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# Effect of precision nitrogen management on yield and nitrogen use efficiency in different varieties of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during two consecutive winter (*rabi*) seasons of years 2015-16 and 2016-17 to study the effect of different nitrogen scheduling on yield and nitrogen use efficiency of different varieties of wheat (*Triticum aestivum* L.). The experiment was laid out in split-plot design with three replications; in which three varieties (*viz.* HUW 234, K 0307 and HD 2967) were planted in main plots. The combinations of 6 nitrogen scheduling practices which included different N application rates from 0 to 150 kg/ha in various split doses along with the use of LCC and Greenseeker was planned in sub plots. Results reveal that the yield attributing characters, grain yield, straw yield and biological yield were recorded significantly highest in HD 2967 as compared to other varieties. Whereas, varietal parameter did not significantly influence the agronomic efficiency, recovery efficiency and nitrogen harvest. Among nitrogen scheduling, application of 150 kg N/ha in three equal splits recorded significantly higher yield attributes, grain yield (4.70 and 4.81 t/ha), straw yield, biological yield, harvest index, and recovery efficiency of nitrogen. Greenseeker based nitrogen application recorded significantly highest agronomic efficiency and partial factor productivity of nitrogen.

**Key words:** GreenSeeker, Leaf color chart, Nitrogen scheduling, Nitrogen use efficiency, Wheat

Site-specific nitrogen management has the potential to increase fertilizer use efficiency as well as grain yield in the farmers' fields (Nath *et al.* 2013). Improved nutrient management and balanced fertilization are key components of the site-specific nutrient management approach (Witt *et al.* 2005). Application of fertilizer N that corresponds to the spatial variability not only leads to increase N-use efficiency but also reduces possibility of fertilizer N-related environmental pollution. Applying N with crop demand is a way of optimum use of N in crops. Farmers generally use leaf color as a visual and subjective indicator of the wheat crop's nitrogen status to apply N fertilizers. Intensity of leaf color is directly related to chlorophyll content of leaf which, in turn, is related to leaf N status. The concept is based on results that show a close link between leaf chlorophyll content and leaf N content (Alam *et al.* 2006). Estimating the leaf N concentration by the measurement of leaf greenness is one of the easiest N management approaches. Among the different tools available to measure the leaf greenness, the non-destructive measurement of leaf green color intensity using leaf color chart (LCC) are gaining importance (Ravi *et al.* 2007).

The leaf color chart (LCC) is an inexpensive and practically reliable diagnostic tool which can be successfully used to guide need-based fertilizer N application in crops based on spectral properties of leaves. The LCC determines the right time of N application to the wheat crop by measuring leaf color intensity which is related to leaf N status. Unlike in rice, where N can be top-dressed any time during the growth period, N application in wheat has to be linked with irrigation event and thus decisions in making in-season need based N top dressing is more complex, thus fixed time variable dose method is generally used in wheat (Bijay-Singh *et al.* 2010).

GreenSeeker is another tool for site-specific need based N fertilizer management in wheat. It measures visible and near infrared (NIR) spectra response from plant canopies to detect the N status (Raun *et al.* 2011). Spectral vegetation index-the normalized difference vegetation index (NDVI) recorded by GreenSeeker is useful in indirectly estimating photosynthetic efficiency, productivity potential, and potential yield (Raun *et al.* 2001) and has been found to be sensitive to leaf area index, green biomass. However, comparative data on efficiency of LCC and GreenSeeker in wheat (*Triticum aestivum* L.) are limited. Keeping this in view present study was undertaken to evaluate the effect

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of different nitrogen scheduling on yield, nitrogen use efficiency and economics of different varieties of wheat.

## MATERIALS AND METHODS

The study was conducted during the winter (*rabi*) seasons of two consecutive years 2015-16 and 2016-17 at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25º18′ N latitude, 83º30′ E longitudes and at altitude of 128.93 m above the mean sea level), Uttar Pradesh (India).The climate of Varanasi is subtropical with extremes of hot in summer and cold in winter. The mean monthly temperature during experiment was 19.0 to 41.4ºC with average annual rainfall of about 1100 mm and avarage annual evapotranspiration was about 1500 mm. Initial soil samples collected from experiment were mixed, air dried, sieved, and analyzed for physical and chemical characteristics. The soil was sandy loam, non-saline, with a pH of 7.4 and 7.3 in the year 2015-2016 and 2016-2017, respectively. It was moderately fertile, contained 0.36% and 0.35% organic carbon, 210.68 and 205.98 kg/ha available nitrogen, 17.32 and 16.26 kg/ha available phosphorus and 238.45 and 237.74 kg /ha available potassium during 2015-16 and 2016-17, respectively.

The experiment was laid out in split-plot design, comprising 18 treatment combinations. Three varieties, *viz.* $V_1$-HUW 234, $V_2$-K 0307 and $V_3$-HD 2967 were assigned to main plot and six nitrogen scheduling practices, *viz.* $N_0$-No nitrogen, $N_1$-150 kg N/ha (in three equal splits at basal, first irrigation and at second irrigation), $N_2$-125 kg N/ha (50 kg N $ha^{-1}$as basal, 50 kg N at first irrigation and 25 kg N/ha at LCC ≤4 at second irrigation), $N_3$-135 kg N/ha (50 kg N $ha^{-1}$as basal, 50 kg N/ha at first irrigation and 35 kg N/ha at LCC ≤4 at second irrigation), $N_4$- 135 kg N/ha (50 kg N/ha as basal, 50 kg N at first irrigation and 45 kg N/ha at LCC ≤4 at second irrigation) and $N_5$-50 kg N/ha was applied as basal, 50 kg N/ha at first irrigation and at second irrigation N was applied based on GreenSeeker reading (Table 1) assigned in sub plots. Treatments were allocated to each plot randomly and replicated thrice.

A rectangular plot having uniform fertility and even topography was selected for conducting field trial. Prior to sowing of wheat field was ploughed once by harrow after that twice by using cultivator. The pre sowing irrigation was applied to the field prior to sowing of crop. Sowing was done on 23rd November in 2015-2016 and 16th November in 2016-2017 with drilling the seed (120 kg/ha) at 20 cm row spacing using seed-cum-fertilizer drill. The doses of nitrogen, phosphorus and potassium were applied as per treatment through urea, single super phosphate and muriate of potash. The levels of nitrogen were applied in split doses as per the treatment specifications (Table 2) and 60 kg $P_2O_5$/ha and 60 kg $K_2O$/ha were applied as basal in all the plots. In general, wheat was irrigated at the crown root initiation, tillering, jointing and dough stages by flooding the plots up to the point where 5 cm water was standing in the field.

A six panel leaf color chart developed by the IRRI (Philippines) was used for reading. The LCC reading was taken in the morning hours from 8.00 am to 10.00 am or in evening at 2.0 pm to 4.00 pm. The topmost fully expanded leaf was chosen for leaf color measurement. The color of a single leaf was measured by holding the LCC vertically and placing the middle part of the leaf 1cm in front of a color strip for comparison. Readings were taken for 10 leaves at random for each plot and then the average score was compared to determine the need for N top dressing.

The GreenSeeker Trimble hand held optical sensor unit Model 505 was used to measure NDVI from the crop canopy. The sensor uses light emitting diodes (LED) to generate red (660 nm) and near infrared (770 nm) light. The light generated is reflected off from the crop and measured by a photodiode located at the front of the sensor head and calculates NDVI as

$$\text{NDVI} = \frac{\text{NRI} - \text{RED}}{\text{NIR} + \text{RED}}$$

where, NIR is the reflectance in the near infrared region and RED is the reflectance in the red region of the electromagnetic spectrum.

The readings were collected by holding the unit at a height of about 80 cm above the plant canopy. The unit senses a 0.6 × 0.1 $m^2$ area when held at a distance of approximately 0.6-1.0 m from the illuminated surface. The trigger of GreenSeeker optical sensor was pressed continuously while moving in plot and trigger was released after completing one plot. The sensor outputs NDVI at a rate of 10 readings per second. A N-rich strip was established by applying 200 kg N/ha in split doses to ensure that nitrogen was not limiting. The NDVI measurements from the N rich strip ($NDVI_{NRICH}$) and the test plots ($NDVI_{TEST}$) were used to apply N fertilizer. The N-rich strips were characterized

Table 1 Total nitrogen applied during experimentation (kg/ha)

| Treatment | 2015-2016 | | | | 2016-2017 | | | |
|---|---|---|---|---|---|---|---|---|
| | Basal | 1st split | 2nd split | Total | Basal | 1st split | 2nd split | Total |
| $N_0$ | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| $N_1$ | 50 | 50 | 50 | 150.0 | 50 | 50 | 50 | 150.0 |
| $N_2$ | 50 | 50 | 25 | 125.0 | 50 | 50 | 25 | 125.0 |
| $N_3$ | 50 | 50 | 35 | 135.0 | 50 | 50 | 35 | 135.0 |
| $N_4$ | 50 | 50 | 45 | 145.0 | 50 | 50 | 45 | 145.0 |
| $N_5$ | 50 | 50 | 18.49 | 118.49 | 50 | 50 | 18.45 | 118.45 |

Table 2 Effect of varieties and nitrogen scheduling on number of earhead, earhead length, grains per earhead and test weight of wheat (mean of two years)

| Treatment | Earhead (no./$m^2$) | Earhead length (cm) | Grains per earhead (no.) | Test weight (g) |
|---|---|---|---|---|
| *Varieties* | | | | |
| V1 : HUW 234 | 312.50 | 8.36 | 36.50 | 39.31 |
| V2 : K 0307 | 304.50 | 8.33 | 35.00 | 39.15 |
| V3: HD 2967 | 338.50 | 9.06 | 38.50 | 40.16 |
| SEm ± | 4.92 | 0.14 | 0.56 | 0.53 |
| CD (P=0.05) | 19.32 | 0.55 | 2.21 | NS |
| *Nitrogen scheduling* | | | | |
| N0: Control (0 kg N/ha) | 238.00 | 7.32 | 31.50 | 38.32 |
| N1: 150 kg N/ha (Three equal splits) | 348.00 | 9.12 | 38.50 | 40.65 |
| N2: 125 kg N/ha (50 basal+50 first irrigation + 25 kg N/ha at LCC≤4 at second irrigation) | 316.00 | 8.41 | 36.50 | 38.95 |
| N3: 135 kg N/ha (50 basal+50 first irrigation + 35 kg N/ha at LCC≤4 at second irrigation) | 342.00 | 8.95 | 37.50 | 39.68 |
| N4: 145 kg N/ha (50 basal+50 first irrigation + 45 kg N/ha at LCC≤4 at second irrigation) | 345.50 | 9.06 | 38.50 | 40.42 |
| N5: 50 basal+50 first irrigation+GreenSeeker based at second irrigation | 321.50 | 8.56 | 37.00 | 39.22 |
| SEm ± | 5.43 | 0.18 | 0.64 | 0.55 |
| CD (P=0.05) | 15.68 | 0.51 | 1.84 | 1.58 |
| Interaction | NS | NS | NS | NS |

by the highest NDVI values. The measurements were taken close to solar noon (between 11 am and 1 pm). The data from the sensor was exported to a desktop computer for analysis. Data was put in GreenSeeker calculator for calculating nitrogen requirement on per plot basis.

Yield attributing characters, *viz.* number of earheads/$m^2$, earhead length, number of grains per earhead, test weight, grain, straw and biological yield and harvest index were recorded at harvest. The mature crop was harvested from the net plot area and bundle weight was recorded. Grain yield was recorded (kg/plot) after threshing, winnowing and cleaning. Thereafter grain yield was expressed as t/ha at 14% moisture content. After threshing, straw yield was calculated plot wise by subtracting grain yield from bundle weight and expressed in t/ha. The sum of grain and straw yield was considered biological yield.

The N use efficiency measures, agronomic efficiency ($AE_N$), recovery efficiency ($RE_N$), and partial factor productivity ($PFP_N$) as described by Cassman *et al.* (1998) and nitrogen harvest index (NIH) were computed as:

$$AE_N \text{ (kg grain/kg N applied)} = \frac{\text{(Grain yield in N-fertilized plots) - (Grain yield in zero-N plot)}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

$$RE_N\ (\%) = \frac{\text{Nitrogen nuptake (treated plot) – Nitrogen uptake (Control plot)}}{\text{Plant nitrogen applied (treated plot)}} \times 100$$

$$PFP_N \text{ (kg grain/kg N applied)} = \frac{\text{Grain yield (kg/ha) in N fertilized plot}}{\text{Quantity of fertilizer N applied N (kg/N ha)}} \times 100$$

$$PFP_N \text{ (kg grain/kg N applid)} = \frac{\text{Grain yield (kg/ha) in N fertilized plot}}{\text{Quantity of fertilizer N applied N (kg/N ha)}}$$

$$NHI = \frac{\text{Nutrient accumulated in grain (kg/ha)}}{\text{Nutrient accumulated in above ground dry matter (kg/ha)}} \times 100$$

Data generated from experiments were analyzed following analysis of variance (ANOVA) using MS office 7 excel and mean comparisons were performed based on least significant difference (LSD) test at 0.05 probability level.

## RESULTS AND DISCUSSION

*Effect on yield attributes*

Yield attributing characters, *viz.* number of earhead/$m^2$, earhead length, earhead weight and grains per earhead were significantly highest in variety HD 2967 as compared to HUW 234 and K 0307 (Table 2). Whereas, test weight did not differ significantly with different varieties. Yield attributes are the function of vegetative growth. The difference in earhead length of studied varieties might be due to its genetic makeup (Singh and Singh 2006, Mattas *et al.* 2011). Genetic variability among different varieties results to differences in number of grains per earhead. These results are in line with Sokolo *et al.* (2013), they reported significant effect of different wheat varieties on number of grains per earhead. More number of grains in HD 2967 might also be due to the more photosynthate availability and its translocation to earhead (Gonzalez *et al.* 2011). In general number of tillers/m$^2$, leaf area and dry matter were highest in HD 2967 which resulted in improved yield attributes due to increase in photosynthetic activity of leaves and good translocation of photosynthate from source to sink.

Among nitrogen scheduling highest number of earheads/m$^2$, earhead length, earhead weight and grains per earhead were recorded with the application of 150 kg N/ha in three equal splits ($N_1$) which was on par to $N_3$ (35 kg N/ha at LCC≤4 at second irrigation) and $N_4$ (45 kg N/ha at LCC≤4 at second irrigation). However, it was significantly superior over rest of the treatments (Table 2). Higher number of earhead recorded in these treatments might be due to the higher number of effective tillers due to supply of sufficient N. Similar findings also have been reported by Jan *et al.* (2013). The increase in length of earhead in $N_1$ treatment might be attributed to better nutrition of panicle primodia by better availability of nitrogen and more photosynthates availability. This is in agreement with the finding of Shah *et al.* (2011). The increase in grains per earhead is the result of number of fertilized spikes which is determined primarily by amount of nitrogen absorption and amount of carbohydrates produced at the time of spiklets differentiation.

*Effect on yield and harvest index*

Marked variation in the grain, straw and biological yield of wheat was observed in different varieties, whereas, harvest index did not differed significantly with varieties during both the years. Variety HD 2967 recorded highest grain, straw as well as biological yield followed by HUW 234 and K 0307 (Table 3).The economic yield of the wheat depends upon the various yield components like effective tillers/m$^2$, length of the ear (cm), number of grains per ear and the test weight (g). As number of tillers/m$^2$, leaf area and dry matter were highest in HD 2967 which resulted in improved yield attributes due to increase in photosynthetic activity of leaves and good translocation of photosynthate from source to sink and thus resulted in highest yield as compared to other varieties. Suleiman *et al.* (2014), Tomar *et al.* (2014) and Singh *et al.* (2017) also reported significant difference in yield of wheat under different varieties.

In case of nitrogen scheduling, application of 150 kg N/ha in three equal splits ($N_1$) recorded significantly higher grain yield, straw yield as well as biological yield (Table 3). This might be due to more number of earhead, longest earhead, more grains per earhead and test weight and higher photosynthetic activity as compared to other treatments. It is also well known fact that with increasing nitrogen supply, the intensity and nutrient supply capacity of soil increases. As such high fertility utilization and greater nutrient uptake favoured the plant growth and yield attributes and finally the grain and straw yields (Reena *et al.* 2017).

Treatment $N_1$ recorded highest harvest index which was on par with rest of the treatments except control during

Table 3 Effect of varieties and nitrogen scheduling on yield and harvest index of wheat (mean of two years)

| Treatment | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| *Varieties* | | | | |
| V1 : HUW 234 | 4.13 | 5.56 | 9.69 | 42.64 |
| V2 : K 0307 | 4.04 | 5.30 | 9.33 | 43.08 |
| V3: HD 2967 | 4.45 | 5.89 | 10.29 | 43.21 |
| SEm ± | 0.08 | 0.10 | 0.16 | 0.58 |
| CD (P=0.05) | 0.29 | 0.36 | 0.64 | NS |
| *Nitrogen scheduling* | | | | |
| N0: Control (0 kg N/ha) | 2.28 | 3.28 | 5.56 | 4.10 |
| N1: 150 kg N/ha (Three equal splits) | 4.76 | 6.13 | 10.87 | 4.37 |
| N2: 125 kg N/ha (50 basal+50 first irrigation + 25 kg N/ha at LCC≤4 at second irrigation) | 4.41 | 5.87 | 10.28 | 4.29 |
| N3: 135 kg N/ha (50 basal+50 first irrigation + 35 kg N/ha at LCC≤4 at second irrigation) | 4.62 | 6.04 | 10.65 | 4.34 |
| N4: 145 kg N/ha (50 basal+50 first irrigation + 45 kg N/ha at LCC≤4 at second irrigation) | 4.70 | 6.09 | 10.79 | 4.36 |
| N5: 50 basal+50 first irrigation+GreenSeeker based at second irrigation | 4.47 | 5.89 | 10.35 | 4.32 |
| SEm ± | 0.08 | 0.11 | 0.20 | 0.06 |
| CD (P=0.05) | 0.22 | 0.32 | 0.57 | 0.17 |
| Interaction | NS | NS | NS | NS |

both the years of experimentation. Harvest index indicates directly the allocation of biomass to grain and indirectly the partitioning between grain and straw production. Favorable effect on harvest index might be due to higher leaf area and higher chlrolophyll content associated with high photosynthetic efficiency of wheat plant leading to enhanced photosynthetic accumulation and translocation under adequate N supply ($N_1$ treatment). Rani *et al.* (2000) and Maqsood *et al.* (2002) also observed the significant increase in harvest index up to 150 kg N/ha as compared to lower rate of nitrogen application.

*Effect on nitrogen use efficiency*

Different varieties did not significantly influence agronomic efficiency, recovery efficiency and nitrogen harvest index during both the years but differed in partial factor productivity (Table 4).This might be due to application of equal quantity of N in all the three varieties. Satyanarayana *et al.* (2017) and Haile *et al.* (2012) reported that different wheat varieties had non-significant effects on agronomic and recovery efficiency respectively. Highest partial factor productivity in HD 2967 might be due to improved growth, yield, N accumulation and uptake. A number of studies have indicated genetic diversity amongst wheat varieties in their response to nitrogen. Sikander *et al.* (2008) also reported significant variation in N uptake among rice varieties which resulted in different partial factor productivity.

Among different N scheduling treatments GreenSeeker based nitrogen application ($N_5$) recorded significantly maximum agronomic efficiency and partial factor productivity. This was due to application of less nitrogen and in synchronization with crop demand under GreenSeeker based nitrogen scheduling treatment than other treatments. Agronomic efficiency is a product of nutrient recovery from fertilizer and the efficiency with which the plant uses each additional unit of nutrient. Since N was supplied based on crop demand as indicated by leaf greenness (plant N concentration), a better agronomic efficiency and partial factor productivity could be achieved under GreenSeeker based N management over the existing blanket recommendation. The present results are in accordance with the findings of Bijay-Singh *et al.* (2011). The decreased agronomic efficiency and partial factor productivity with increasing amounts of N applied can be attributed to relatively less improvement in tonnage in presence of higher nutrient supplementation beyond certain level. Similarly, lower efficiencies with recommended dose of nitrogen simulate the findings of Singh *et al.* (2002). They opined that N losses from soil-plant system are large, leading to low NUE, when N application is not synchronized with crop demand.

Treatment $N_1$ (150 kg N/ha in three equal splits) recorded highest recovery efficiency. This might be due to high grain yield and higher uptake of nitrogen. Since available nitrogen in experimental field was low, application of higher dose of nitrogen enhanced uptake of applied nitrogen and gave high

Table 4 Effect of varieties and nitrogen scheduling on agronomic efficiency, recovery efficiency, partial factor productivity and nitrogen harvest index of wheat (mean of two years)

| Treatment | Agronomic efficiency (kg grain increase per kg N) | Recovery efficiency (%) | Partial factor productivity (kg grain/kg N applied) | N harvest index (%) |
|---|---|---|---|---|
| *Varieties* | | | | |
| V1 : HUW 234 | 17.55 | 50.72 | 33.79 | 64.95 |
| V2 : K 0307 | 17.37 | 49.63 | 33.02 | 64.19 |
| V3: HD 2967 | 16.81 | 50.21 | 36.01 | 63.40 |
| SEm ± | 0.29 | 1.31 | 0.58 | 0.81 |
| CD (P=0.05) | NS | NS | 2.28 | 3.18 |
| *Nitrogen scheduling* | | | | |
| N0: Control (0 kg N/ha) | - | - | | |
| N1: 150 kg N/ha (Three equal splits) | 16.56 | 53.07 | 31.68 | 64.51 |
| N2: 125 kg N/ha (50 basal+50 first irrigation + 25 kg N/ha at LCC≤4 at second irrigation) | 17.07 | 44.45 | 35.29 | 63.73 |
| N3: 135 kg N/ha (50 basal+50 first irrigation + 35 kg N/ha at LCC≤4 at second irrigation) | 17.37 | 50.60 | 34.23 | 64.49 |
| N4: 145 kg N/ha (50 basal+50 first irrigation + 45 kg N/ha at LCC≤4 at second irrigation) | 16.73 | 51.86 | 32.43 | 64.55 |
| N5: 50 basal+50 first irrigation+GreenSeeker based at second irrigation | 18.49 | 50.96 | 37.72 | 63.77 |
| SEm ± | 0.34 | 1.25 | 0.55 | 64.06 |
| CD (P=0.05) | 0.98 | 3.64 | 1.61 | 0.91 |
| Interaction | NS | NS | NS | NS |

yield. Recovery efficiency of nitrogen is dependent to a large extent on the crop nitrogen demand and the available N supply (Bijay-Singh *et al.* 2006). Quite expectedly higher yield under $N_1$ treatment led to higher N removal and thus higher recovery of applied nitrogen. Sen *et al.* (2011) also reported that higher grain yield and nutrient uptake leads to higher nitrogen use efficiency. Nitrogen harvest index did not differ significantly under different nitrogen scheduling treatments.

*Conclusions*

Different varieties respond differently to nitrogen which should be tested for profitable production. LCC and GreenSeeker based nitrogen application at 2nd irrigation stage can ensure high use efficiency of applied nitrogen. Therefore, to improve fertilizer N use efficiencies in irrigated wheat the blanket application of fixed N doses over large area should be gradually replaced by need based fertilizer N management in different varieties.

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