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Precision nitrogen-management practices influences growth and yield of wheat (*Triticum aestivum*) under conservation agriculture

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ABSTARCT

A field experiment was conducted at New Delhi during the winter (*rabi*) season of 2012–13, to study the precision nitrogen management in wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] grown under conservation agriculture. The experiment was laid out in a factorial randomized-block design with 20 treatments combinations of four nutrient management in preceding maize (*Zea mays* L.) [absolute control, recommended dose of fertilizers (RDF), 50% RDF and site-specific nutrient management (SSNM)] and 5 precision nitrogen-management practices in wheat [control, RDF, green seeker, SPAD and soil-test crop response (STCR)]. Among the tested technologies for precision N management; a saving of N by 9.5 and 30 kg with green seeker and SPAD, respectively, while enhancement of 18.4 kg N/ha by STCR was found compared with RDF. The STCR-based nutrient-management plots received very less potassium (5.6 kg/ha) than RDF (40 kg/ha). The wheat growth parameters, viz. plant height, dry-matter accumulation, leaf-area index (LAI), tillers, crop-growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were significantly higher by STCR-based nutrient management as well as with nutrient expert-based SSNM applied in maize as residual effect. The yield attributes, viz. effective tillers/m^2, grains/spike, harvest index and 1,000-grain weight, were also recorded significantly higher with STCR and SSNM. However, the grain yield was 5% higher with STCR compared to RDF which was on a par with green seeker-based N management. Thus, the RDF in wheat needs to be revisited in western Indo Gangetic plains (IGP) as it responded to higher N levels and lower K application and green seeker sensor can be used for real time N management of wheat in this region while SSNM found best for maize.

Key words *:* Growth parameters, NDVI, SPAD, STCR, Yield attributes and Yield

Wheat is the most important staple food of about 36% of the world population. Worldwide, this crop provides nearly 55% of the carbohydrates and 20% of the food calories. It is grown in all the continents of the world covering an area of 218.5 million hectares with production of 713.2 million tonnes and productivity of 3,265 kg/ha during 2013. Wheat is the second most important cereal crop after rice in India and during 2013–14 it was cultivated on 30.5 million ha area with production of 93.5 million tonnes and productivity of 3,145 kg/ha and was grown in rotation with maize on an area of 1.86 million ha.

Nitrogen is subjected to different kinds of losses like denitrification, volatilization and leaching which causes environmental threats. Nitrous oxide has 310 times the global warming potential of carbon dioxide, and its emissions are affected by poor nitrogen management in intensive crop production which is major source for it. The potential for enrichment of ground and surface waters with nitrates also increases with excessive N fertilizer applications causing eutrophication of aquatic ecosystem and methamoglobinemia in infants (Jat *et al*., 2014). However, insufficient N availability to wheat plants results in low yields and significantly reduced profits compared to a properly fertilized crop. Efficient nutrient-management programmes supply plant nutrients in adequate quantities to sustain maximum crop productivity and profitability while minimizing environmental impacts of nutrient use (Jat *et al*., 2013). Ensuring optimum nutrient availability

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through effective nutrient-management practices requires knowledge of the interactions between the soil, plant and environment. The zero-till wheat became success in south Asia but people are not taking it at very large scale due to less information available on the nutrient application, as the residue retention under conservation agriculture (CA) might enhance or reduce the requirement of nutrients as compared to traditional practices.

The use of some tools for in season N management like Soil Plant Analysis Development (SPAD) chlorophyll meter or green seeker sensor or site-specific nutrient management (SSNM) through soil-test crop response (STCR) or nutrient expert helps in fulfilling the crop nutrient requirement with less environmental footprints (Jat *et al*., 2014; Kumar *et al*., 2014). Keeping this in view, the available tools like green seeker, SPAD and STCR were tested in wheat in this study for precision nutrient management under conservation agriculture which was grown in rotation with maize.

A field experiment was conducted on sandy loam soil during the winter (*rabi*) season 2012–13 at the research farm of the Indian Agricultural Research Institute, New Delhi. The rainfall received during the crop-growing period from November to April was 176 mm. The experimental was soil sandy loam, having pH 7.6 and was low in organic carbon (0.46%) and available N, medium in available phosphorus and high in available potassium. The experiment was laid out in a factorial randomized-block design (FRBD) with 20 treatments combinations comprising 4 nutrient-management in preceding maize [absolute control, RDF (150 : 60 : 40 kg N : P_2O_5 : K_2O/ha), 50% RDF, site-specific nutrient management (SSNM : 170 : 40 : 48 kg N : P_2O_5 : K_2O/ha] and 5 nitrogen-management practices in wheat [control, RDF (120 : 60 : 40 kg N : P_2O_5 : K_2O/ha), green seeker (110.5 : 60 : 40 kg N : P_2O_5 : K_2O/ha), SPAD (90 : 60 : 40 kg N : P_2O_5 : K_2O/ha), STCR (138.4 : 64 : 5.6 kg N : P_2O_5 : K_2O/ha)] and each treatment replicated thrice. The calculated whole amount of P and K fertilizer along with one-third N in RDF and STCR, while half of the recommended dose of N (60 kg/ha) in SPAD and green seeker were applied basal before sowing of wheat. After this, wheat cultivar 'HD 2967' was sown using seed rate of 100 kg/ha. The rest amount of N in RDF and STCR were applied in 2 equal splits-before first (20–25 days after sowing (DAS) and third (50–55 DAS) irrigation, while in SPAD and green seeker real time N management was done. The SPAD values were recorded using SPAD meter and N was applied @ 30 kg/ha when the readings in plots were < 45 at maximum tillering stage. The NDVI values were taken by hand-held green seeker sensor in test plot and N-enriched strips and N was applied as per the algorithms developed for Indian spring wheat at 75 and 105 DAS. Calculations were done for finding out the fertilizer nitrogen required for achieving the targeted yield of 5 tonnes in STCR method by using the region-specific equation developed. All the growth and yield attributes were recorded using standard procedure and grain yield was calculated at 12% moisture content. The crop growth rate (CGR) and relative growth rate (RGR) were calculated using the standard procedure and formulae. The leaf-area index (LAI) was calculated by dividing leaf area with ground area available for each plant. The data obtained for each parameter were analyzed using SAS 9.2 software in general linear model.

Among different precision N-management practices in wheat, STCR recorded significantly the highest and absolute control recorded significantly the lowest plant height of wheat at harvest and dry-matter accumulation and LAI at 90 DAS; however, STCR remained at par with RDF and green seeker (Table 1). Among residual effect of treatments applied in maize, significantly highest dry-matter accumulation and LAI at 90 DAS and plant height at harvesting were obtained by SSNM which remained at par with RDF and 50% RDF and the lowest was recorded by absolute control. The numbers of tillers in wheat at 90 DAS increased significantly by SSNM applied in maize which was at par with RDF but significantly lowest were recorded with absolute control. Amongst precision N-management practices to wheat, significantly highest tillers at 90 DAS were recorded by STCR while it remained at par with green seeker and lowest was found in absolute control. The leaf area indicates the photosynthetic efficiency of any crop field. It seems that balanced nutrient dose provided as per the crop requirement to maize and hence, better growth attributes were observed with direct and residual effect of better nutrition.

The CGR and RGR of wheat increased significantly by SSNM applied in maize (Table 2). Among different precision N management practices to wheat, significantly highest CGR was recorded by STCR and lowest by absolute control at all the growth stages. However; RDF and green seeker remained at par with STCR. Among precision N-management practices significantly highest RGR was obtained by STCR which remained at par with RDF and green seeker and lowest RGR was obtained by absolute control at 0–30 DAS. However, at later stages all the treatments were found non-significant. It clearly indicated that owing to better availability of nutrients CGR and RGR was highest in SSNM and STCR.

Significantly, the highest NAR was obtained by SSNM at 0–30 DAS but at 30–60 and 60–90 DAS, the NAR was not significantly affected by different nutrient application in maize as a residual effect on wheat (Table 2). Amongst precision N-management practices in wheat significantly the highest NAR was obtained, by STCR and absolute control at 0–30 and 60–90 DAS respectively. However, at 30–60 DAS, NAR was not significantly affected by different precision N-management practices. It clearly indicated that due to direct and residual effect of better nutrition availability of nutrients gave initial boost to the crop which resulted in higher RGR and NAR under conservation agriculture. Almost similar results were also reported by Kumar *et al.* (2014) while working on maize under conservation agriculture.

Effective tillers/m^2, grains/spike and 1,000-grain weight of wheat were recorded significantly higher by SSNM which remained at par with RDF applied in preceding maize under conservation agriculture (Table 3). With re-

Table 1. Effect of nutrient-management practices on plant height, dry-matter accumulation, leaf-area index and effective tillers/ m^2 of wheat grown under conservation agriculture

Treatment	Plant height at harvesting (cm)	Dry matter at 90 DAS (g/m^2)	Leaf-area index at 90 DAS	Tillers/m^2 at 90 DAS
Nutrient management in maize				
Control	99.7	746.2	5.27	330
RDF	103.6	783.9	5.37	406
50% RDF	100.8	757.9	5.35	354
SSNM	104.7	795.9	5.44	445
SEm±	1.64	11.00	0.072	22.7
CD (P=0.05)	4.84	32.40	0.212	67.2
Precision nitrogen-management in wheat				
Control	99.0	739.2	5.09	265
RDF	102.4	775.8	5.41	402
Green seeker	103.5	780.8	5.41	409
SPAD	102.1	755.8	5.19	362
STCR	104.0	803.2	5.66	479
SEm±	1.69	11.30	0.074	23.5
CD (P=0.05)	4.90	36.20	0.237	75.1

RDF, Recommended dose of fertilizer; DAS, days after sowing; SSNM, site-specific nutrient management; SPAD, soil plant analysis development; STCR, soil-test crop response

Table 2. Effect of nutrient-management practices on crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) of wheat grown under conservation agriculture

Treatment	CGR (g/m^2/day)			RGR (g/g/day)			NAR (g/m^2/day)		
	0–30 DAS	30–60 DAS	60–90 DAS	0–30 DAS	30–60 DAS	60–90 DAS	0–30 DAS	30–60 DAS	60–90 DAS
Nutrient-management in maize									
Control	1.18	3.09	20.60	0.0513	0.0188	0.0257	1.1780	0.0087	0.0172
RDF	1.31	3.28	21.54	0.0531	0.0181	0.0252	1.3126	0.0090	0.0166
50% RDF	1.22	3.22	20.82	0.0520	0.0187	0.0252	1.2177	0.0090	0.0181
SSNM	1.35	3.42	21.75	0.0535	0.0183	0.0249	1.3517	0.0092	0.0162
SEm±	0.036	0.116	0.378	0.00047	0.00056	0.00048	0.03553	0.00036	0.00108
CD (P=0.05)	0.105	0.342	1.119	0.00140	NS	NS	0.10510	NS	NS
Precision nitrogen-management in wheat									
Control	1.13	3.12	20.38	0.0509	0.0191	0.0256	1.1349	0.0094	0.0198
RDF	1.30	3.32	21.23	0.0530	0.0183	0.0249	1.3042	0.0090	0.0150
Green seeker	1.31	3.26	21.46	0.0531	0.0183	0.0252	1.3140	0.0088	0.0160
SPAD	1.22	3.17	20.80	0.0519	0.0186	0.0254	1.2213	0.0090	0.0176
STCR	1.35	3.40	22.03	0.0536	0.0181	0.0251	1.3506	0.0087	0.0167
SEm±	0.037	0.120	0.391	0.00048	0.00058	0.00049	0.03670	0.00038	0.00112
CD (P=0.05)	0.118	0.382	1.251	0.00150	NS	NS	0.11750	NS	0.0036

RDF, Recommended dose of fertilizer; DAS, days after sowing; SSNM, site-specific nutrient management; SPAD, soil plant analysis development; STCR, soil-test crop response

Table 3. Effect of nutrient-management practices on yield attributes, grain yield and harvest index of wheat grown under conservation agriculture

Treatment	Effective tillers/m^2	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Harvest index (%)
Nutrient-management in maize					
Control	310.4	46.44	38.63	2.26	36.61
RDF	397.5	49.67	39.55	4.42	45.85
50% RDF	346.6	47.62	38.89	4.04	42.49
SSNM	434.3	51.15	40.41	5.16	48.71
SEm±	24.62	1.520	0.598	0.084	1.2
CD (P=0.05)	72.81	4.495	1.769	0.249	3.462
Precision nitrogen-management in wheat					
Control	263.5	43.47	38.69	3.24	42.09
RDF	397.8	49.83	39.17	4.14	43.94
Green seeker	401.4	46.31	39.78	4.31	44.54
SPAD	328.8	48.45	39.18	3.81	40.92
STCR	469.4	55.55	40.03	4.34	45.59
SEm±	25.43	1.570	0.618	0.087	1.2
CD (P=0.05)	81.40	5.025	1.978	0.278	3.871

RDF, Recommended dose of fertilizer; DAS, days after sowing; SSNM, site-specific nutrient management; SPAD, soil plant analysis development; STCR, soil-test crop response

gards to different precision N-management practices applied in wheat, STCR recorded significantly higher effective tillers/m^2 and grains/spike, which remained at par with RDF and green seeker, while 1,000-grain weight was found statistically at par between STCR, RDF, SPAD and green seeker. The better growth parameters of wheat resulted in enhanced photosynthesis and thus gave higher values of yield attributes with SSNM as a residual effect and in STCR as direct effect. Similar results were also reported by Mauriya *et al*. (2013), where all the yield-attributing characters in wheat were found better with site-specific crop management.

The grain yield of wheat was increased significantly by SSNM in preceding maize to the tune of 16.72, 27.51 and 128.53% over RDF, 50% RDF and absolute control, respectively. Significantly, the highest harvest index was found in SSNM over absolute control, 50% RDF, however, it remained at par with RDF. Moreover, this residual effect was might be due to application of nutrients in fixed rows every year in the same place without tilling might help in better nutrient availability in root zone. This root zone nutrient under traditional tillage practice always inverted and might go far from reach of the following crops root and thus residual effects might not be found under such situations. Among different precision nitrogen-management practices in wheat, STCR resulted in significantly higher grain yield by 13.86 and 33.83% over SPAD and control, respectively, but it remained at par with green seeker and RDF. The harvest index was significantly increased by STCR over other precision nitrogen-management practices except with RDF. There is always a positive correlation found in dry-matter accumulation and yield of any crop and the dry-matter accumulation was higher in better nutrient-management which result in higher yields. Khurana *et al.* (2008) and Singh (2008), also reported similar findings in wheat with precision nutrient-management practices.

Based on these results, it can be inferred that the growth parameters, yield attributes and yield increase in wheat obtained with STCR based nutrient management in wheat and SSSNM-based nutrient-management in preceding maize. It shows that these precision nutrient-management options of SSNM and STCR can be better option over blanket recommended fertilizer prescription in maize–wheat cropping system under conservation agriculture. In addition to this, real time N management basal on green seeker was also found effective in wheat under conservation agriculture.

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