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Research Communication

Nitrogen management in irrigated wheat (*Triticum aestivum*) using optical sensor GreenSeeker

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2013–14 at Hisar, to study the GreenSeeker optical sensor based N management vis-a-vis recommended N application in wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]. Application of 25 + 50 kg N/ha at sowing and 25 days after sowing (DAS) and GreenSeeker guided N application at second and third irrigation i.e. 33 and 31 kg N/ha produced maximum grain yield (6.60 t/ha) and saved 11 kg N/ha. The same treatment recorded 8.4 to 15% and 11 to 27% higher agronomic efficiency and recovery efficiency, respectively as compared to recommended dose of N application. GreenSeeker guided N both at second and third irrigation stage, resulted into significantly improved yield and N-use efficiency. Single stage GreenSeeker guided N at second irrigation was better than third irrigation in terms of yield and N-use efficiency. Three split N application resulted in significantly higher nitrogen recovery efficiency (14.4%) than 2 split application.

Key words **:** Fixed rate and time of N application, GreenSeeker, N-use efficiency, Precision nitrogen management, Wheat

Nitrogen is one of the most important factors for growth and development of plants and most limiting nutrient in crop production particularly in irrigated cereal-based cropping systems. Blanket recommendation, most prevailing N management strategy in India could not help in increasing the nutrient use efficiency beyond a limit (Singh, 2008) because temporal and spatial variability is not taken into account. Moreover, farmers have a tendency to apply N in excess of the requirement of crop to avoid risk of N deficiency. Overall farmers use about 10.5 to 24.5% higher N dose in rice–wheat cropping system of Haryana (Singh *et al.*, 2012; Erenstein *et al.*, 2007), which lower the N recovery efficiency.

Traditional diagnostic tools such as soil testing, plant tissue analysis and long-term field trials have limited use due to time delay between sampling and obtaining results. Thus, instant and reliable methods having greater temporal and spatial precision for assessing N status and requirements of field crops are needed.

For this, leaf and canopy characteristics are being increasingly used with the help of different tools/devices such as leaf colour chart (LCC), chlorophyll meter (SPAD), optical sensors etc. A predetermined dose of N is applied using chlorophyll meter and LCC when a critical value or critical colour shade is obtained. These tools have provided an excellent opportunity in terms of developing real-time N management strategies but do not take into account photosynthetic rates or the biomass production and expected yields for working out fertilizer N requirements (Singh *et al.,* 2011). Application of remote sensing in N management is a new approach. There was a very promising relationship between remotely sensed index like NDVI derived from satellite data and GreenSeeker optical sensor (R^2 =0.86) as revealed in the progress report of rice–wheat consortium by Gupta *et al.* (2011).

The field experiment was carried out at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar during the winter (*rabi*) season of 2013–14. The soil was sandy loam with *p*H 8.3, low in available N (135 kg/ha), medium in available P (16 kg/ha) and high in available K (351 kg/ha). The experiment was laid out in randomized block design with three replications. There were 12 treatments comprising N application with and without using GreenSeeker. N application without using

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GreenSeeker consisted of two treatments having recommended dose (150 kg/ha) in 2 (75 kg/ha each) and three (50 kg/ha each) equal splits. GreenSeeker guided N application was combined with fixed rate (75, 100 and 125 kg/ha) and fixed time of N application (9 treatments) as basal and at 25 days after sowing (DAS). GreenSeeker® (Trimble Navigation Ltd., Sunnyvale, CA, USA) optical sensor was used with each fixed level of N application at second (50 DAS) and/or third irrigation (65 DAS). One treatment was control where no N fertilizer was applied. Phosphorous and potash were drilled @ 60 and 40 kg/ha, respectively. Wheat 'WH 711' was sown on 19 November, 2013 using a seed rate of 125 kg/ha with a row- to- row spacing of 20 cm and was harvested on 24 April, 2014. Four irrigations were applied to the crop. N content in grain and straw was determined by digesting the samples in diacid mixture (H_2SO_4 and $HClO_4$) followed by analysis using Nessler's reagent method (Lindner, 1944).

Procedure reported by Singh *et al.* (2011) was adopted for calculating fertilizer N requirement by crop using NDVI readings. For predicting potential yield without adding fertiliser N (YP_0), in season estimated yield (INSEY) - grain yield relationship.

Thus, at second irrigation stage: $YP_0 = 602.47 (INSEY)^{1.1348}$ and at third irrigation stage: $YP_0 = 2581 (INSEY)^{1.4072}$

The N use efficiency measurements from applied N were calculated in the form of RE_n (Recovery efficiency), AE_n (Agronomic efficiency), PE_n (Physiological or internal efficiency) and PFP_n (Partial factor productivity) as follows:

AE_n (kg yield increase per kg N applied) = $(Y_t - Y_0)/N_a$

PE_n (kg yield increase per kg increase in N uptake) = $(Y_t - Y_0) / (U_t - U_0)$

RE_n (kg increase in N uptake per kg N applied) = $(U_t - U_0) / N_a$

PFP_n (kg grain yield per kg N applied) = Y_t / N_a

Where, Y_t is grain yield in test plot (kg/ha) ; Y_0 is grain yield in control plot (kg /ha); U_t is total N uptake in test plot (kg/ha); U_0 is total N uptake in control plot (kg/ha); N_a is N applied in test plot (kg/ha)

Fertilizer N doses using yield potential without additional fertilizer (YP_0) and potential responsiveness to applied N (RI_{NDVI}) and a N-use efficiency factor (0.5) were calculated at 50 DAS and 65 DAS as per treatment. When fixed level of N application at sowing and 25 DAS was low, the total amount (fixed dose + GS guided) of N applied was low (*i.e.* total N dose was 11 to 41 kg/ha lower than recommended dose at 75 kg N/ha as fixed dose) (Table 1). Doses similar to recommended dose were obtained only when 100 or 125 kg N/ha was applied at planting and 25 DAS. Singh *et al.* (2011) also reported that total fertilizer remained low unless the 100 kg or more N was applied as prescriptive dose either at planting or both at planting and CRI stages. In case of single stage GS guided N application, amount of N turned out to be slightly less at 50 DAS than at 65 DAS. This might be due to the higher RI_{NDVI} values at 65 DAS than at 50 DAS. Similarly, GS guided N was less at 65 DAS than at 50 DAS when GS was used at both of these stages. More was the amount of fixed rate N application at sowing and 25 DAS, less was the GS guided N, irrespective of stages of using GS. This may be due to luxurious growth of plant in terms of biomass as well as green leaf area which resulted into higher NDVI values of test plots and lower probability of response (RI_{NDVI}) to further addition of fertilizer N. Optical sensor guided N doses were low when total amount of N applied at planting and CRI was more and when previous fertiliser N event was too close (Singh *et al.,* 2011).

Highest grain yield was obtained when N was applied in combination i.e. 25 and 50 kg/ha at sowing and 25 DAS, respectively, as fixed dose and 33 and 31 kg/ha at second and third irrigation stage, respectively, as guided by GS and it was at par with treatments having application of recommended dose of N in two and three equal splits and treatment having 125 kg N/ha as fixed rate coupled with GS guided N application at two stages i.e. second and third irrigation. Moreover, 11 kg N/ha was saved as compared to recommended N dose (150 kg/ha) and this resulted into higher N-use efficiency. Agronomic efficiency and recovery efficiency were 8.4 to 15% and 11 to 27% higher, respectively as compared to recommended dose N application treatments. Similar findings on N fertilizer saving and increased N-use efficiency were reported by Coventry *et al.* (2011) from Haryana.

Total N uptake and N uptake by wheat grain and straw increased by 9.4, 7.0 and 16.5%, respectively, with application of recommended dose of N in 3 splits as compared to that in 2 splits. The reason may be that more frequent application of N resulted in increased availability of N throughout the active growth period when it was most needed. Dhuka *et al.* (1992) reported that application of N in three splits resulted in highest grain and straw N uptake. Generally, GS guided N application alone at third irrigation combined with different fixed rate N application levels, led to significantly lower N uptake by grain, straw and total N uptake as compared to GS guided N application both at second and third irrigation. This might be due to increased total N availability in the two stage GS guided N application, resulting in higher N content in grain and straw and higher yield. Among single stage GS guided N application treatments, higher N uptake was recorded when N was applied at second irrigation as compared to third irrigation applied N. Also second irrigation applied N led to better translocation of photosynthates to grains and finally it produced higher yield and higher N uptake than third irrigation applied N (Table 1). However, single stage GS guided N application at second irrigation was significantly inferior in grain N uptake and total N uptake and numerically inferior in straw N uptake than two stage GS guided N application. This indicates that third irrigation applied N is more important regarding the grain N uptake.

Irrespective of the level of fixed rate applied N, GS guided N application alone at second irrigation achieved significantly higher AE_n (12.02, 10.35 and 7.27 % at 75, 100 and 125 kg/ha as fixed N doses, respectively) than third irrigation applied N. However, both the treatments were statistically at par in RE_n (Table 1). Ortiz Monasterio and Raun (1994) also reported lower RE_n with delayed application of N beyond Feekes 5–6 stage. However, PE_n followed the reverse trend in this case because comparative decrease in RE_n was higher (13.73, 12.63 and 9.40% at 75, 100 and 125 kg/ha as fixed N doses, respectively) while decrease in AE_n was lower (10.7, 9.5 and 6.8%, respectively) and RE_n being denominator caused increase in PE_n. Singh *et al.,* (2011) also recorded similar results from Karnal as PE_n increased by 0.3 to 14.9% when GS was applied at third irrigation instead of second irrigation. Similarly, PE_n of 3-split N application without using GS was numerically lower than that of 2 split N application. Kaur *et al.* (2010) also reported 6% decrease in PE_n when they applied split doses of N at sowing, first irrigation and anthesis (foliar spray) as compared to split doses at sowing and first irrigation.

Adding more N as fixed level doses at sowing and 25 DAS generally resulted into decreased RE_n and AE_n because this caused the higher total dose of N thereby the yield response to N is typical following the law of diminishing returns. Among combined N application treatments, significantly higher RE_n was achieved when GS guided N was applied at both the stages as compared to single GS guided N application (Table 1). Application of recommended dose of N in 3 splits resulted in significantly higher RE_n (14.4%) than 2 split application. AE_n was also 6.1% higher in 3 split application of recommended N than 2 split application though both the treatments were statistically at par. Alcoz *et al.* (1993) reported increased apparent recovery and agronomic efficiency in split application over no split.

Based on the study, it is concluded that application of 25 kg/ha N as basal + 50 kg/ha N at 25 DAS com-

Table 1. Quantification of N fertilizer doses using GreenSeeker indices, yield potential, response index and nitrogen use efficiency of wheat

Treatment	Nitrogen application (kg/ha)				Total N (kg/ha)	50 DAS		65 DAS		Grain yield (t/ha)	Total N uptake (kg/ha)	AE_n (kg grain increased/ kg N applied	RE_n (%)	PE_n (kg grain increased/ kg N uptake)
	Basal	Days after sowing 25	50 (second irrigation	60 (third irrigation)		YP_0	RI_{NDVI}	YP_0	RI_{NDVI}					
1	75	75	-	-	150	-	-	-	-	6.32	143.3	27.2	61.5	44.3
2	50	50	50	-	150	-	-	-	-	6.57	156.7	28.8	70.4	41.1
3	25	50	34	-	109	3.97	1.24	-	-	5.53	131.7	30.2	74.1	40.8
4	25	50	-	36	111	-	-	3.90	1.26	5.24	123.6	26.9	65.1	41.5
5	25	50	33	31	139	3.98	1.24	4.13	1.21	6.60	160.1	31.3	78.2	40.0
6	25	75	29	-	129	4.11	1.20	-	-	5.66	139.7	26.3	68.4	39.0
7	25	75	-	33	133	-	-	4.04	1.23	5.42	131.8	23.9	60.7	39.4
8	25	75	28	23	151	4.17	1.19	4.45	1.15	5.80	152.3	23.5	67.0	35.2
9	50	75	20	-	145	4.41	1.13	-	-	5.74	144.7	24.0	64.5	37.4
10	50	75	-	28	153	-	-	4.25	1.19	5.68	141.5	22.4	58.9	38.4
11	50	75	19	18	162	4.44	1.12	4.69	1.11	6.46	164.6	26.0	70.1	37.2
12	0	0	-	-	0	-	-	-	-	2.24	51.1	-	-	-
SEm±										0.103	3.9	0.77	2.94	1.83
CD (P=0.05)										0.305	11.6	2.28	8.68	5.40

N at second and third irrigation was applied as guided by GreenSeeker optical sensor

YP_0, Yield potential without additional fertilizer N; RI_{NDVI}, response index; Fertilizer N Requirement, 1.8 YP_0 (RINDVI-1)×10/0.5

bined with GreenSeeker guided N application both at second and third irrigation stages *i.e.* 33 kg/ha and 31 kg/ha recorded the highest grain yield (6.60 t/ha), 8.4 to 15% higher agronomic efficiency and 12 to 27% higher recovery efficiency than recommended dose of N application with a saving of 11 kg N/ha.

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