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Winter wheat response in precision nitrogen management and conservation tillage practices under irrigated condition of western India: Effect on soil nutrient availability, physicochemical properties and nutrient use efficiency

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Abstract
Conservation agriculture (CA) continues to be critical for dealing with interannual fluctuations in climatic conditions, which has an effect on winter wheat production and food security. The aim of this study was to see how different tillage, previous crop and precision nitrogen management affected the agronomic and the economic output of rained winter wheat in a semi-arid environment in Western India. Tillage practices included four crop establishment methods (Zero tillage (ZT), Reduced tillage (RT), Furrow irrigation raised beds (FIRB), Conventional tillage (CT)) in main plot and precision five nitrogen management (F1 – N 80:20 - N rate split as 80% basal and 20% at second irrigation, F2 - N 33:33:33 - N rate split as 33% basal, 33% at CRI stage (20–25 DAS) and 33% at second irrigation (40–45 DAS), F3 - N 80 – LCC - Split as 80% basal and further application of N based on LCC, F4 – N 50:50 - N rate split as 50% basal and 50% at CRI stage and F5 – FFP - farmers fertilization practice) in sub-plot and laid out in split-plot design with three replications. Results revealed that among the nutrient sources wheat use of furrow irrigated raised bed system (FIRB) along with the application of nutrient as N E 80-LCC seems to best combination for achieving higher on soil nutrient availability, good physicochemical Properties and nutrient use efficiency under northwestern plain zone of Uttar Pradesh.

Keywords: Fertilizer nitrogen management, LCC, Nitrogen use efficiency, Tillage

Introduction
Wheat (*Triticum aestivum* L.) production must increase by more than 40% globally over the next two decades to meet the rising population's food demand (Ray *et al.* 2013) [12]. As the growing urbanization makes the cultivable land area of wheat difficult to grow, an increase in grain production per unit area is the best way to achieve food and nutritional security. India is the second-largest producer of wheat in the world, having been blessed and endowed with a diverse agro-ecological environment, ensuring food and nutrition protection to the majority of the Indian population through production and consistent supply, especially in recent years. The crop has been grown on approximately 30 million hectares, yielding an all-time high output of 109.24 million tons of wheat with a record average productivity of 3371 kg/ha (DOE&S 2020) [4]. Implementing a strategy focused on the sustainable intensification of wheat-based cropping systems remains critical for food security in order to address this alarming situation. Conservation agriculture (CA) has been proposed as an adapted set of crop management principles that assures a more sustainable agricultural production, reduces soil degradation, and also contributes to making agricultural systems more resilient to climate change. Conservation agriculture (CA) has been proposed as an adapted set of crop management principles that assures a more sustainable agricultural production, reduces soil degradation, and also contributes to making agricultural systems more resilient to climate change (Kassam *et al.* 2013) [8].
Nitrogen is the most essential nutrient for plant growth and plays an important role in agricultural crop yield and quality. Plant production is primarily limited by nitrogen availability in many natural and cultivated systems. For optimum plant growth and production, high rates of N fertilizers are generally applied to meet plant nitrogen requirements (Souri, Rashidi, and Kianmehr 2018) [15].

The applied amounts of nitrogen are frequently much beyond the recommended rates. Urea is the world's most used nitrogen fertilizer that hydrolyzes rapidly into ammonium in soil and then nitrate through microbial enzymes. This transformation makes it vulnerable to losses via various processes, as the plant uptake efficiency of nitrogen fertilizers is generally 35–50%, while 50–65% of applied nitrogen is lost and contributes to various environmental pollutions (Allaire and Parent 2004; Souri 2017) [1].

Site-Specific Nutrient Management (SSNM) entails maximizing nutrient inputs based on the demand (plant needs) and supply (from soil native sources) of nutrients as they vary over time and space, ensuring field-specific nutrient management during a given cropping season (Dobermann *et al*. 2004) [2]. A variety of tools and practices, such as the Leaf Color Chart (IRRI, 2020) and decision support systems such as Nutrient Expert (NE (http://software.ipni.net), are available to assist farmers in implementing SSNM and improving NUE.

In order to increase soil fertility and NUE of crops, adjustment of N management is necessary for the transition phase in the CA-adoption in accordance with changes in soil characteristics and processes in Conservation tillage practices with precision nitrogen management.

The aim of this paper is to contribute to the discussion in India about the scope and utility of conservation agriculture. Our main goal is to compare effects on the agronomic and economic performance of rained winter wheat in semi-arid West Indian conditions from conservation tillage and precise nitrogen management, under four tillage and five levels of N fertilizer rates. Our results highlight the importance of no-tillage-based CA combined with precision nitrogen management, increase soil fertility, N-use efficiency. These findings provide the evidence of the Positive impact of CA for rainfed winter wheat under semi-arid region of Western India.

Materials and Methods

Experimental Site

The field experiment was conducted during *rabi* seasons of 2017-18 at Crop Research Centre (Chirodi) farm of the Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) located in Indo-Gangetic plains of Western Uttar Pradesh and in North Western plains of wheat growing zone. The farm is geographically located at 29^0 05' 19" North latitude, 77^0 41' 50" East longitudes and at an elevation of 237 meters above the mean sea level. The climate of the area (Crop Research Centre, Chirori (Meerut)) is a subtropical, semiarid type with hot and dry summers from April to June, followed by humid and sultry climates from June to September and chilly winters from November to January. The average rainfall of the area is 650 mm. The experimental field had an even topography with good drainage system.

Treatment Description

The experiment under study included treatment combinations involving different combinations of tillage crop establishment methods and precision nitrogen management. All treatments were replicated thrice in a split plot design. A uniform dose of phosphorus (60 kg ha^{-1}) and potash (60kg ha^{-1}) were applied through Single super phosphate, muriate of potash to all the plots as basal application. Nitrogen was applied through urea as per treatments.

Collection of Soil Samples

Surface soil samples were taken before the wheat was sown in November 2017 and after the wheat was harvested in April 2018. Five samples were taken from each plot and combined to make a representative soil sample. Air dried samples were ground in a wooden mortar and sieved with a 2-mm plastic sieve.

Analysis of Soil Samples

The pH of the soil samples was calculated using a 1:2 ratio of soil–water suspension (Jackson 1973) and electrical conductivity (EC) was determined using a 1:2 ratio of soil–water supernatant (Richard, 1954). The organic carbon (OC) content was determined using the wet combustion method given by Walkley and Black [1934] [17]. The alkaline potassium permanganate method was used to calculate the available nitrogen (*Subbiah et al*. 1956) [16] and available phosphorus in soil was determined by using the method given by Olsen *et al*. (1954) [10]. The available potassium in soil was determined using Jacksons method (1967) [7], which involves extracting soil with a neutral ammonium acetate solution.

Nutrient Use Efficiency

The estimated values of Partial factor productivity of applied nitrogen (PFP) were calculated using the following formula (Dobermann, 2007) [3].

Partial factor productivity of applied nitrogen (PFP)

$= Yt / Na$

where, Yt= Yield under treatment (kg ha^{-1})

Na= Amount of nutrient added (kg ha^{-1})

The experimental data were subjected to statistical analysis using Split plot design in statistical package OPSTAT software (Sheoran *et al*. 1998). The Bartlett test was used to ensure that the error variances were homogeneous prior to analysis. A LSD test was used to compare differences between treatment means at a P 0.05 level (Gomez and Gomez, 1984) [5].

Results

Impact of tillage crop establishment methods and precision nitrogen management on Physicochemical Properties of Soil

The data mentioned in Table 1 (1.1) revealed that the among the different tillage practices, highest electrical conductivity status after wheat crop harvest (0.24 dS/m) was obtained in conventional tillage, which remained at par with reduced tillage and FIRB but significantly higher than zero tillage of the treatment. The lowest electrical conductivity status after wheat crop harvest was observed in zero than rest of tillage techniques.

Among precision nitrogen management treatment highest value of soil electrical conductivity of soil after harvest of wheat crop was observed in farmers fertilization treatment which remained at par with S R 50:50 treatment but significantly higher than rest of the nutrient management treatments. The lowest value of electrical conductivity of soil was noticed in N80:20 treatments.

The data presented in Table 1 (Fig-1.) illustrated that the soil pH status after wheat crop harvest was not significantly influenced due to different tillage practices and precision nitrogen management treatments.

However, the highest and lowest values (7.29 & 7.21) of soil pH were observed in conventional tillage and furrow irrigated raised beds treatments, respectively. Among the precision nutrient management treatments, soil pH did not influenced significantly, however, the highest and lowest value of soil pH were noticed in N E 80-LCC and FFP treatments, respectively. The OC content among the different tillage practices, highest soil organic carbon status after wheat crop harvest (0.44%) was obtained in zero tillage which remained at par with reduced tillage but significantly higher than rest of the treatment. The lowest soil organic carbon status after wheat crop harvest was observed in conventional tillage than rest of tillage techniques during the year of study. Pronounced effect of precision nitrogen application through inorganic sources was observed on the soil organic carbon status after wheat crop harvest during the year of experimentation. The highest value of soil organic carbon status after wheat crop harvest was noticed in NE 80-LCC which remained at par with N E 33:33:33 treatment but significantly higher than rest of treatments. The lowest value of soil organic carbon status after wheat crop harvest was noticed in FFP treatment.

Impact of tillage crop establishment methods and precision nitrogen management on Buildup of Nutrient Status of Soil Available Macronutrients (N, P, and K)

The data presented in Table 2 (Fig-2.) illustrated that the among the different tillage practices, highest nitrogen status after wheat crop harvest (219.72 kg/ha) was obtained in ZT, which remained at par with RT but significantly higher than rest of the treatments. The significantly lowest value of available nitrogen in soil after wheat crop harvest was observed in CT tillage than rest of tillage techniques during the year of study. Pronounced effect of precision nitrogen application through inorganic sources was observed on the nitrogen status after wheat crop harvest during the year of experimentation. The highest value of nitrogen status after wheat crop harvest was noticed in NE 80-LCC which was significantly higher than rest of treatments. The significantly lowest value of nitrogen status after wheat crop harvest was noticed in FFP treatment.

The data mentioned in Table 2 (Fig-2.) revealed that among the different tillage practices, highest phosphorus status after wheat crop harvest (15.50 kg/ha) was obtained in ZT, which was significantly higher than rest of the treatment. The significantly lowest phosphorus status after wheat crop harvest was observed in CT than rest of tillage techniques during the year of study.

The data presented in Table 2 (Fig-2) illustrated that among the different tillage practices, highest potassium status after wheat crop harvest (245.60 kg/ha) was obtained in ZT, which was significantly higher than rest of the treatment. The significantly lowest potassium status after wheat crop harvest was observed in CT than rest of tillage techniques during the year of study. In case of precision nitrogen management highest value of potassium status after wheat crop harvest was noticed in NE 80-LCC which remained at par with N E 33:33:33 treatment but significantly higher than rest of treatments. The lowest value of potassium status after wheat crop harvest was noticed in FFP treatment.

Impact of tillage crop establishment methods and precision nitrogen management on Partial Factor Productivity (PFP) of nutrient applied in wheat

The data presented in Table 3 (Fig-3) illustrated that the maximum value of to PFP of nitrogen fertilizer was noticed in FIRB treatment which was significantly higher than rest of the tillage practices. The significantly lowest value of PFP of nitrogen fertilizer was observed in CT. Among PNM practices, significantly higher PFP of nitrogen fertilizer was obtained in N E 80-LCC based nutrient management.

Discussion

Impact of tillage crop establishment methods and precision nitrogen management on different Properties of Soil.

Perusal of the data on fertility status of the study area revealed that, soil pH values varied from 7.15 to 7.27 indicating the soils were neutral to slightly alkaline in reaction. The electrical conductivity varied from 0.21 to 0.25 dS m^{-2} indicating the soils were normal with respect to salinity. The organic carbon content of the soils ranged from 0.40 to 0.44 per cent and was in low range. Low organic carbon in the soil was due to low incorporation of crop residues as well as rapid rate of decomposition due to high temperature. Similar result has been reported by Meena *et al.* (2020) [9]. The organic matter degradation and removal taken place at faster rate coupled with low vegetation cover thereby leaving less changes of accumulation of organic matter in the soil. Nutrient status of the soil indicated that the entire study area was low in available nitrogen (210.4 to 220.5 kg ha^{-1}) which might be due to low organic matter content in the soil. With respect to available phosphorus (14.1 to 15.9 P_2O_5 kg ha^{-1}), were medium in range. The possible reasons for low available nitrogen and phosphorus could be intensive rice-wheat cropping system followed in last four years of experiment. Available potash status (237.40-246.3 K_2O kg ha^{-1}) was medium after experimentation.

Impact of tillage crop establishment methods and precision nitrogen management on Partial Factor Productivity (PFP) of nutrient applied in wheat

More efficient nutrient use (e.g. PFP) of applied nitrogen on furrow irrigated raised beds and zero tillage than other tillage was probably due to improved conservation of moisture under furrow irrigated raised beds and zero tillage, as this could have facilitated the uptake of plant nutrients. Formation of a layer of crop residues on the soil surface under no tillage system minimizes water loss through evaporation (Sapkota, 2012) [14] which enhances higher growth rate of crop leading to higher rates of nutrient uptake. Better nutrient use efficiency of applied nutrients according to NE recommendation than farmers' practice indicates that location-specific nutrient application rates and better nutrient application timing are important (i.e. more number of splits and matching physiological demand of the crops) nitrogen losses were minimized and improved nutrient efficiency. There was a small difference in nitrogen PFP between NE-based applications and state recommendations but a significant difference between NE-based applications and farmers' practice indicates nutrient use efficiency of nitrogen was predominantly improved by potassium application combined with a better nitrogen rate split. Farmers are generally not using a K fertilizer for the production of wheat, which results in a disrupted management of fertility, which ultimately reduces the efficiency of other nutrients. Systematic approach of NE to capture site information thus improves nutrient use efficiency by providing location specific recommendation considering the crop's nutrient requirement and inherent soil nutrient supplying capacity (Pampolino *et al.* 2012) [11]. As a result, the findings clearly showed that precision nitrogen management and tillage practices on wheat production can significantly improve the partial factor productivity of applied nutrients.

Table 1: Effect of tillage crop establishment methods and precision nitrogen management on physical properties (EC & pH) after wheat crop harvest

Treatments	EC (dSm^{-1})	pH	Organic Carbon (%)
Tillage crop establishment methods (TCEM)			
T_1 - ZT	0.22	7.15	0.44
T_2 - RT	0.23	7.24	0.43
T_3 - FIRB	0.23	7.26	0.41
T_4 - CT	0.24	7.25	0.40
S.Em±	0.003	0.03	0.002
C D (P=0.05)	0.01	N.S.	0.008
Precision nitrogen management(PNM)			
F_1 - N 80:20	0.21	7.21	0.42
F_2 - N E 33:33:33	0.22	7.26	0.43
F_3 - NE 80-LCC	0.23	7.27	0.4
F_4 - SR 50:50	0.24	7.20	0.41
F_5 - FPP	0.25	7.18	0.40
S.Em±	0.001	0.03	0.002
C D (P=0.05)	0.01	N.S.	0.006
Initial value	0.21	7.46	0.43

ZTW- Zero tillage, RT-Reduced tillage, FIRB-furrow irrigation raised bed, CTW-Conventional tillage, LCC-leaf color chart, SR-straight recommendation, NE-nutrient expert, FFP-farmer fertilization practices

Table 2: Available nitrogen, phosphorus, potassium in soil after wheat harvest as influenced by tillage and precision nutrient management practices

Treatments	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Tillage Crop establishment methods (TCEM)			
T_1 – ZT	219.7	15.5	245.6
T_2 – RT	218.1	15.2	243.4
T_3 – FIRB	214.4	14.1	240.8
T_4 – CT	210.4	14.5	237.4
S.Em±	0.75	0.06	0.52
C D (P=0.05)	2.59	0.17	1.82
Precision nitrogen management(PNM)			
F_1 - N 80:20	215.0	15.2	241.5
F_2 - N 33:33:33	216.8	15.5	244.3
F_3 - NE 80-LCC	220.5	15.9	246.3
F_4 - SR 50:50	214.3	14.5	239.5
F_5 - FFP	211.7	14.4	237.5
S.Em±	0.62	0.07	0.82
C D (P=0.05)	1.79	0.22	2.36
Initial value	221.6	15.6	240.5

ZTW- Zero tillage, RT-Reduced tillage, FIRB-furrow irrigation raised bed, CTW-Conventional tillage, LCC-leaf color chart, SR-straight recommendation, NE-nutrient expert, FFP-farmer fertilization practices

Table 3: Effect of tillage crop establishment methods and precision nitrogen management on Partial Factor Productivity (PFP) of nitrogen applied in wheat

Treatments	PFP (kg grain/kg nitrogen applied)
Tillage Crop establishment methods (TCEM)	
T_1 – ZT	38.6
T_2 – RT	37.8
T_3 – FIRB	40.1
T_4 – CT	36.9
S.Em±	0.1
C D (P=0.05)	0.4
Precision nitrogen management (PNM)	
F_1 - N 80:20	37.5
F_2 - N 33:33:33	39.5
F_3 - NE 80-LCC	40.7
F_4 - SR 50:50	37.4
F_5 - FFP	36.5
S.Em±	0.2
C D (P=0.05)	0.5

ZTW- Zero tillage, RT-Reduced tillage, FIRB-furrow irrigation raised bed, CTW-Conventional tillage, LCC-leaf color chart, SR-straight recommendation, NE-nutrient expert, FFP-farmer fertilization practices

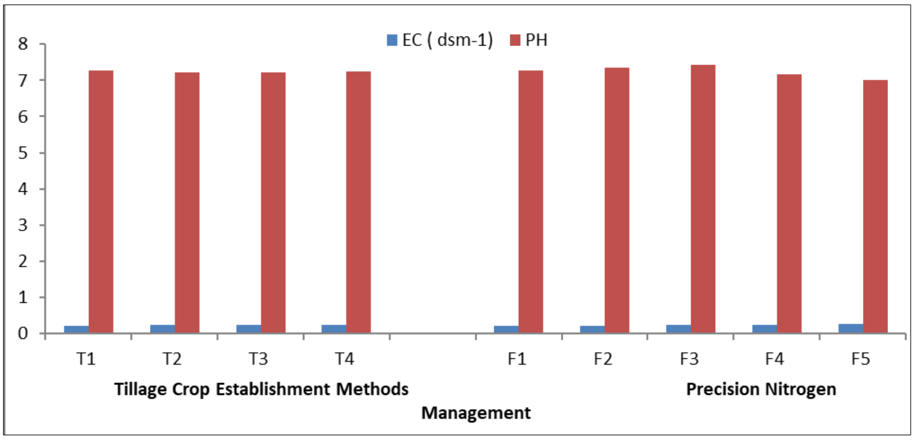

Fig 1: Effect of tillage and precision nutrient management practices on soil physical properties after wheat crop harvest

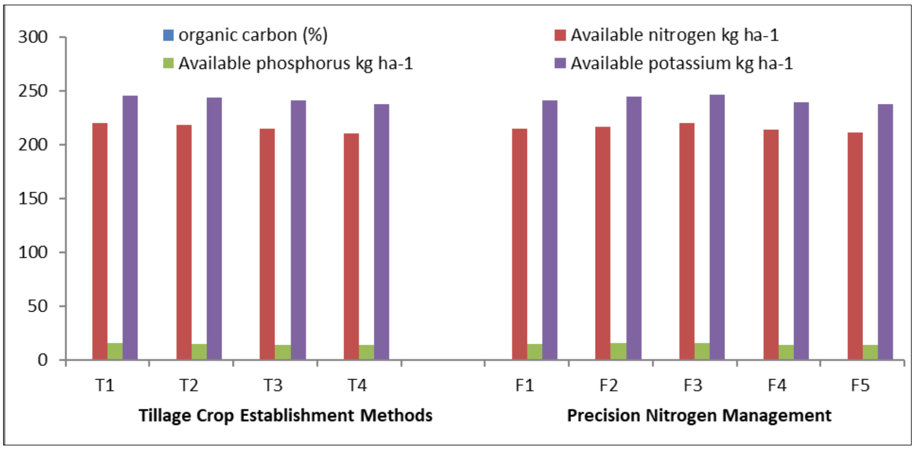

Fig 2: Effect of tillage and precision nutrient management practices on soil organic carbon, nitrogen, phosphorus, potassium status after wheat crop harvest

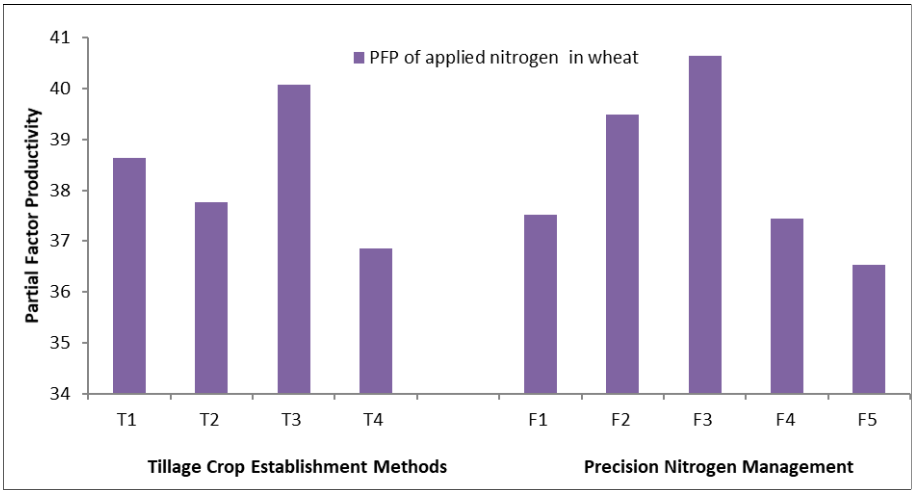

Fig 3: Effect of tillage crop establishment methods and precision nitrogen management on Partial Factor Productivity (PFP) of nutrient applied in wheat

Conclusions

From the present study, it may be concluded that the wheat use of furrow irrigated raised bed system along with application of nutrient as N E 80-LCC seems to best combination for achieving good physical parameters, nitrogen uptake, nitrogen content, nutrient use efficiency and improving soil health under north western plain zone of Uttar Pradesh.

Furthermore, wheat production under the tillage systems can be carbon neutral if NE-based recommendations are supplemented with leaf colour chart guided nutrient management. For wheat production in North-West India, this combination of tillage and nutrient management strategy can be recommended to increase yield, efficiency, and profitability in addition to reducing agriculture's contribution to climate change.

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