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Performance of wheat (*Triticum aestivum*) as influenced by tillage, varieties and precision nitrogen management

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ABSTRACT

The field experiment was conducted at Punjab Agricultural University, Ludhiana, Punjab during *rabi* of 2014-15 and 2015-16 to assess various precision nutrient management practices in different varieties of wheat (*Triticum aestivum* L.) under different tillage systems. The experiment was laid out in split plot design with three replications. The main plot consisted of the combination of two tillage systems [conventional tillage (CT) and zero tillage (ZT)] and two varieties (WH 1105 and HD 2967) and the sub plots consisted of six nitrogen management practices, viz. Control, SSNM-NE (N_{170}), SSNM-NE+GS ($N_{153/158}$), N_{120} before Irrigation, N_{120} after Irrigation, N Rich (N_{180})]. Different tillage practices and varieties gave statistically similar grain yield, however, in terms of economics, ZT recorded 8.4% higher net returns than CT. Among nitrogen management practices, N rich (N_{180}), SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) recorded significantly higher grain yield (53.7 q/ha) compared to other treatments. SSNM NE+GS ($N_{153/158}$) recorded 17.3 and 18.7% higher grain yield compared to N_{120} application before and after irrigation, respectively, whereas, it recorded 89.2 and 130.5% higher grain yield and net returns, respectively, than no N control.

Keywords: Economics, GreenSeeker, Nutrient Expert, Precision nitrogen management, Tillage, Wheat

Wheat (*Triticum aestivum* L.) is the second most important cereal crop after rice in India grown on 31.0 million ha (mha) area with a total production of 101.2 million tonnes (AICWBIP 2019). In the Indo-Gangetic Plains (IGP) of India, farmers tend to follow intensive tillage operations and blanket fertilizer recommendations leading to high production costs, higher nitrogen losses and significant environmental externalities. Also, due to short time for land preparation after harvesting of paddy, sowing of wheat crop is often delayed. This delay is reported to reduce grain yield by 15.5 kg/ha/day when sowing is delayed after November (Tripathi *et al.* 2013). With technological advancement, mindset of farmers has shifted to reduce cost of production without reducing productivity and keeping in focus the sustainability of natural resources. Therefore, zero tillage (ZT) is emerging as an alternative to intensive cultivation, nullifying the harmful impacts of conventional practices (Bhale and Wanjari 2009). Under Indian conditions, the blanket fertilizer recommendations are based on average of crop response data gathered from a large geographic area and thus, these recommendations fail to consider the spatial variability in soil nutrient supplying capacity (Majumdar *et al.* 2013). This practice leads to low nutrient uptake especially nitrogen, thus, lower nitrogen use efficiencies (Kaur *et al.* 2018). This imbalanced application of nutrients for longer duration has led to emergence of multi-nutrient deficiencies in soils under the rice-wheat system (Ladha *et al.* 2009). Thus, site-specific nutrient management (SSNM) would enhance yield and profitability of wheat production. SSNM tools like GreenSeeker takes into account spectral properties of leaves, and Nutrient Expert software captures location-specific information and designs fertilizer recommendations best suited to a farmer's field. Nutrient Expert in combination with GreenSeeker can help improve declining fertilizer efficiency and increase grain yield (Kaur *et al.* 2020). Varieties respond differently to varied nitrogen management practices, therefore, they are also needed to be evaluated with SSNM tools. Thus, the present study was conducted to evaluate the effect of different precision nitrogen management practices under different tillage options in combination with different wheat varieties on growth, vigour, productivity and economics of wheat.

MATERIALS AND METHODS

The experiment was conducted at Research Farm, Wheat Section, Punjab Agricultural University, Ludhiana (30° 56' N latitude and 75° 52' E longitude, 247 metres amsl) during winter (*rabi*) of 2014–15 and 2015–16. It has sub-tropical and semi-arid climate. The average annual rainfall

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ranges from 500 to 750 mm, the greater proportion of which is received during monsoon months of July to September and scanty rainfall during December to February. The soil of the experimental site was loamy sand with normal electrical conductivity (0.13 to 0.14 dS/m), neutral *p*H (7.7 to 7.9), low in organic carbon (0.29 to 0.31%), low in available nitrogen (188.2 to 200.7 kg/ha), medium in phosphorous (22.6 to 23.5 kg/ha) and potassium (205.3 to 224.0 kg/ha). The experiment was laid out in split plot design with combination of two varieties (WH 1105 and HD 2967) and two tillage options (Conventional and Zero tillage) in main plot and six nitrogen management practices, viz. No N (control), Nutrient Expert for wheat (SSNM NE), 70% N with Nutrient Expert for wheat + GreenSeeker (SSNM NE+GS), N_{120} before irrigation, N_{120} after irrigation and N_{180} (N rich) in sub plots replicated thrice. Sowing of the experiment was done on 4th November during both the years using 100 kg seed/ha by *kera* method behind manually operated plough as per treatments. Whole P and K were applied at sowing while N application was carried out in three equal splits i.e. at sowing, at 1st irrigation and at 2nd irrigation [No N (Control); SSNM-NE (N_{170}): 57+57+57; SSNM NE+GS ($N_{153/158}$): 60+60+33/38 (year 1 and 2, respectively); N_{120} before irrigation: 40+40+40; N_{120} after irrigation:40+40+40; N Rich (N_{180}):60+60+60)]. Fertilizer required to be added using Nutrient Expert was estimated as per Majumdar *et al.* (2013) whereas fertilizer application using GreenSeeker at 2nd irrigation was done by calculating the amount of fertilizer required as per the equation given by Singh *et al.* (2011). As basal application along with 1/3rd N, 62 kg P/ha and no K was applied in plots with N_{120} before irrigation and N_{120} after irrigation, 68 kg P/ha and 101 kg K/ha was applied in plots with SSNM-NE and 93 kg P/ha and no K was applied in plots with N Rich. Total five irrigations were given throughout the season. Harvesting was done manually with the help of sickles from the net area of each plot separately. The tiller count (m^2), plant height (cm), dry matter accumulation (DMA), grain yield (kg/ha) and harvest index (%) of wheat crop were recorded from plot of 20 m^2. Plant vigour characters, viz. normalized difference vegetation index (NDVI) values were collected using hand-held GreenSeeker while leaf area index (LAI) and photosynthetically active radiation interception (PARI) were recorded with the SunScan plant canopy analyser, periodically. Periodic chlorophyll content was recorded using *atLeaf* and later the value observed was converted to SPAD (soil plant analysis division) value using the model proposed by Zhu *et al.* (2012). Economic assessment of wheat in terms of net returns and benefit:cost (B:C) ratio was worked out by using prevailing prices of the inputs used and produce of the crop for both the years. The grain and straw samples from each plot were analysed to determine nitrogen, phosphorus and potassium content. Nutrient uptake was calculated by multiplying the percent of nutrient content of grain/straw with their respective yield and then total uptake was calculated. Statistical analyses of data was carried out using PROC GLM in SAS 9.4 software. Multiple comparisons were made using ADJUST= LSD at $P<0.05$ to determine significant effects and LSMEANS with STDERR to estimate standard error.

RESULTS AND DISCUSSION

Crop growth and vigour: Varieties exhibited significant variation in crop growth (plant height, tiller density) and vigour parameters (PARI, LAI, NDVI) on pooled basis (Table 1). Variety HD 2967 recorded significantly taller plants (88.5 cm at 120 DAS) and higher tiller density (345.8 tillers/m^2) in comparison to WH 1105. The different plant height of varieties was due to their different genetic potential (Kaur *et al.* 2016). Maximum DMA was registered in variety HD 2967 (96.8 q/ha at 120 DAS) which was significantly better than WH 1105 (95.1 q/ha at 120 DAS). Higher DMA in HD 2967 can be ascribed to higher number of tiller density and plant height. Basu *et al.* (2014) also reported significant effect of varieties on DMA. Varieties had a significant effect on crop vigour parameters, viz. LAI, PARI, NDVI and chlorophyll content where variety HD 2967 performed better in all the parameters in comparison to WH 1105. It might be due to taller plants and more DMA in HD 2967.

The tillage systems did not affect periodic tiller density, plant height and DMA significantly. However, CT observed numerically higher tiller density, taller plants consequently numerically higher DMA than ZT during study. Gupta *et al.* (2011) also recorded similar tiller density under different tillage treatments. Different tillage options did not significantly affect LAI and PARI. Similar results of PARI in ZT and CT have been reported by Ram *et al.* (2010). Different nitrogen management methods had a statistically observable effect on plant height, tiller density and DMA. N rich (N_{180}), SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) were statistically similar to each other but significantly better than N_{120} (before or after irrigation) as well as control. Higher dose of nitrogen has resulted in enhanced tiller density in treatment N rich (N_{180}), SSNM NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) by providing the required nutrition and keeping the crop free from nutritional stress as observed in control treatment where less tiller density was observed due to nutritional stress. These results are in agreement with the findings of Mohanty *et al.* (2015) that use of GreenSeeker (110.5 kg N/ha) significantly increases tiller density over recommended practice and control. More profuse and taller plants resulted in higher LAI, PARI, NDVI and chlorophyll content. N rich (N_{180}) recorded the highest LAI at 90 and 120 DAS (4.51 and 4.38) which was statistically at par with SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) and significantly better than other treatments. Kaur *et al.* (2016) also reported significantly higher LAI with higher doses of N over control. The higher LAI in these treatments might be due to better accumulation of photosynthates as depicted by higher DMA because of more availability of nutrients. Higher chlorophyll in higher N schedules might be due to availability N for plant uptake which is the key component of chlorophyll pigment. Treatments SSNM-NE (N_{170}), SSNM

Table 1 Effect of nitrogen management practices on crop growth and vigour in wheat in different varieties under different tillage systems

	Tiller density (m^2)		Plant height (cm)		Dry matter accumulation (q/ha)		PAR interception (%)		LAI		NDVI		Chlorophyll content (mg/g fresh leaves)	
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
Variety														
HD 2967	357.3	345.8	63.6	88.5	73.7	96.8	84.7	81.9	4.26	4.07	0.74	0.65	2.78	2.51
WH 1105	340.4	335.0	62.2	86.0	73.1	95.1	81.9	78.9	4.05	3.88	0.72	0.62	2.62	2.32
SEm±	3.3	2.4	0.5	0.7	0.7	0.5	0.6	0.4	0.046	0.049	0.005	0.005	0.42	0.039
CD (P=0.05)	11.3	8.7	NS	1.8	NS	1.1	0.7	1.9	0.17	0.13	0.012	0.019	NS	0.09
Tillage														
CT	351.4	343.3	63.4	87.6	73.4	96.3	83.6	80.9	4.19	4.0	0.74	0.65	2.73	2.45
ZT	346.3	337.5	62.3	86.9	73.3	95.5	83.0	79.9	4.12	3.95	0.73	0.62	2.66	2.38
SEm±	3.3	2.3	0.5	0.7	0.7	0.5	0.6	0.4	0.046	0.049	0.004	0.005	0.04	0.04
CD (P=0.05)	NS	NS	NS	1.8	NS	NS	NS	NS	0.07	NS	0.02	0.013	NS	NS
Nitrogen management practices														
Control	284.4	273.9	49.6	67.5	60.4	84.6	65.2	61.3	3.24	3.05	0.54	0.49	2.11	1.8
SSNM NE (N_{170})	380.5	379.5	67.1	93.3	79.1	102.1	88.5	87.3	4.48	4.33	0.79	0.68	2.84	2.6
SSNM NE+GS ($N_{153/158}$)	383.2	378.7	66.4	93.2	77.9	100.3	88.7	85.9	4.47	4.35	0.78	0.68	2.9	2.7
N_{120} before Irrigation	329.9	317.2	63.5	88.8	74.2	94.1	83.9	81.1	4.14	3.86	0.75	0.64	2.7	2.32
N_{120} after Irrigation	329.2	315.4	63.0	87.8	70.9	93.2	82.7	79.0	4.1	3.88	0.74	0.63	2.68	2.36
N Rich (N_{180})	385.8	377.6	67.7	92.9	77.7	101.3	90.7	87.9	4.51	4.38	0.79	0.68	2.96	2.7
SEm±	5.6	4.0	0.9	1.1	1.1	0.8	0.9	0.7	0.077	0.08	0.007	0.009	0.071	0.066
CD (P=0.05)	17.1	11.5	2.5	3.0	3.5	2.4	3.0	2.2	0.11	0.18	0.03	0.02	0.21	0.19

Pooled mean of 2 years

NE+GS ($N_{153/158}$) and N rich (N_{180}) recorded statistically similar chlorophyll content (2.84-2.96 mg/g and 2.60-2.70 mg/g fresh leaves at 90 and 120 DAS, respectively) and better than other treatments. Similar trend was observed for NDVI.

Crop productivity: Tillage levels recorded no statistical difference for grain yield, however, CT recorded numerically higher grain yield (46.7 q/ha) than ZT (45.2 q/ha) (Table 2). Similarly, variety WH 1105 recorded, although non-significantly yet numerically higher (1.84 %) grain yield (46.4 q/ha) over HD 2967 (45.5 q/ha). Significant impact of varieties was observed on harvest index, WH 1105 recorded significantly better harvest index (44.8) in comparison to HD 2967.

Among the nitrogen management treatments, N rich (N_{180}) recorded significantly higher grain yield (53.7 q/ha) which was similar to SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) and significantly better than N_{120} before or after irrigation and control. It recorded 92.9 % higher grain yield than control. SSNM NE+GS ($N_{153/158}$) recorded 17.3 and 18.7 % higher grain yield compared to blanket fertilizer treatments N_{120} before and after irrigation, respectively, and 89.2 % higher than unfertilized control. Higher values of DMA, PARI, NDVI and yield attribute in these treatments have ascribed significant enhancement in grain yield. Kaur *et al.* (2020) also reported significantly improved grain yield with use of higher nitrogen doses and specifically with the GreenSeeker. The lowest grain yield in unfertilized control might be due to the fact that control treatment speed up the phenology, and thus, reduce the grain filling period which leads to lower grain yield (Kaur *et al.* 2019). Yield enhancement in SSNM treatments could be attributed to increase of assimilation area as depicted by higher LAI, helping in realization of higher grain yield. N rich (N_{180}) and SSNM NE+GS ($N_{153/158}$) recorded higher harvest index (44.8) which was statistically similar to all other treatments except control. Harvest index indicates the allocation of biomass, thus, higher value of harvest index in these treatments could be attributed to adequate N supply in these treatments creating favourable conditions for higher LAI and other vigour parameters leading to enhanced photosynthetic accumulation and translocation.

Economics: Among tillage system, total cost was numerically higher in CT (₹33597/ha) compared to ZT (₹27094/ha). Net returns were significantly higher in ZT (₹54344/ha) in comparison to CT (₹50123/ha). ZT recorded 8.4 % higher net returns than CT. Similarly, higher B:C ratio (2.97) was recorded in ZT. Higher net returns in ZT system

Table 2 Effect of nitrogen management practices on grain yield, economics and nutrient uptake in wheat in different varieties under different tillage systems

	Grain yield (q/ha)	Harvest Index	Total cost	Net returns	B:C Ratio	Total N uptake kg/ha	Total P uptake kg/ha	Total K uptake kg/ha
Variety								
HD 2967	45.5	42.6	30,336	52,223	2.73	112.7	24.1	83.4
WH 1105	46.4	44.8	30,355	52,244	2.72	112.1	23.6	78.2
SEm±	0.50	0.49	24.45	821.3	0.027	0.26	1.10	0.97
CD (P=0.05)	NS	1.16	-	NS	NS	NS	NS	2.38
Tillage								
CT	46.7	44.1	33,597	50,123	2.47	113.6	24.1	80.2
ZT	45.2	43.3	27,094	54,344	2.97	111.2	23.5	81.4
SEm±	0.49	0.48	24.3	816.4	0.027	0.25	1.10	0.97
CD (P=0.05)	NS	NS	-	2169	0.07	NS	NS	NS
Nitrogen management practices								
Control	27.9	39.7	25,296	26,758	2.08	62.3	14.1	47.1
SSNM NE (N_{170})	51.7	44.6	33,122	59,360	2.82	132.7	27.1	97.3
SSNM NE+GS ($N_{153/158}$)	52.8	44.8	32,723	61,689	2.91	136.1	27.6	98.6
N_{120}before Irrigation	45.0	44.4	29,597	50,991	2.75	103.4	28.5	74.4
N_{120}after Irrigation	44.5	43.8	29,597	50,359	2.73	103.5	22.8	74.9
N Rich (N_{180})	53.7	44.8	31,740	64,243	3.05	136.4	23.0	92.5
SEm±	0.84	0.83	41.3	1386	0.046	0.43	1.87	1.64
CD (P=0.05)	2.50	2.56	-	3757	0.13	1.09	1.19	4.59

(Pooled mean of 2 years

was due to lower production cost but similar grain yield with CT. Different varieties had not significantly influenced the economics, WH 1105 recorded (₹52244/ha) similar net returns as recorded in variety HD 2967 (₹52223/ha).

Different nitrogen management practices had a statistically pronounced effect on economics. Total variable cost was higher in SSNM-NE (N_{170}) (₹ 33122/ha) followed by SSNM NE+GS ($N_{153/158}$) (₹ 32723/ha) and N rich (N_{180}) (₹ 31740/ha). The lowest production cost was recorded in control (₹ 25296/ha). Maximum net returns were observed in N rich (N_{180}) (₹64243/ha) which were statistically similar to SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$). Similarly, higher B:C ratio was recorded in N rich (N_{180}) (3.05) which was at par with treatments SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$). SSNM NE+GS ($N_{153/158}$) recorded 21.0 to 22.5% higher net returns in comparison to blanket fertilizer treatments N_{120} before and after irrigation, respectively, and 130.5% higher net returns than control treatment. Kaur *et al.* (2018) also recorded higher net returns in SSNM treatments comprising of GreenSeeker and Nutrient Expert.

Nutrient uptake: Different tillage systems had not significantly affected total N, P and K uptake. However, CT recorded numerically higher total N uptake (113.6 kg/ha) and total P uptake (24.1 kg/ha), however, K uptake was numerically higher in ZT (81.4 kg/ha) (Table 2). Among varieties, no statistical difference was recorded in total N and P uptake, however total K uptake was significantly higher in variety HD 2967 (83.4 kg/ha) as compared to WH 1105 (78.2 kg/ha). Different nitrogen management practices had a significant effect on total N, P and K uptake. Treatment N rich (N_{180}) recorded higher total N uptake (136.4 kg/ha) which was statistically similar to SSNM-NE (N_{170}) and SSNM NE+GS ($N_{153/158}$) and significantly better than all other treatments. SSNM NE+GS ($N_{153/158}$) recorded maximum total P and K uptake (27.6 and 98.6 kg/ha, respectively) which remained statistically similar to SSNM-NE (N_{170}) and significantly better than all other treatments. This was the result of application of higher dose of phosphatic and potash fertilizer as recommended by Nutrient Expert leading to higher availability nutrients to crop, thus, leading to higher uptake.

It could be concluded that zero tillage could help reduce the production cost without compromising grain yield. Site specific nitrogen management practice comprising of Nutrient Expert and GreenSeeker based application of 153 to 158 kg N/ha (60+60 +33/38 kg/N) produced higher yield and economic returns and thus, could be recommended to farmers' field under Punjab conditions.

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