000; Ullah et al., 2010). Additionally, at higher rates, N increases photosynthetic processes, leaf area production, Leaf Area Duration (LAD) as well as Net Assimilation Rate (NAR). The development of individual leaf area and total leaf area of crop plant ultimately contribute towards higher grain yield (Rafiq et al., 2010). The study was carried out to examine the effect of N rates on growth, yield and yield components of 10 wheat cultivars under semi-arid conditions of Faisalabad, Punjab, Pakistan.

## MATERIALS AND METHODS

### Site and Soil

A field study was conducted to examine the influence of N rates and genotypes on growth and yield of wheat at Agronomic Research Area, University of Agriculture, Faisalabad (31.26 °N, 73.06 °E and Altitude 184 m) during 2008-09 and 2009-10 growing seasons. The analysis of soil was carried out before sowing and after harvesting of the crop. A composite soil sample was collected at the depth of 30 cm with the help of Soil Auger tube and analyzed for its physio-chemical properties. Percentage of sand, silt and clay was determined by Bouyoucos hydrometer method using 1% sodium hexametaphosphate as a dispersing agent. Textural class was determined by using the international textural (Moodie et al., 1959). Soil was analyzed for its various chemical properties using the method as described by Homer and Pratt (1961). Detail soil characteristics are presented in Table 1.

**Table 1: Soil physio-chemical properties**

| | |
|---|---|
| (a) Physical properties of soil | |
| Soil type/ Soil Series | Sandy Clay Loam/ fine loam, shallow/Lyallpur series brown on color along with the %age of sand (66%), silt (16%) and clay (24%). |
| (b) Chemical properties of soil | |
| Organic matter | 1.28% |
| TTS (Total soluble salt) | 12.29% |
| pH | 7.54 |
| Nitrogen (N) | 0.64% |
| Phosphorus ($P_2O_5$) | 6.93 ppm |
| Potassium (K) | 19.4 ppm |

### Experimental Layout

The experiment was laid out at Agronomic Research Area of the University of Agriculture, Faisalabad in randomized complete block design (RCBD) with split plot arrangement having three replications. The net plot size was 10 m x 2.4 m. The experiment tested ten cultivars (Faisalabad-2008, Lasani-2008, Miraj-2008, Sahar-2006, Shafaq-2006, GA-2002, Bakkhar-2001, Inqlab-91, Chakwal-50 and Chakwal-97) in sub plots and four N levels ($N_1$= 0 kg ha$^{-1}$, $N_2$ = 55 kg ha$^{-1}$, $N_3$ = 110 kg ha$^{-1}$, $N_4$ = 220 kg ha$^{-1}$) in main plots. Four levels of N used are represented as $N_1$, $N_2$, $N_3$, $N_4$ and cultivar as cv. The wheat crop was sown on 12$^{th}$ November during both the years of 2008-2009 and 2009-2010 with the help of single row hand drill, keeping Row x Row distance of 30 cm. The Phosphorus (P) and Potash (K) were applied @ 85 and 60 kg ha$^{-1}$, respectively. Urea, TSP and SOP were used as sources of N, P and K fertilizers, respectively. All the potash and phosphatic fertilizers were applied at the time of sowing, while the nitrogen was top dressed in two splits; at first and second irrigation to the crop as per treatment. Two splits of N fertilizer were applied: first split of half N fertilizer was applied at the time of 1$^{st}$ irrigation after 35 days of sowing and second split of half of N fertilizer at the time of 2$^{nd}$ irrigation after 25 days of first irrigation in both the years. All cultural practices such as weeding, inter-culturing practices and irrigation were kept uniform for all the experimental treatments. Surface irrigation method was carried out to irrigate the crop.

### Crop sampling

Half meter long row from each plot was harvested at ground level after every twenty days interval leaving appropriate borders for the determination of Total Dry Matter (TDM) and Leaf Area Index (LAI). Fresh and dry weight of component fraction of plant (leaf and stem) was determined. A sub-sample in each fraction was taken to dry it in an oven at 70 $^0$C to a constant weight. Also 5g of green leaf laminae was used to record leaf area with leaf area meter (Model CI-202, CID, Inc.). LAI was calculated as the ratio of leaf area to land area (Watson, 1947 not in reference). LAI=leaf area /land area

Sub-sample of 20 plants from each plot was taken randomly for average plant height. Number of spikelets per spike was counted from twenty spikes from each plot randomly, and the mean value was calculated. Number of fertile tillers was counted at maturity from an area of 1 m$^{-2}$. A sub sample of thousand grains was taken from each plot with the help of Seed Buro, Model Number 801-10/C & Serial Number CO 452 and weighed on an electric balance. From each plot an area of 12m$^{-2}$ was harvested at random avoiding the boarder effects and threshed the grain manually from the sample. Grain yield per unit area was determined and expressed the yield in kg ha$^{-1}$. Harvest index was calculated as the ratio of economic yield to TDM, and expressed in %. HI = (Grain yield/TDM) x 100

### Statistical analysis

All data presented as mean values of three replications. Data were analyzed statistically for Analysis of Variance (ANOVA) following the method described by (Gomez and Gomaz, 1984). MSTATC computer software was used to carry out statistical analysis (Russel and Eisensmith, 1983). The significance of differences among means was compared by using Duncans's Multiple Range (DMR) Test (Steel and Torrie, 1997). Response of yield and plant growth to N rates was evaluated by using polynomial contrast (linear, quadratic and cubic) within the analysis of variance structures.

## RESULTS AND DISCUSSION

### Growth traits

### Total dry matter (TDM) accumulation

TDM accumulation was significantly affected by different N levels. An increasing trend in total dry matter accumulation was observed, from 46 Days After Sowing (DAS) (29th December) to 126 DAS (18th March) in all treatments during both years. Application of 220 kg N $ha^{-1}$ (treatment $N_4$) significantly increased TDM accumulation over $N_3$ (110 kg $ha^{-1}$), $N_2$ (55 kg $ha^{-1}$) (Fig. 1). The cultivars showed significant effect on total dry matter accumulation at 86 and 126 DAS during both the years. The cv. Faisalabad-2008 significantly increased maximum TDM during both study years while the cultivar Miraj-2008, Lasani-2008 and Faisalabad-2008 were statistically different in TDM accumulation but at final harvest all cultivars showed similar increase in Total Dry Matter. Similarly all cultivars showed similar trend in TDM production at earlier stages; the slow trend of TDM accumulation at 46 DAS (29 December) to 66 DAS (18 January) was observed then subsequently fast increase in accumulation of TDM up to 126 DAS (18 March) was recorded. Cv. Sahar-2006 gave the maximum (1110.41$gm^{-2}$) TDM and it was statistically at par with cultivar Shafaq-2006 (1064.16 $gm^{-2}$) (Fig. 2).

**Leaf area index**

LAI is main physiological determinant for the crop yield. Figs. 3 and 4 present the effect of N on LAI of various cultivars during both the seasons.

N application significantly affected the LAI of crop during both growing seasons and its effect was linear during both the growing seasons. The maximum LAI (5.38 and 5.18 during 2008-09 and 2009-10, respectively) was recorded by the application of N @ 220 kg $h^{-1}$ ($N_4$) over other N levels while minimum LAI (3.91 and 3.82 during 2008-09 and 2009-10, respectively) was observed in control. Cultivars showed significant effect on LAI during most of the crop season. Cv. Faisalabad-2008 produced the maximum LAI (4.97 and 4.79 during 2008-09 and 2009-10, respectively). The LAI continuously increased up to 90 DAS and then it gradually declined towards maturity due to leaf senescence. Overall, mean LAI for all the cultivars ranged from 4.34 to 4.87. In this study all the treatments showed similar increasing trend in LAI during whole growing season. Wajid et al. (2002) reported that N treatments significantly increased LAI.

**A) Yield related traits**

**Plant height**

The data of plant height in Table-2 revealed that plant height at the time of final harvest was affected by N levels during both the years of study. Increasing rate of N application significantly increased plant height (P<0.01) than lower rates of N applications and this response was linear in nature during both the years of study. Maximum plant height was recorded for $N_4$ due to availability of more nutrients and minimum was recorded for $N_1$ due to less availability of nutrients. Averaged over the two years, mean plant height were 81.43, 84.97, 88.52 and 92.28 cm in $N_1$, $N_2$, $N_3$ and $N_4$

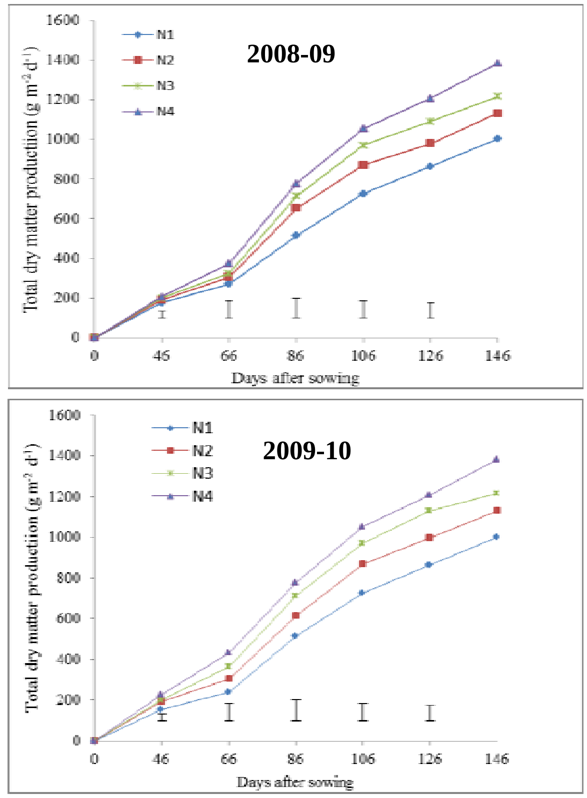


**Fig. 1: Effect of nitrogen levels on TDM accumulation**

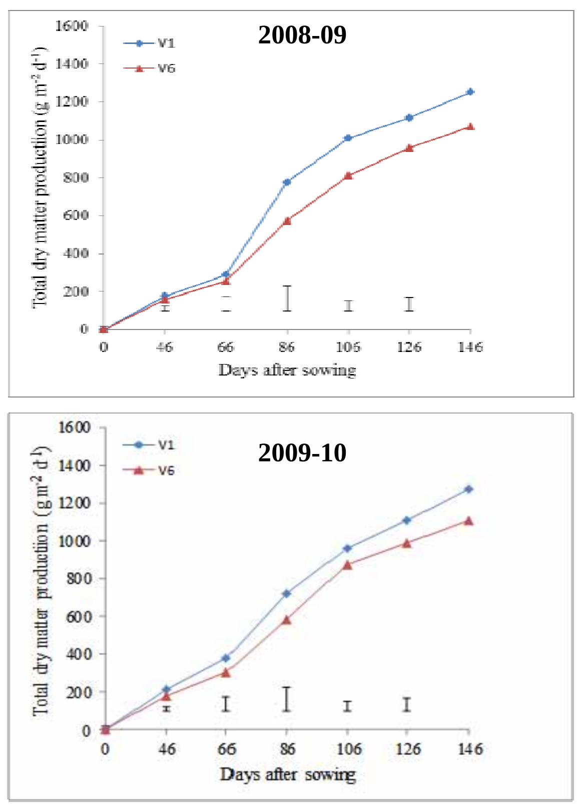


**Fig. 2: Effect of cultivars on TDM accumulation**

treatments, respectively. The plant height increased with increasing level of N through elongation of internodal distance. Several authors (Khaliq et al., 1999; Sarwar et al., 2010) have reported direct relation between N application and plant height.

Differences in plant height among different varieties were also significant in both the seasons. Faisalabad-2008 significantly increased plant height than all other varieties, and minimum plant height was produced by GA-2002 in both the years. Averaged over the seasons mean plant height ranged from 80.97 cm to 92.1 cm among different cultivars (Table-2). The difference in plant height of the cultivars was attributed to differences in their genetic makeup. These results were supported by Hussain et al. (2006) who observed the 82.2 cm plant height in wheat at 200 kg N $ha^{-1}$. Mattas et al. (2011) stated that higher levels of N from 120 to 150 and to 180 $kgha^{-1}$ significantly increased the height of plant from 85.10, 90.31 and 94.12 cm, respectively. This increase was due to more available N.

**Number of productive tillers ($m^{-2}$)**

Plant density at the time of final harvest is most important yield determining factor in wheat. Tillering capacity of a cultivar is controlled by genetic behavior and external environment. Increasing rate of N significantly enhanced the number of productive tillers ($m^{-2}$) over the lower rates of N application where tillering bud remain dormant and this response was linear in nature during 2009-10 while non-significant during 2008-09. It is evident from Table-2 that averaged two years data, increased level of N from 0, 55, 110 and to 220 kg $ha^{-1}$ increased significantly the number of productive tillers 215.55, 244.08, 266.37 and 305.73 $m^{-2}$, respectively. However, it is clear that with each unit increase of N application number of productive tillers increased. This increase in number might have occurred due to better response of cultivars to N application at the time of tillering stage that results in greater simulation of vegetative growth. In both the years of cropping, Faisalabad-2008 significantly increased the number of tillers $m^{-2}$ compared to all other varieties. Lowest number of tillers were produced by GA-2002 in both the years. These results were supported by Hussain et al. (2006) who recorded 351.4 productive tillers @ 200 kg N $ha^{-1}$. The production of tillers is crucial genotypic character but Bhorghi (2000) reported that by increasing N at plant level, the TDM increase is allied with wider leaves that stay green longer, tall stems and a large number of tillers reaches up to maturity. Productive tillers increased with the application of more N as compared to lesser levels of N and application of N at booting stage increase the availability of N at later stages of crop growth that are directly related to increase in yield of crop (Pandey and Sinha, 2006).

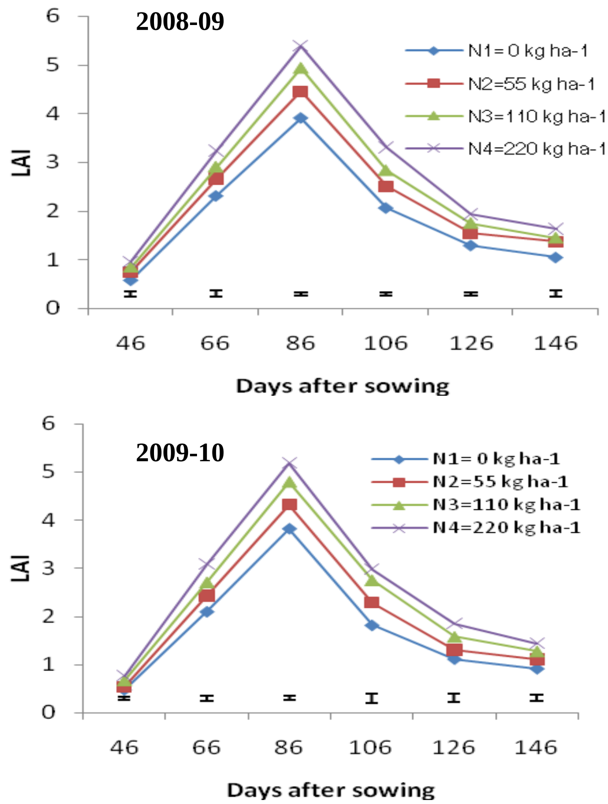


**Fig. 3: Effect of nitrogen levels on LAI**

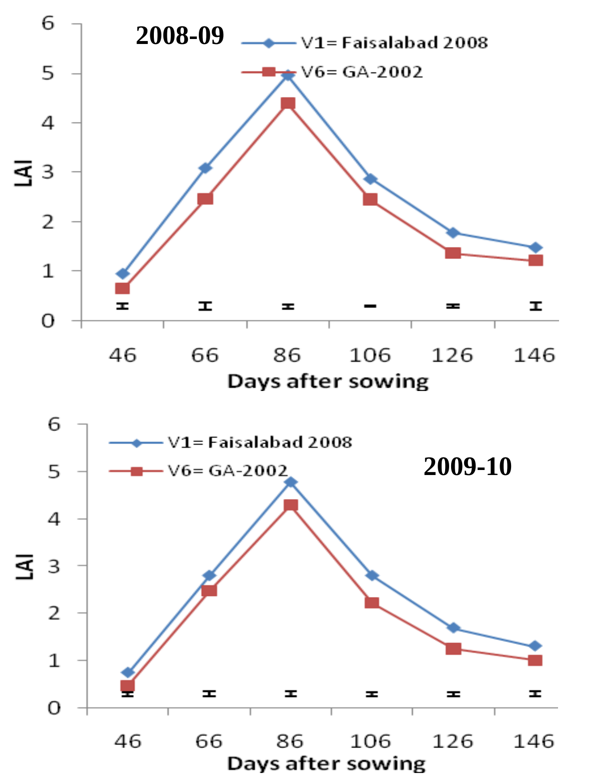


**Fig. 4: Effect of cultivars on LAI**

**Number of Grains per Spike**

Data in Table 2 showed that an increasing rate of N application significantly increased the number of grains spike$^{-1}$, and this response was linear in both the cropping seasons. Effect of N application on number of grains per spike was statistically significant (*P≤0.01*). It is clear from averaged over the two years data, mean number of grains per spike were 39.84, 45.75, 49.89 and 54.48 spike$^{-1}$ for $N_1$, $N_2$, $N_3$ and $N_4$, respectively and $N_4$ (220 kg ha$^{-1}$) produced maximum number of grains. These results are in accordance to Geleto et al. (1995) who reported that number of grains per spike increased at 120 kg N ha$^{-1}$.

Differences in the number of grains spike$^{-1}$ among different varieties were also significant in both the years of study. Faisalabad-2008 produced more number of grains spike$^{-1}$ compared to other varieties except that the Lasani-2008 and Sahar-2006 where the number of grains spike$^{-1}$was statistically at par. Minimum numbers of grains spike$^{-1}$ were given by Bhakkar-2001 in both the seasons (Table-2). Hussain et al. (2006) reported the same results i.e., the application of N resulted in increased number of grain in each spike compared to the control. Kaya et al. (2002) also recorded significant positive correlation between spike length and number of grains per spike. The grains per spike play a vital role in grain yield (Guarda et al., 2004).

**1000-Grain Weight**

Table 3 shows that increasing rate of N application significantly and linearly increased 1000-grain weight compared to other rates of N application in both the cropping seasons. The effect of N was linear during 2008-09 and linear and cubic during 2009-10. The potential of wheat variety is determined by the number of grains spike$^{-1}$ which is an important yield component of grain yield. Averaged over the two years data, mean 1000-grain weight was 33.39, 41.15, 46.46 and 53.21 in $N_1$, $N_2$, $N_3$ and $N_4$ treatments, respectively. Nitrogen increments linearly increased 1000-grain weight in both the seasons. Differences in 1000-grain weight between different varieties were also significant. In both the years, Faisalabad-2008 increased mean grain weight over all other varieties. However, differences between Faisalabad-2008, Lasani-2008 and Sahar-2006 regarding 1000-grain weight was statistically at par in both the years. The minimum 1000-grain weight was produced by Bakkhar-2001 (2008-2009) and GA-2002 (2009-2010). Bellido et al. (2006) also observed that nitrogen application at sowing and on later stage of stem elongation significantly increased the 1000-grain weight.

**Grain yield (kg ha$^{-1}$)**

The highest grain yield is the end product of all positive relationships of the yield components and fertilizer (especially Nitrogen) application enhances the grain yield of wheat varieties. Nitrogen application effect was quadratic in 2008-09 and linear in 2009-01. Grain yield (kg ha$^{-1}$) was affected by all of the factors under study. Data showed that increasing rate of N application significantly increased grain yield over $N_1$ (0 kg ha$^{-1}$) and lower rates of N (55, 110 kg ha$^{-1}$) application in both the seasons and this response was linear in nature. Two years average data showed 2670, 3140, 3480 and 4370 grain yield kg ha$^{-1}$ in $N_1$, $N_2$, $N_3$ and $N_4$ treatments, respectively. Hussain et al. (2006) reported the same results at higher levels of N. Differences in grain yield among different varieties were also significant in both the cropping seasons. Faisalabad-2008 significantly out yielded all other varieties. However, in 2009-10, differences in grain yield between Faisalabad-2008, Lasani-2008 and Sahar-2006 were significant (3480, 3370, 3340 kg ha$^{-1}$, respectively). The minimum grain yield was produced by GA-2002 and Bakkhar-2001 in 2008-09 and GA-2002 in 2008-2010 seasons. Two years mean data showed 3800, 3570, 3450, 3540, 3310, 3200, 3210, 3370, 3390 and 3310 kg ha$^{-1}$ in Faisalabad-2008, Lasani-2008, Miraj-2008, Sahar-2006, Shafaq-2006, GA-2002, Bakkhar-2001, Inqlab-91, Chakwal-50 and Chakwal-97, respectively (Table-2). Productive tillers are the key component of grain yield. These results were in line with those of Tahir and Sarwar (2013) and Rehman et al. (2013).

**Harvest index (%)**

Table 3 presents the effect of treatments on Harvest Index (HI). Increasing rate of N application significantly enhanced HI in 2009-10 but not in 2008-09. Differences in HI between $N_2$, $N_3$ and $N_4$ treatments were, however, non-significant in 2008-09. Two years average data showed 26.74, 27.75, 28.40 and 32.14% in $N_1$, $N_2$, $N_3$ and $N_4$, HI respectively. Mattas et al. (2011) reported that N level 120, 150 and 180 kg ha$^{-1}$ had significant effect on harvest index 44.50, 44.65 and 44.81%, respectively. In the experiment, 150, 180 and 120 kg N ha$^{-1}$ significantly increased the grain and straw yield and their N content were also enhanced significantly because more N uptake. In both the years, differences in HI among different varieties were non-significant. Averaged over the two years data mean HI ranged from 28.04% to 29.90% among different varieties (Table-3). According to Andersson and Johansson (2006), harvest index is related to the above ground dry matter, and depends upon environment and genotype interaction.

**Relationship between yield and yield related traits**

There was strong positive linear relationship between grain yield and number of grains per spike, (Fig. 5) grain yield and 1000-grain weight (Fig. 6) during both the years of study. Regression accounted for 88.8% and 89.9% variations in the data during the year of 2008-09. Relationship between grain yield and number of grains per spike was positive and linear ($R^2$=0.636) and 1000-

**Table 2: Yield and yield components of wheat genotypes affected by variable nitrogen rates**

| Treatments | Plant height (cm) | | | No. of Productive tillers ($m^{-2}$) | | | No. of grains per spike | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | Mean | 2009-10 | 2009-10 | Mean | 2008-09 | 2009-10 | Mean |
| $N_1$= 0 kg $ha^{-1}$ | 79.81d | 83.04c | 81.43 | 221.07d | 210.03d | 215.55 | 39.2d | 40.47d | 39.84 |
| $N_2$=55 kg $ha^{-1}$ | 84.26c | 85.68b | 84.97 | 254.6c | 233.57c | 244.08 | 45.29c | 46.21c | 45.75 |
| $N_3$=110 kg $ha^{-1}$ | 89.21b | 87.82a | 88.52 | 276.77b | 255.97b | 266.37 | 50.03b | 49.74b | 49.89 |
| $N_4$=220 kg $ha^{-1}$ | 94.71a | 89.84a | 92.28 | 322.33a | 289.13a | 305.73 | 55.55a | 53.41a | 54.47 |
| DMR (5%) | 2.07 | 2.13 | | 13.19 | 13.99 | | 1.99 | 3.13 | |
| Linear | ** | ** | | NS | * | | ** | ** | |
| Quadratic | NS | NS | | NS | NS | | NS | NS | |
| Cubic | NS | NS | | NS | NS | | NS | NS | |
| $V_1$= Faisalabad-2008 | 93.33a | 90.89a | 92.11 | 302.00a | 282.17a | 292.08 | 52.5a | 52.6a | 52.55 |
| $V_2$= Lasani-2008 | 91.38ab | 88.75b | 90.06 | 285.67ab | 267.08ab | 276.38 | 50.86ab | 50.87ab | 50.86 |
| $V_3$= Miraj-2008 | 87.37cd | 87.31bc | 87.34 | 278bc | 251.17bc | 264.58 | 49.08bc | 48.27bc | 48.68 |
| $V_4$= Sahar-2006 | 89.12bc | 87.75bc | 88.43 | 281.67bc | 265b | 273.33 | 49.87abc | 48.65b | 49.26 |
| $V_5$= Shafaq-2006 | 85.03def | 86.78c | 85.91 | 265cd | 239.17cd | 252.08 | 46.88c | 47.37bc | 47.13 |
| $V_6$= GA-2002 | 81.92g | 80.02e | 80.97 | 231.67e | 223.92d | 227.79 | 42.88d | 43.18d | 43.03 |
| $V_7$= Bakkhar-2001 | 84.17fg | 84.07d | 84.12 | 235.67e | 226.75d | 231.21 | 43.17d | 43.2d | 43.18 |
| $V_8$= Inqlab-91 | 86.07def | 86.96c | 86.51 | 272.75bcd | 239.58cd | 256.17 | 47.45c | 47.95bc | 47.70 |
| $V_9$= Chakwal-50 | 86.98cde | 87.29bc | 87.14 | 276.17bcd | 240.67cd | 258.48 | 48.9bc | 48.13bc | 48.52 |
| $V_{10}$= Chakwal-97 | 84.65ef | 86.14c | 85.39 | 258.33d | 236.25cd | 247.29 | 43.59d | 44.37cd | 43.98 |
| DMR (5%) | 2.667 | 1.579 | | 18.99 | 15.77 | | 3.12 | 3.66 | |

Mean sharing different letters in column vary significantly at P≤0.05; DMR = Duncan's Multiple Range; *,** = Significance at 5% and 1%, respectively; CV = coefficient of variation; NS = non-significant; $N_1$= 0 kg $ha^{-1}$; $N_2$=55 kg $ha^{-1}$; $N_3$=110 kg $ha^{-1}$; $N_4$=220 kg $ha^{-1}$.

**Table 3: Yield and yield components of wheat genotypes affected by variable nitrogen rates**

| Treatments | 1000-Grain weight (g) | | | Grain yield (kg $ha^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | Mean | 2008-09 | 2009-10 | Mean | 2008-09 | 2009-10 | Mean |
| Nitrogen (kg $ha^{-1}$) | | | | | | | | | |
| $N_1$= 0 kg $ha^{-1}$ | 33.89d | 32.89d | 33.39 | 2860c | 2480c | 2670 | 28.63b | 24.85 | 26.74 |
| $N_2$=55 kg $ha^{-1}$ | 41.60c | 40.70c | 41.15 | 3280c | 3000bc | 3140 | 28.87ab | 26.62 | 27.75 |
| $N_3$=110 kg $ha^{-1}$ | 46.89b | 46.02b | 46.46 | 3830b | 3130b | 3480 | 30.85ab | 25.94 | 28.40 |
| $N_4$=220 kg $ha^{-1}$ | 53.50a | 52.93a | 53.21 | 4600a | 4140a | 4370 | 34.39a | 29.89 | 32.14 |
| DMR (5%) | 1.43 | 1.22 | | 0.55 | 0.57 | | 4.81 | - | |
| Linear | ** | ** | | ** | ** | | NS | ** | |
| Quadratic | NS | NS | | * | NS | | NS | NS | |
| Cubic | NS | * | | NS | NS | | NS | NS | |
| Varieties | | | | | | | | | |
| $V_1$= Faisalabad-2008 | 49.10a | 47.90a | 48.50 | 4120a | 3480a | 3800 | 32.67 | 27.13 | 29.90 |
| $V_2$= Lasani-2008 | 49.03ab | 46.27ab | 47.65 | 3770b | 3370ab | 3570 | 30.45 | 26.87 | 28.66 |
| $V_3$= Miraj-2008 | 45.24bcd | 43.97abcd | 44.61 | 3720bc | 3180bcd | 3450 | 30.81 | 26.38 | 28.60 |
| $V_4$= Sahar-2006 | 45.84abc | 44.89abc | 45.37 | 3744b | 3340abc | 3540 | 30.96 | 26.72 | 28.84 |
| $V_5$= Shafaq-2006 | 42.63cde | 41.63cde | 42.13 | 3550bc | 3070d | 3310 | 30.27 | 26.69 | 28.48 |
| $V_6$= GA-2002 | 41.23ef | 39.34e | 40.29 | 3370c | 3030d | 3200 | 31.3 | 27.23 | 29.27 |
| $V_7$= Bakkhar-2001 | 37.75f | 40.64de | 39.19 | 3370c | 3040d | 3210 | 30.07 | 27.25 | 28.66 |
| $V_8$= Inqlab-91 | 43.05cde | 42.21bcde | 42.63 | 3610bc | 3130d | 3370 | 29.97 | 26.10 | 28.04 |
| $V_9$= Chakwal-50 | 43.78cde | 43.60bcd | 43.69 | 3640bc | 3140cd | 3390 | 30.22 | 26.5 | 28.36 |
| $V_{10}$= Chakwal-97 | 42.03de | 40.88cde | 41.45 | 3520bc | 3090d | 3310 | 30.13 | 27.38 | 28.76 |
| DMR (5%) | 3.79 | 4.13 | | 0.32 | 0.22 | | - | - | |

Mean sharing different letters in column vary significantly at P≤0.05; DMR = Duncan's Multiple Range; *,** = Significance at 5% and 1%, respectively; CV = coefficient of variation; NS = non-significant; $N_1$= 0 kg $ha^{-1}$; $N_2$=55 kg $ha^{-1}$; $N_3$=110 kg $ha^{-1}$; $N_4$=220 kg $ha^{-1}$.

**Table 4: Correlation coefficient between grain yield and yield components**

| Characteristics | 2008-2009 (n=14) | 2009-2010 (n=14) | Pooled (n=28) |
|---|---|---|---|
| Grain yield vs number of tillers ($m^{-2}$) | 0.724** | 0.743** | 0.836** |
| Grain yield vs No. of Spikelets | 0.554* | 0.500* | 0.656** |
| Grain yield vs No. of grains $spike^{-1}$ | 0.772** | 0.631** | 0.783** |
| Grain yield vs 1000-grain weight | 0.603* | 0.723** | 0.795** |
| Grain yield vs total dry matter | 0.761** | 0.749** | 0.814** |
| Grain yield vs harvest index | 0.780** | 0.755** | 0.787** |

** = Significant at 1% level

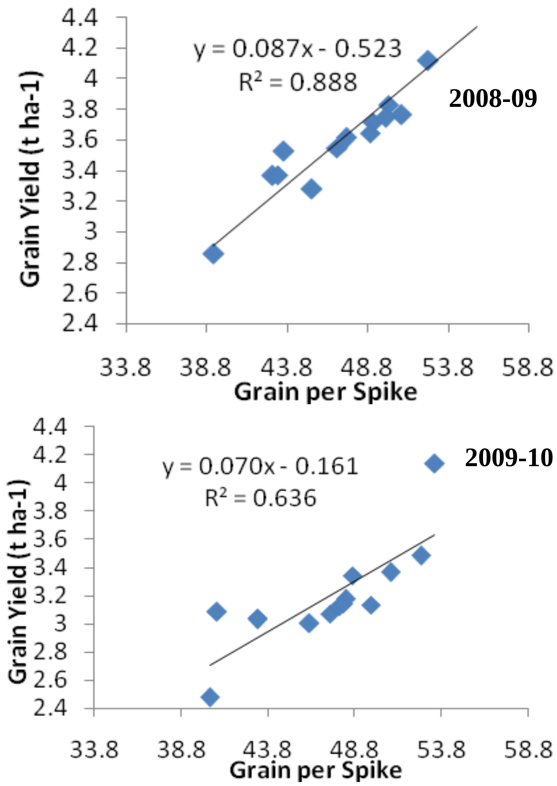


**Fig. 5: Relationship between grain yield and number of grains per spike**

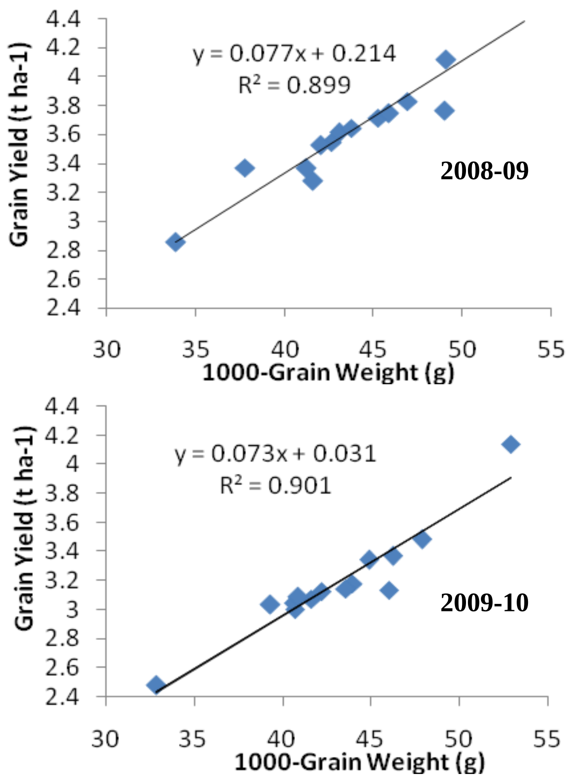


**Fig. 6: Relationship between grain yield and 1000-grain weight**

grain weight was also positive and linear ($R^2$ =0.90) (2009-10).

**Correlation coefficients between yield and yield components**

Table-4 shows the simple correlation between grain yield and yield components. In both seasons, number of tillers $m^{-2}$, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$ and 1000-grain weight were highly positive and there was significant association between grain yield and total dry matter. The regression of grain yield and number of grains $m^{-2}$ and mean grain weight and number of grain $m^{-2}$ was linear and positive.

**Conclusion**

The results suggest that there is considerable scope to exploit the yield potential of various wheat cultivars with different N application rates, depending upon the prevailing climatic conditions. It may be concluded that $N_4$ (220 kg $ha^{-1}$) treatment is recomended for achieving higher yield. Faisalabad-2008 is the best compared to other cultivars but Lasani-2008 can also be grown for economical yields under semi-arid irrigated conditions of Faisalabad.

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