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Research Paper

GreenSeeker-based nitrogen scheduling in wheat (*Triticum aestivum*) for higher nitrogen-use efficiency and productivity

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2014–15 and 2015–16 at Ludhiana, Punjab to study the effect of nitrogen scheduling using GreenSeeker on growth, productivity and nitrogen-use efficiency (NUE) of wheat (*Triticum aestivum* L.). The soil of the experimental field was loamy sand, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. The experiment was conducted in complete randomized block design with eight treatments, viz. control, recommended N application (150 kg /ha) in 3 equal splits (50 kg N at sowing : 50 kg N at first irrigation : 50 kg N/ha at second irrigation), 3 treatments with fertilizer application in 3 splits up to 2[nd] irrigation using optical sensor GreenSeeker (GS) : 60 kg N/ha + $GS_{2nd\ irri}$ (30 : 30 : 61/51 kg/ha), 84 kg N/ha + $GS_{2nd\ irri}$ (42 : 42 : 53/46 kg/ha), 120 kg N/ha + $GS_{2nd\ irri}$ (60 : 60 : 44/41 kg/ha) and 3 treatments with fertilizer application in four splits i.e. upto 3[rd] irrigation using GreenSeeker : 60 kg N/ha + $GS_{3rd\ irri}$ (20 : 20 : 20 : 14/20 kg/ha), 84 kg N/ha + $GS_{3rd\ irri}$ (28 : 28 : 28 : 6/20 kg/ha), 120 kg N/ha + $GS_{3rd\ irri}$ (40 : 40 : 40 : 6/13 kg/ha). Treatment 120 kg N/ha + GS 2[nd] or 3[rd] irrigation had resulted in better growth and yield of wheat. Application of 160–164 kg N/ha with GreenSeeker at 2[nd] irrigation (60 kg N at sowing + 60 Kg N at first irrigation + 40/44(GS) kg N/ha) recorded higher but statistically similar grain yield in comparison to the blanket application of 150 kg N/ha. Delayed application of N GreenSeeker up to third irrigation (40 : 40 : 40 : 6/13 kg N/ha) resulted in N saving of 17–24 kg/ha, upto 59.5% N recovery and 2.5% higher grain yield than 150 kg N/ha application. .

***Key words* :** Agronomic efficiency, Economics, Green Seeker, Leaf-area index, Nitrogen scheduling, N uptake, NDVI, PAR interception, Wheat, Yield

Punjab is the food bowl of India which contributes 15.09 million tonnes of wheat from 3.50 million hectare area with productivity of 4.30 t/ha (Anonymous, 2016). Under Indian conditions, the nutrient recommendations are based upon crop response data averaged over large geographic areas and do not consider the spatial variability in nutrient supplying capacity of soils (Majumdar *et al*., 2013), leading to yield stagnation. Blanket fertilizer application results into under or over-fertilization. Farmers tend to apply N in excess to avoid risk of N deficiency. Overall farmers use about 10.5 to 24.5% (166 to 187 kg/ha as against recommended 150 kg N/ha) higher dose in rice-wheat cropping system (Singh *et al.,* 2012). Nitrogen-use efficiency (NUE) falls within the range of 30–40% depending upon the agronomic practices used (Krupnik *et al.,* 2004). Higher N use in agriculture not only increase the cost of cultivation but also increase the leaching which causes pollution in the soil (Guarda *et al.,* 2004). The optimized nutrient management through site-specific approaches is required to enhance wheat production. Spectral properties of leaves should be used in a more rational manner to guide need-based fertilizer N application, by taking into account photosynthetic rates, biomass production and expected yields for working out N requirement, with the help of optical sensors. Application of remote sensing in N management is a new approach. Normalized difference vegetation index (NDVI) value can be utilized as a tool to ensure optimum supply of crop nitrogen requirements tailored to a specific growing environment. NDVI can be calculated as

$$NDVI = \frac{(NIR_{ref} - RED_{ref})}{(NIR_{ref} + RED_{ref})}$$

Here NIR_{ref} is reflectance of near infrared radiation

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and RED_{ref} is reflectance of red radiations. NDVI can predict the overall growth and crop yield. GreenSeeker, a hand held device, can measure the NDVI easily in the field. Various algorithms were developed by different scientists across the world under different cultural conditions with application of graded doses of the N fertilizer in wheat crop. If the growth of the crop is good then N requirement calculation with the help of GreenSeeker will be more but if the growth is poor then it will guide us in quantifying of higher doses of N. Keeping in view the above facts on experiment was conducted to study the effect of nitrogen scheduling using GreenSeeker on growth, productivity and NUE of wheat crop.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) season of 2014–15 and 2015–16 at Punjab Agricultural University, Ludhiana. The soil of the experimental site was loamy sand having electrical conductivity 0.13 dS/m, *p*H 7.9, low in organic carbon (0.29%) and available nitrogen (188.2 kg/ha) and medium in available phosphorous (23.5 kg/ha) and potassium (224.0 kg/ha). The experiment was laid out in complete randomized block design with 8 treatments including [control, blanket fertilizer application of N_{150} in 3 equal splits, 3 treatments having fertilizer application in 3 splits upto 2nd irrigation using GreenSeeker (GS) : N_{60} + $GS_{2nd\ irri}$ (30 : 30 : 61/51 kg/ha), N_{84} + $GS_{2nd\ irri}$ (42 : 42 : 53/46 kg/ha), N_{120} + $GS_{2nd\ irri}$ (60 : 60 : 44/41 kg/ha) and 3 treatments having fertilizer application in 4 splits upto 3rd irrigation using GreenSeeker : N_{60} + $GS_{3rd\ irri}$ (20 : 20 : 20 : 14/20 kg/ha), N_{84} + $GS_{3rd\ irri}$ (28 : 28 : 28 : 6/20 kg/ha), N_{120} + $GS_{3rd\ irri}$ (40 : 40 : 40 : 6/13 kg/ha]. Fertilizer application was done as per treatments: N was applied in 3 or 4 splits as per treatment, 60 kg P_2O_5 was applied at the time of sowing. The algorithm developed by Singh *et al.* (2011) was used for calculating the amount of fertilizer required using GreenSeeker at 2nd or 3rd irrigation. Wheat variety 'WH 1105' was sown in rows 20 cm apart using 100 kg/ha seed. Five irrigations were given to crop during both the years. The NDVI data were collected using handheld GreenSeeker. Leaf-area index was recorded periodically using Sunscan leaf-area meter and PAR interception was measured with the help of SS1 SunScan plant canopy analyzer. Ear bearing tillers were counted from 1.0 m length of crop row at 4 locations in each plot at harvest, and expressed as tillers/m^2. Five ears from the bundle of each plot were collected and threshed manually and their grains were counted and expressed as grains/ear. Thousand grains were collected from the produce of the plot and weighed to express 1,000-grain weight. Represented samples of grains and straw were collected from each plot for determination of nitrogen content by modified Kjeldahl's method. Nitrogen uptake was calculated by multiplying the per cent of nutrient content of grain/straw with their respective yield and nitrogen-use efficiency indices were computed (Fageria, 1992). Economics of wheat was calculated by using prevailing prices of the inputs used and produce of the crop for both the years. Gross returns were calculated by multiplying the grain and straw yield of wheat with their respective selling prices. The cost of cultivation of crop was calculated by using the inputs and labour used. Net returns were calculated after deducting the cost of cultivation from gross return. Data were analyzed in SAS 9.4 using the GLM procedure to evaluate differences between the treatments and means were compared using Fisher's protected LSD test at $P < 0.05$.

RESULTS AND DISCUSSION

Growth and photosynthetically active radiation interception

The tallest plants were recorded in N_{150} treatment which were significantly higher than control but was statistically at par with all other treatments (Table 1). Leaf-area index (LAI) gives an idea about the total surface for photosynthetically active radiation (PAR) interception. All nutrient schedule treatments recorded significantly higher LAI than control. The highest LAI at 90 and 120 days after sowing (DAS) was recorded in treatment N_{120} + $GS_{2nd\ irri\ (44/41)}$.. The higher plant height and LAI in higher N doses treatment was due to higher N supply in these treatments. Taller plants in wheat with site-specific crop management practices have also been reported by Kumar *et al*. (2016). Leaf area index (LAI) and photosynthetically active radiation interception (PARI) are determinants of crop growth. Higher LAI helps the crop to intercept higher PAR which helps the crop plant to grow better.

All N schedule treatment recorded significantly higher PARI than control. Treatment N_{120} + $GS_{2nd\ irri\ (44/41)}$ recorded the highest PARI which was statistically similar to all the other treatments except the N_{60} + $GS_{3rd\ irri(14/20)}$ at 120 DAS. Higher PARI in these treatments might be due to higher N application and higher LAI. These results corroborate with the research finding of Kaur *et al.* (2016) that nitrogen management practices had a significant effect on LAI. NDVI was also significantly affected by various N schedules. The treatments N_{120} + $GS_{2nd\ irri\ (44/41)}$ and N_{150} recorded significantly higher NDVI which were statistically similar to all other treatments except control. It might be due to higher N application, higher LAI and higher PARI in these treatments.

Yield-attributing characters and yield

All the yield attributing characters recorded in different

N schedules were significantly higher than control (Table 2). It showed an increasing trend with amount of fertilizer applied. The highest tiller density was recorded in treatment $N_{120} + GS_{2nd\ irri(44/41)}$ which was statistically at par with $N_{84} + GS_{2nd\ irri(53/46)}$, $N_{84} + GS_{3rd\ irri(6/20)}$, $N_{120} + GS_{3rd\ irri(6/13)}$ and N_{150} but significantly higher than $N_{60} + GS_{2nd\ irri\ (61/51)}$, $N_{60} + GS_{3rd\ irri\ (14/20)}$ and control. Higher value of yield attributes in treatments $N_{120} + GS_{2nd\ irri\ (44/41)}$ and $N_{120} + GS_{3rd\ irri(6/13)\ b}$ might be due to better N distribution, higher LAI, PARI and consistent availability of nutrients. Number of grains/ear was highest in $N_{120} + GS3_{3rd\ irri\ (6/13)}$.

Biological yield was significantly higher in treatment $N_{120} + GS_{2nd\ irri\ (44/41)}$ which remained statistically similar to all other treatments except $N_{60} + GS_{3rd\ irri\ (14/20)}$ and control (Table 1). The possible reason for higher biomass accumulation in these treatments could be availability of sufficient nitrogen required for its proper growth which was evident from higher LAI and NDVI in these treatments. Straw yield was higher in treatment $N_{120} + GS_{2nd\ irri\ (44/41)}$ which was statistically similar in all the treatments except control.

Among treatments in which N application was completed at 2nd irrigation, treatment $N_{120} + GS_{2nd\ irri\ (44/41)}$ recorded significantly higher grain yield which was statistically at par with $N_{84} + GS_{2nd\ irri\ (53/46)}$ and $N_{60} + GS_{2nd\ irri\ (61/51)}$. In treatments where N application was delayed upto 3rd irrigation, treatment $N_{120} + GS_{3rd\ irri(6/13)}$ recorded significantly better grain yield than other two treatments. Overall, $N_{120} + GS_{2nd\ irri(44/41)}$ recorded highest grain yield which was statistically similar to other treatments in which fertilizer application was done at 2nd irrigation using GreenSeeker, blanket application with N_{150} and $N_{120} + GS_{3rd\ irri(6/13)}$. All the treatments were significantly better than control. The results revealed that in case of extended splits upto 3rd irrigation when optimum N was not applied to the crop it suffered and resulted in significant yield reduction in comparison where optimum N is applied in previous stages. When the complete N was applied upto 2nd irrigation, all 3 treatments irrespective of the amount of N applied in first 2 splits (as basal and at 1st irrigation) recorded statistically similar yield. It might be due to the reason that the optimum crop requirement had been met

Table 1. Effect of different nitrogen schedules on crop growth and vigour in wheat (pooled mean of 2 years)

Nitrogen schedule	Nitrogen schedule (kg/ha)				Plant height (cm) At harvest	Leaf-area index		PAR interception (%)		NDVI	
	At sowing	At first irrigation	At second irrigation	At third irrigation		90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
Control	0	0	0	0	64.4	2.2	2.5	69.5	60.3	0.51	0.47
N_{150}	50	50	50	–	86.7	3.5	4.4	88.8	84.2	0.77	0.67
$N_{60} + GS_{2nd\ irri(61/51)}$	30	30	61/51	–	82.1	3.2	3.9	84.5	72.1	0.73	0.65
$N_{84} + GS_{2nd\ irri(53/46)}$	42	42	53*/46**	–	83.2	3.3	4.3	87.2	82.7	0.76	0.67
$N_{120} + GS_{2nd\ irri(44/41)}$	60	60	44*/41**	–	85.9	3.6	4.7	89.4	88.0	0.77	0.67
$N_{60} + GS_{3rd\ irri(14/20)}$	20	20	20	14*/20**	74.6	2.8	3.8	83.7	79.4	0.72	0.60
$N_{84} + GS_{3rd\ irri(6/20)}$	28	28	28	6*/20**	78.4	3.0	3.9	84.0	79.3	0.73	0.65
$N_{120} + GS_{3rd\ irri(6/13)}$	40	40	40	6*/13**	83.7	3.3	4.2	89.4	84.3	0.75	0.65
SEm±	–	–	–	–	2.72	0.10	0.13	2.27	2.32	0.02	0.03
CD (P=0.05)	–	–	–	–	7.9	0.3	0.4	6.6	6.7	0.06	0.07

*Year 2014–15; **Year 2015–16; NDVI, Normalized difference vegetation index; DAS, days after sowing

Table 2. Yield and yield attributes as affected by nitrogen scheduling in wheat (pooled mean of 2 years)

Nitrogen schedule	Effective tillers/m^2	1,000-grain weight (g)	Number of grains/earhead	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Control	264.4	40.7	27.0	2.88	8.24	35.0
N_{150}	335.7	41.9	40.8	5.72	12.97	44.5
$N_{60} + GS_{2nd\ irri(61/51)}$	314.8	41.9	40.1	5.29	12.07	44.1
$N_{84} + GS_{2nd\ irri(53/46)}$	338.4	41.9	39.9	5.64	13.01	43.5
$N_{120} + GS_{2nd\ irri(44/41)}$	350.4	42.1	40.5	5.97	13.36	44.9
$N_{60} + GS_{3rd\ irri(14/20)}$	306.6	41.8	38.9	4.98	11.65	43.6
$N_{84} + GS_{3rd\ irri(6/20)}$	322.9	41.6	38.9	5.21	11.99	44.2
$N_{120} + GS_{3rd\ irri(6/13)}$	339.9	42.4	40.7	5.86	13.10	44.8
SEm±	7.42	0.26	1.29	0.15	0.31	1.6
CD (P=0.05)	21.4	0.8	3.7	0.45	0.90	4.6

before yield realization thus, even with application of lower fertilizer doses in earlier phases of crop growth, fertilizer required to achieve high yield had been met before commencement of reproductive phase using GreenSeeker. When comparing fertilizer scheduling upto 2nd or 3rd irrigation, it could be observed that of all 3 treatments in which fertilizer application had been extended to 3rd irrigation only N_{120} + $GS_{3rd\ irri(6/13)}$ had yield comparable to high yielding treatment N_{120} + $GS_{2nd\ irri(44/41)}$. Other two treatments (N_{60} + $GS_{3rd\ irri(14/20)}$ and N_{84} + $GS_{3rd\ irri(6/20)}$) had low yield because they had been deprived of optimum nitrogen application throughout life cycle thus even with increase in number of splits there is no yield benefit. Split application also improves the grain yield as well as the nutrient-use efficiency (Kharub and Chander, 2010). The highest harvest index was recorded in treatment N_{120} + $GS_{2nd\ irri(44/41)}$ which was statistically at par with rest of the nutrient schedule treatments but significantly higher than control.

Nitrogen uptake and nitrogen-use efficiencies

All the N schedule treatments recorded significantly higher N uptake (grain + straw) than control (Table 3). The highest total N uptake was recorded in treatment N_{120} + $GS_{2nd\ irri\ (44/41)}$ which was statistically similar to N_{150}, N_{84} + $GS_{2nd\ irri(53/46)}$ and N_{120} + $GS_{3rd\ irri(6/13)}$ but was significantly higher than control, N_{60} + $GS_{2nd\ irri\ (61/51)}$, N_{60} + $GS_{3rd\ irri(14/20)}$ and N_{84} + $GS_{3rd\ irri(6/20)}$ treatments. The total N uptake recorded in N_{120} + $GS_{2nd\ irri\ (44/41)}$ was 81.84 kg/ha higher than control. Uptake had shown an increasing trend in response to N applied and also when N applied at 3rd irrigation, even with lower amount (126/133 kg N/ha) of fertilizer there is uptake similar to higher fertilizer dose (164/161) applied in 3 splits. It might be due to less loss of nitrogen in 3 splits as compared to 2 splits. The higher leaching loss in higher fertilizer dose applied in few splits was also recorded by Guarda *et al.* (2004).

Nitrogen-use efficiencies i.e. agronomic efficiency (AE) and, recovery efficiency (RE), decreased with increasing fertilizer doses (Table 3). Among all the treatments fertilizer application in 4 splits i.e GS based fertilizer application at 3rd irrigation had higher AE as well as RE. Treatment N_{120} + $GS_{3rd\ irri(6/13)}$ has resulted in 21.7 and 19.2% increase in AE and RE over blanket fertilizer application (N_{150}). The possible reason was lower fertilizer dose and higher uptake with respect to lower grain yield in these treatments thus better utilization of N per unit grain yield. Increase in NUE with increasing number of splits has been observed by Guarda *et al.,* (2004) and Zhao and Si (2015). Ratanoo *et al*.(2016) also reported that application of nitrogen in 3 splits as guided by GreenSeeker also increased the nitrogen recovery efficiency than application in 2 split.

Economic analysis

All the GreenSeeker treatments and control recorded lower variable costs as compared to the blanket recommendation of 150 kg N/ha. The lower variable costs in these treatments were due to no N or less dose of N application. The highest gross and net returns were recorded in N_{120} + $GS_{2nd\ irri(44/41)}$ which was statistically at par with N_{150}, N_{84} + $GS_{2nd\ irri(53/46)}$ and N_{120} + $GS_{3rd\ irri(6/13)}$ but significantly higher than rest of the treatments including control. Higher gross and net returns recorded in these treatments was due to higher grain yield recorded.

In view of these findings, it could be concluded that application of total N of 164–161 kg/ha with split application of 60 kg N at sowing + 60 kg N at first irrigation followed by application of N with GreenSeeker at 2nd irrigation (44/41 kg/ha) recorded better growth, yield attributes, grain yield and economics comparable with the recommended application of 150 kg N/ha. Delayed N application with four splits of 126/133 kg N/ha with GreenSeeker at 3rd irrigation (40 kg N at sowing + 40 kg N at first irri-

Table 3. Effect of different nitrogen schedules on nitrogen uptake, nitrogen-use efficiencies and economics of wheat (pooled mean of 2 years)

Nitrogen schedule	Total N uptake (kg/ha)	Agronomic efficiency (kg/kg)	Recovery efficiency (%)	Variable costs (× 10³ ₹/ha)	Gross returns (× 10³ ₹/ha)	Net returns (× 10³ ₹/ha)
Control	67.06	–	–	31.64	55.91	24.26
N_{150}	141.9	18.9	49.9	34.08	102.28	68.19
N_{60} + $GS_{2nd\ irri(61/51)}$	124.9	20.8	49.1	32.91	94.63	61.71
N_{84} + $GS_{2nd\ irri(53/46)}$	137.7	20.7	52.5	33.12	101.41	68.29
N_{120} + $GS_{2nd\ irri(44/41)}$	148.9	19.0	50.2	33.47	106.33	72.86
N_{60} + $GS_{3rd\ irri(14/20)}$	113.7	27.2	61.7	32.45	89.73	57.28
N_{84} + $GS_{3rd\ irri(6/20)}$	123.4	24.0	59.7	32.69	93.39	60.71
N_{120} + $GS_{3rd\ irri(6/13)}$	143.3	23.0	59.5	33.08	104.30	71.23
SEm±	3.14	1.4	3.0	–	2.26	2.26
CD (P=0.05)	9.06	4.1	8.7	–	6.57	6.57

gation + 40 kg N at second irrigation followed by GreenSeeker guided N 6/13 kg N/ha) recorded N saving of 17–24 kg/ha and 2.5% higher grain yield than recommended dose of 150 kg N/ha with 21.7% higher agronomic efficiency.

REFERENCES

Anonymous. 2016. *Package of Practices for Rabi Crops.* pp 1–20. Punjab Agricultural University, Ludhiana.

Fageria, N.K. 1992. Maximizing crop yields. New York Marcel Dekker.

Guarda, G., Padovan, S. and Delogu, G. 2004. Grain yield, nitrogen use efficiency and baking quality of old and modern Italian bread wheat cultivars grown at different nitrogen levels. *European Journal Agronomy* **21**(2): 181-–192.

Kaur, H., Ram, H., Sikka, R. and Kaur, H. 2016. Productivity, agronomic efficiency and quality of bread wheat [*Triticum aestivum* (L.)] cultivars in relation to nitrogen. *International Journal of Agriculture Environment and Biotechnology* **9**(1): 101–106.

Kharub, A.S. and Chander, S. 2010. Effect of nitrogen scheduling on wheat productivity and quality under alternate tillage practices. *Indian Journal of Agricultural Sciences* **80**(1): 29–32.

Krupnik, T.J., Six, J., Ladha, J.K., Paine, M.J. and Van, K.C. 2004. An assessment of fertilizer nitrogen recovery efficiency by grain crops. In : Agriculture and the nitrogen cycle: Assessing the impacts of fertilizer use on food production and the environment (SCOPE 65) (Eds) Mosier, A.R., Syers, J.K., Freney, J.R. pp. 193–208. Island Press, London.

Kumar, D., Singh, R.A. and Singh, Y. 2016. Influence of sowing dates and nitrogen scheduling on growth behavior and productivity of late sown wheat (*Triticum aestivum*) in north Indian plains. *Annals Agricultural Research* **37**(1) : 61–65.

Majumdar, K., Jat, M.L., Pampolino, M., Dutta, S. and Kumar, A. 2013. Nutrient management in wheat: current scenario, improved strategies and future research needs in India. *Journal of Wheat Research* **4**(1): 1–10.

Pradhan, S., Bandopadhyay, K.K., Sahoo, R.N., Sehgal, V.K., Singh, R., Joshi, D.K. and Gupta, V.K. 2013. Prediction of wheat (*Triticum aestivum*) grain and biomass yield under different irrigation and nitrogen management practices using canopy reflectance spectra model. *Indian Journal of Agricultural Sciences* **83**(11): 1,136–1,143.

Ratanoo, R., Kumar, S., Dhaka, A.K., and Singh, B. 2016. Nitrogen management in irrigated wheat (*Triticum aestivum*) using optical sensor GreenSeeker. *Indian Jornal of Agronomy* **61**(1): 105–108.

Singh, B., Sharma, R.K., Kaur, J., Jat, M.L., Martin, K.L., Singh, Y., Singh, V., Chandna, P., Choudhary, O.P., Gupta, R.K., Thind, H.S., Singh, J., Uppal, H.S., Khurana, H.S., Kumar, A., Uppal, R.K., Vashistha, M., Raun, W. and Gupta, R. 2011. Assessment of the nitrogen management strategy using an optical sensor for irrigated wheat. *Agronomy for Sustainable Development* **31**(3): 589–603.

Singh, S., Malik, R.K., Garg, R., Devraj, R., and Sheoran, P. 2012. On-farm nitrogen use pattern in rice-wheat cropping system of the trans-gangetic plains of india. *Cereal Research Communications* **40**(1): 122–134.

Zhao, H. and Si, L. 2015. Effects of topdressing with nitrogen fertilizer on wheat yield, and nitrogen uptake and utilization efficiency on the Loess Plateau. *Acta Agriculturae Scandinavica, Section B — Soil and Plant Sci*ence **65**(8): 681–87.