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Precision nitrogen-management practices and efficient planting system influences crop-water productivity, grain quality and profit of wheat (*Triticum aestivum* L) in *inceptisol*

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Abstract
The challenge that the world is facing has been to maximize food production to feed the increasing population. Further, agriculture at present encompasses many problems such as stagnating food-grain production, multi-nutrient deficiency, declining fertilizer response, reduction in land availability for cultivation, environmental pollution and land degradation. To manage long term soil fertility, productivity as well as environment quality, efficient nutrient management practices integration can be the most efficient planting practices to adopt. Therefor a field experiment was conducted during 2016-17 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.). The treatments comprised of all possible combinations of the two factors *viz.*, efficient planting techniques (05) as main plot factor and precision nitrogen management strategies (05) as sub plot factor and replicated thrice. Experimental results revealed that the yield attributes number of grains spike^{-1}, spike length (cm), numbers of spikelet spike^{-1} and test weight increased significantly in FIRB plots. The improvement in grain yield 28.9 and 23.2% due to land configuration under FIRB and zero tillage plots, respectively over roto till practices. The FIRB and zero tillage increased the water productivity of 29.2 and 16.2% over conventional, reduced and roro tillage treatments. Among precision N management practices, targeted yield and SPAD produced significantly higher nitrogen and potassium partial factor productivity. Target yield based N management resulted significantly higher agronomic efficiency, apparent recovery and physiological efficiency but nitrogen physiological efficiency in SPAD. The yield attributes and grain yield were significantly higher in nitrogen management F_3 and F_5 (SPAD and LCC), over rest of nitrogen management. The highest net return (Rs.54685) was obtained with ZTW> FIRB> RT> CTW> RTW. Among different precision nutrient management practices maximum net return (Rs.58865) was found in targeted yield which is very similar with SPAD (Rs. 52970). Moreover, Net return was obtained with targeted yield >SPAD>LCC>100% RDF>control. However, benefit cost ratio was found to be highest (1.75) with targeted yield which also closely with SPAD (1.65) and lowest with control (1.07). The results suggest that FIRB and ZT with targeted yield and SPAD based nitrogen management were optimum and sustainable strategy to achieve higher yield and also to improve water productivity and profitability in *inceptisol* soil of western Uttar Pradesh.

Keywords: Tillage, SPAD, LCC, productivity, profitability

Introduction
Wheat (*Triticum aestivum* L), a major cereal crop is being cultivated in the country. The main reasons for its low productivity are poor crop establishment and imbalance fertilizer management. Amongst the other agronomic practices proper crop establishment practices may considerably increase the production of wheat to some extent. It is also well known fact that nitrogen management is one of the major factors responsible for achieving better harvest in crop production. Both crop establishment practices and precision nitrogen management are major causes of yield reduction in wheat, which also affect its productivity. Bread wheat (*Triticum aestivum* L) is the most important staple food of about 36% of the world population. India is the second largest wheat producing country after China with an area of 29.64 million hectares, production of 92.46 million tones and average productivity of 3.12 tha^{-1} (Anonymous, 2016) [2]. Uttar Pradesh ranks first in area (36.6%) and production (39.3%) of wheat in the country. Out of 100 leading wheat producing districts (each with more than lakh tones of production), 43 belong to Uttar Pradesh and of them 19 to the western part of the state in particularly wheat productivity is far lower than Panjab and Haryana. Since the mid-1980s, wheat yield in India has either declined or stagnated (Duxbury *et al*., 2000) [9].

This is because of late sowing of wheat due to long duration rice varieties and late harvest of sugarcane, poor seed replacement rate, lack of quality seed at right time and place, lack of inputs (fertilizers, irrigation water) due to limited resources and small holding size and poor mechanization, etc.

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% and affects the sustainable use of soil resources through its influence on soil properties Lal and Stewart, (2013) [15]. The judicious use of tillage practices overcomes edaphic constraints, whereas inopportune tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient. Naresh *et al*. (2013) [19] also found that infiltration was more closely related to pore continuity than to porosity. Field experiments with zero tillage in wheat at several locations in the Indo- Gangetic plains have shown encouraging results (Chaudhary and Singh, 2013) [19]. Farmers have found direct drilling of wheat into post rice systems without tillage feasible and beneficial at several locations. Wheat yields with zero tillage are either equal or even better than those obtained with conventional tillage because of timely planting of wheat, efficient use of fertilizers and weed control. In addition, zero tillage is fuel and energy efficient but also reduces greenhouse gas emissions (Toby *et al*., 2016) [24]. Zero tillage systems conserve the land resource and are cost effective and efficient. Moreover, this tillage system also avoids challenges with clod formation. *Monsefia et al.* (2016) [18] found that furrow-irrigated raised-bed planting system (FIRBS) is a form of tillage wherein sowing is done on raised-beds. This optimizes tillage operation, saves water, reduces lodging, and ensures better fertilizer use. Aziz *et al*. (2013) [4] found no-tillage and reduced tillage systems were most profitable due to saving of labour, time, water and energy costs. There are several reports showing savings in irrigation water, labour and production costs, and higher net economic returns in no tillage and reduced tillage compared with conventional tillage systems.

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) [10]. However, insufficient N availability to wheat plants results in low yields and significantly reduced profits compared to a properly fertilized crop. Efficient nutrient-management practices 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 through effective nutrient-management practices requires knowledge of the interactions between the soil, plant and environment. The use of some tools for in season N management i.e. Soil Plant Analysis Development (SPAD) chlorophyll meter, leaf colour chart (LCC) and targeted yield based in fulfilling the crop nutrient requirement with less environmental footprints (Kumar *et al*., 2014) [13]. Keeping this in view, the available tools i.e. SPAD, LCC and Targeted yield based were tested in wheat in this study for precision nutrient management under efficient planting methods which was grown in rotation with rice.

Materials and Methods

Experimental site: A field experiment was conducted on sandy loam soil during the winter (*rabi*) season 2016–17 at the crop research centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut U.P. (29^0 08', N latitude and77^0 41' ‘E longitude a height of 237m above mean sea level). The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8 ^{0}C. The mean weekly minimum temperature records as low as 4.3 ^{0}C in 2nd week of January. Whereas, mean weekly maximum temperature reaches as high as 36.9 ^{0}C in 4th Week of April.The average annual rainfall is 765 mm, 75 to 80% of which is received through the southwest monsoon during July to September. The predominant soil at the experimental site is classified as *Typic Ustochrept*. Soil samples for 0–20 cm depth at the site were collected and tested prior to applying treatments and the basic properties were non-saline (EC 0.42 dS m^{-1}) but mild alkaline in reaction (pH 7.98). The soil initially had 4.1 g kg^{-1} of SOC and 1.29 g kg^{-1} of total N (TN), 1.23 g kg^{-1} of total phosphorus, 17.63 g kg^{-1} of total potassium, 224 mg kg^{-1} of available N, 4.0 mg kg^{-1} of available phosphorus, and 97 mg kg^{-1} of available potassium.

Treatment details

A detailed description of crop establishment methods are necessary to compare the influence of land configuration practices on environmental performance (Derpsch *et al.*, 2014) [8]. The experiment was laid down in split plot design with three replications, keeping planting techniques as main plot and precision nitrogen management practices as sub-plots. The treatments comprised of five main plots; 1) planting techniques *viz.* zero tillage (ZTW)-T_1, reduced tillage (RT)-T_2, rotavator tillage (RTW)-T_3, furrow irrigated raised beds (FIRB)-T_4, conventional tillage (CTW)-T_5, and five sub-main plots were of precision nitrogen schedules *viz.* Control ($N_0P_0K_0$) - F_1, RDN (150: 75: 60 N: P_2O_5:K_2O kg /ha) - F_2, SPAD (75: 75: 60 N: P_2O_5: K_2O kg/ha), as basal and rest N as SPAD reading on 37 & 79 DAS, respectively- F_3, Targeted yield 5.5 t/ha (170: 75: 60 N: P_2O_5:K_2O kg /ha)- F_4 and Leaf Color Chart (75: 75: 60 N: P_2O_5: K_2O kg /ha), as basal and rest N as LCC reading on 35,49 & 63 DAS)- F_5.

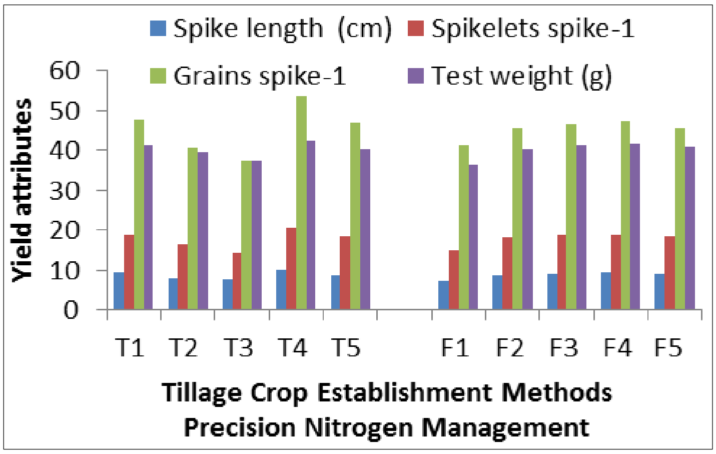
Fertilizers application

In experiment, 150:75:60 (kg ha^{-1}) nitrogen, phosphorus and potassium, respectively was applied under recommended NPK. While, in targeted yield plot nitrogen, phosphorus and potassium was applied based on the inorganic equation in NCR of Delhi [170:75:60 (kg ha^{-1})]. Further, 75:75:60 (kg ha^{-1}) nitrogen, phosphorus and potassium, respectively was used SPAD and LCC and rest nitrogen was applied as per SPAD at 37, and 79 DAS and LCC values recorded at 35, 49 and 63 DAS, respectively. Half dose of N and full dose of P and K were applied as basal at the time of seeding through zero till cum multi crop raised bed planter with inclined plate seed metering device and traditional seed drill. Remaining half N was top dressed in two equal split doses; first split before 1st post-sowing irrigation at crown root initiation stage and the second split before 3rd irrigation at pre-flowering stage, except LCC and SPAD plot where three times top dressing were carried out as per the threshold values of SPAD (30 kg ha^{-1}) and LCC (25 kg ha^{-1}).

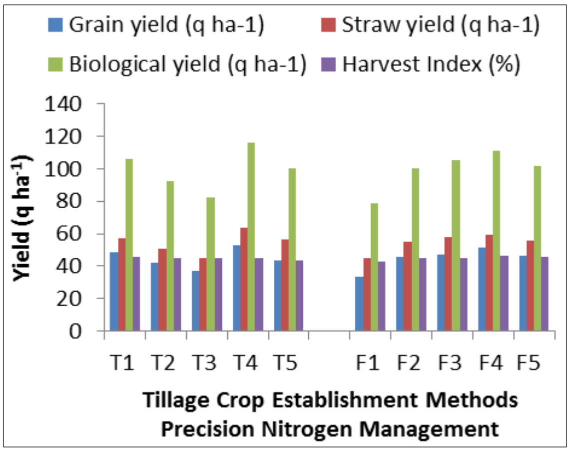
Crop management
Wheat variety DBW-17 was seeded at 100 kg seed ha^{-1} at 20-cm row spacing in conventional tillage, reduced tillage and zero tillage treatments and 80kg seed ha^{-1} in FIRB plots. To control weeds in the experimental field Clodinafop 15% WP was used @ 400 g ha^{-1} 30 DAS. All the growth and yield attributes were recorded using standard procedure and grain yield was calculated at 12% moisture content.

Statistical analysis
All the data recorded were analyzed by analysis of variance technique (ANOVA) using the Statistical Analysis System (SAS Institute, 2001). The comparison of treatment means was made by the least significant difference (LSD) at 5% probability (p=0.05).

Results and Discussion
Data on various yields attributing characters *viz*. spike length, spikelet's spike^{-1}, number of grains spike^{-1}, and test weight, as influenced by tillage-cum-crop establishment methods and different precision nitrogen management are presented in (Fig.1a) revealed that treatment T_4 FIRB tillage crop establishment practices influenced significantly higher spike length followed by ZTW>RT>CTW>RTW. Furrow irrigated raised beds; FIRB (F_4) attained more spikelet's spike^{-1}, number of grains spike^{-1}, and test weight as compared to rest of the treatments. However, they followed closely by ZTW thereafter RT>CTW, respectively. Precision nitrogen strategy had a significant effect on yield attributes. Treatments F_1 and F_2 produced significantly lower average spike length, spikelet's spike^{-1}, number of spikelet's spike^{-1} and test weight as compare to rest of the treatments. Moreover, treatment F_4 produced significantly greater number of spikelet's spike^{-1}, number of spikelet's spike^{-1} and test weight as compared to all treatments except F_3 and F_5 (Fig.1a). The better growth parameters wheat resulted in enhanced photosynthesis and thus gave higher targeted yield (F_4). Similar results were also reported by Mauriya *et al*. (2013) [17]; Naresh *et al*. (2013) [19] where all the yield-attributing characters in wheat were found better with site-specific crop management. Crop yield under T_4 FIRB and T_1 ZTW were at par and significantly superior over other tillage crop establishment practices. However, T_5 CTW was significantly superior over remaining treatments. T_2 and T_3 were at par and lowest yield was obtained under T_3 roto tillage (Fig.1b). The grain yield of wheat was increased significantly by targeted yield (F_4) to the tune of 10.6, 12.2 and 34.6% over LCC, RDF and absolute control, respectively (Fig1b). The higher grain yield in FIRB was mainly due to higher number of productive tiller's and number of grains spike^{-1} as compared with zero tillage. Bilalis *et al*. 2011 [5] and Naresh *et al*, (2012) [20] reported that the yield per hectare was primarily improved due to better nutrient supply, less penetration resistance impedance which responsible for better root development and its beneficial effect on the per plant yield. The grain yield per plant improved with increased nutrient supply mainly through improvement grains spike^{-1}, number of spikelet spike^{-1} and test weight.
The wheat yield revealed that the crop responded significantly to different levels of nitrogen application as compared to control. Data generated from the present field study clearly indicated that significant (P=0.05) increase in straw yield of wheat with increasing in N level significantly up to (targeted yield, SPAD, LCC, and RDF) which was 26.4% over control. Maximum straw yield was recorded (59.4qha^{-1}) with targeted yield and it was significantly superior all over the treatment except SPAD based N management (F_3). The lowest value of straw yield was recorded with unfertilized "control" (F_1) plots (Fig.1b). The straw yield of wheat was significantly increased by the effect of nitrogen management which increased the fertilizer use efficiency and improved the physical and chemical properties of soil hence making better utilization of nutrients might also be a reason towards increased yield. Similar results were reported by Chuan *et al*. (2013) [7]; Pampolino *et al*. 2012 [16]. The harvest index per cent had shown no definite trend. However, treatments under T_1 zero tillage and T_2 reduced tillage practices performed higher values of harvest index.



(a)

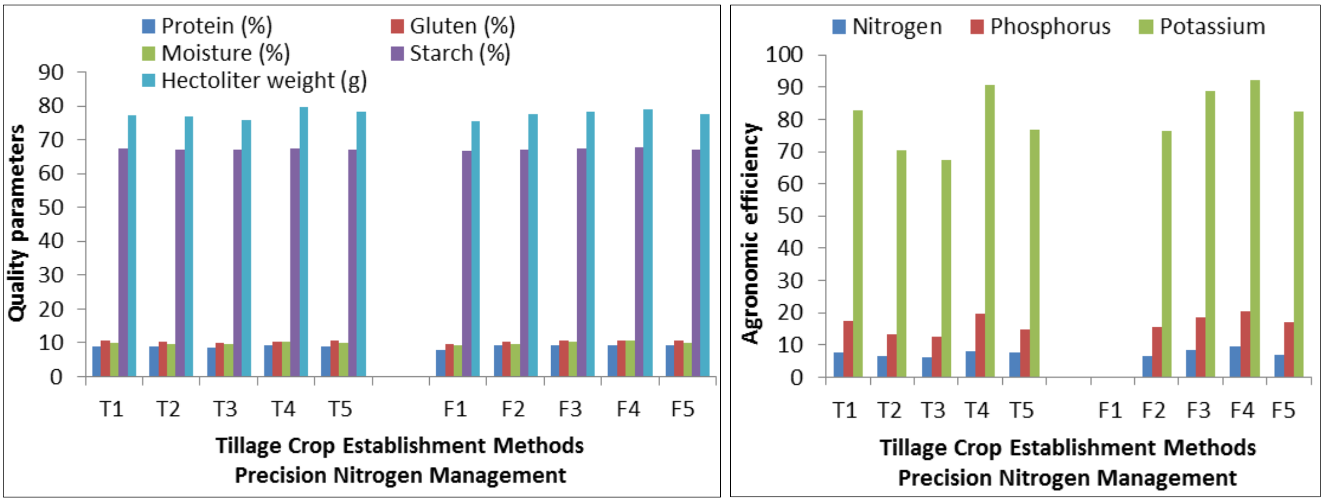


(b)

Fig 1: Effect of efficient planting methods and precision nitrogen management on (a) yield attributes and (b) yield of wheat crop

Grain Quality parameters
Efficient planting techniques had significant effects on grain protein %, Gluten % and Hectolitre weight under zero and reduced tillage as shown in Fig 2a. In general, protein % and Gluten % and Hectolitre weight tin the following order: T_4 FIRB>T_1 ZTW>T_2 RT>T_5 CTW and >T_3 RTW during experimentation. Precision Nitrogen strategies targeted yield (F_4) had significantly higher Gluten % and Hectolitre weight as compared to all other treatments except SPAD based N management. However, F_3 and F_2 were at par at with each other and recorded higher Gluten % and Hectolitre weight than F_1 unfertilized "control" plots the year of study (Fig.2a). Similar result have been reported by Ram *et at.* (2013).

Agronomic efficiency in wheat was significantly influenced by different tillage crop establishment management and precision N management practices (Fig.2b). Significantly higher nitrogen, phosphorus and potassium agronomic efficiency was obtained with FIRB (T_4) whereas lowest was found with roto till (T_3) plots. Figure 2b clearly shows that conservation agriculture practices resulted in significantly higher nitrogen, phosphorus and potassium agronomic efficiency because of higher grain yield produced by FIRB (T_4) followed by zero till (T_1), reduced till (T_2) and conventional till (T_5) plots. Similar result have been reported by Ali *et al.* (2012) [1].



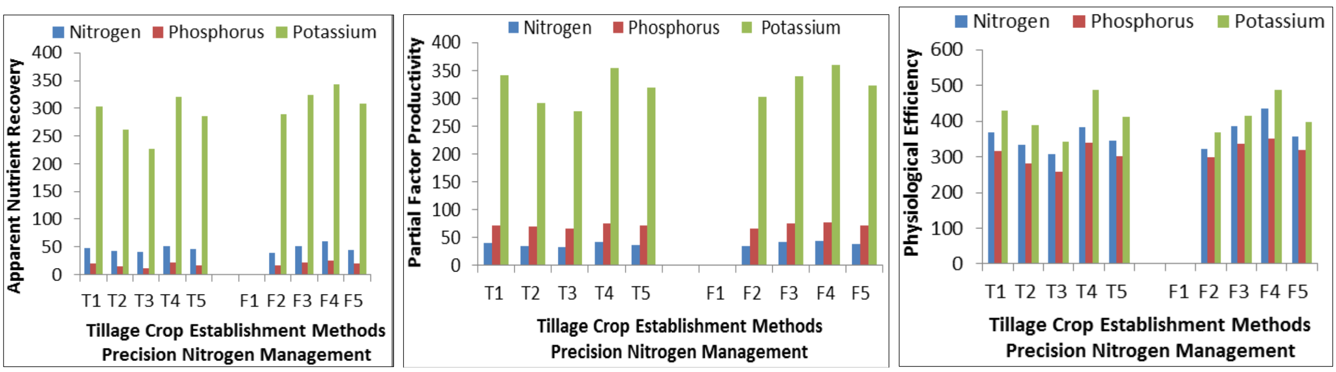
(a) (b)

Fig 2: Effect of efficient planting methods and precision nitrogen management on (a) quality parameters and (b) agronomic efficiency of nutrient applied in wheat crop

Nutrient Efficiencies

Apparent nutrient recovery in wheat was significantly influenced by different tillage practices and precision N management practices depicted in Fig. 3a. Efficient planting techniques FIRB obtained significantly higher nitrogen, phosphorus and potassium apparent recovery followed by zero tillage plots. Because of different tillage practices more availability of nutrients by FIRB, significantly higher apparent recovery (% nutrient applied) was obtained as all of these nutrients are synergistic in nature. Among precision N management practices target yield based nitrogen management resulted significantly higher apparent recovery (N, P & K). However, nitrogen apparent recovery was found at par with SPAD. The partial factor productivity (PFP) of any nutrient shows the direct increase in yield with its application. It was in order of K> P > N. PFP in wheat was significantly influenced by different tillage practices and precision N management practices (Fig.3b). Significantly higher nutrient partial factor productivity (N, P & K) was obtained with FIRB plots. Among precision N management practices, significantly higher nitrogen PFP was obtained by targeted yield based, while significantly higher phosphorus PFP was found by SPAD and LCC over RDF and significantly higher potassium PFP was found with SPAD over LCC and RDF, respectively.

Significantly higher nitrogen and phosphorus physiological efficiency was obtained with FIRB. The potassium physiological efficiency was not significantly influenced by different tillage practices; however, potassium physiological efficiency was found highest with FIRB (Fig.3c). It shows clearly that properly availability of nutrient under FIRB increased physiological efficiency significantly. Among precision N management practices, targeted yield approach produced significantly higher nitrogen physiological efficiency and SPAD produced significantly higher phosphorus and potassium physiological efficiency, respectively. Pasuquin *et al.* (2010) [23] also found that precision N management based practices increased the agronomic efficiency of N fertilizer by 53% compared to the FFP and led to large gains in N use efficiency. Yard stick value (kg of grain kg^{-1} of nutrient applied) was higher targeted yield approach in wheat over general recommended dose and control, which was reported by Keram *et al.* (2012) [12]; Kumar *et al.* (2018) [13].



(a) (b) (c)

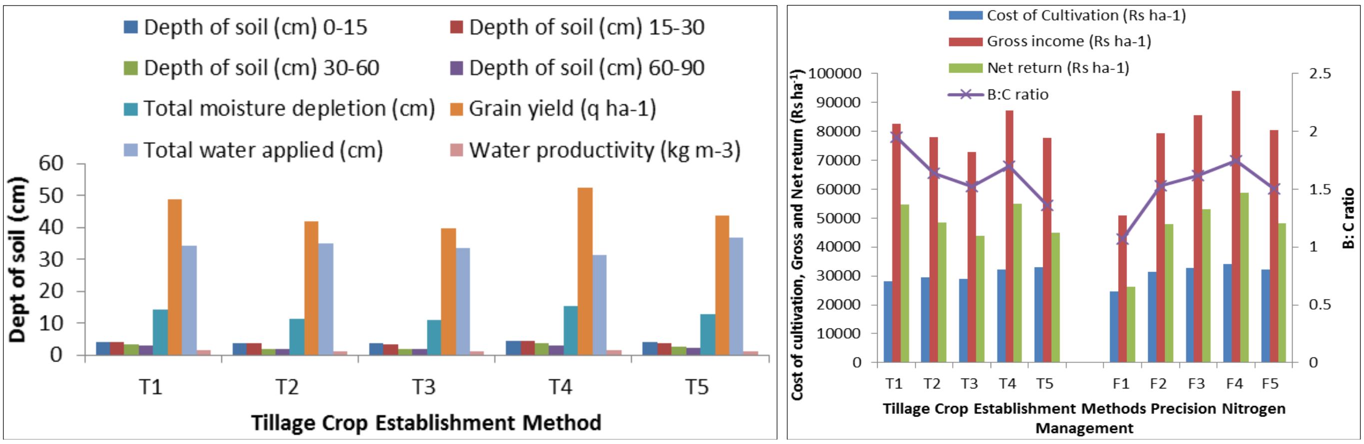
Fig 3: Effect of tillage crop establishment methods and precision nitrogen management on (a) apparent nutrient recovery, (b) partial factor productivity and (c) physiological efficiency of applied nutrient in wheat crop

Moisture extraction pattern and water productivity

The data on soil profile moisture extraction pattern of wheat crop under different irrigation levels and tillage practices treatments revealed that the soil profile was divided in four layers (0-15, 15-30, 30-60 and 60-90 cm) and the maximum amount of water was extracted (absorbed) from 0-15 cm layer followed by 15-30 cm and 30-60 cm. However, minimum water was extracted from 60-90 cm during the year of study. The moisture extraction from the surface layer (0-15 cm) was increased slightly with increase in land configuration during the year of study. The land configuration furrow irrigated raised beds plots stored more moisture from the deeper profile layer than flat planting practice and vice-versa during the year of experimentation (Fig. 4a).

In general, the profile moisture content was highest at the time of sowing (21%) and it was lowest at the time of crop maturity in all the treatments during the year of study. The increases in profile moisture content are visible from the peaks under tillage practices different were because of moisture conserved due to land configuration as per treatments. The moisture content of conventional tilled plots (T_5) was always lower than zero and reduced till plots (T_1 & T_2) during the year of study except in the peaks where the moisture content in the profile was always same due to recharging of profile by application of irrigation. The conventional till crop kept the average profile soil moisture content 1.5% lower than zero till plots throughout the crop season except after recharging the soil profile either by application of irrigation or by rainfall (Fig.4a). The highest total moisture depletion (15.5 cm) from each layer was observed under FIRB method of sowing as compare to other seeding methods, ZTW (T_1), CT (T_5), RT (T_2), and RTW (T_3), due to more availability of moisture in rhizospher. The amount of moisture depleted decreased with the soil depth due to lower density of roots in deeper layer compared with the upper layer. Due to increased surface evaporation the percentage contribution of upper 30 cm layer was more. The highest moisture depletion under the FIRB method might be due to less availability of moisture at upper layer and more evaporation from upper surface. Similar results have been reported by Naresh *et al.* (2013) [19]; Ram *et al.* (2013).

The crop water use increased markedly in conventional till plots (T_5) than zero till and FIRB plots (T_1 & T_4) during the year of study. The water productivity increased with the increased yield and less water use during experimentation. The WP was remarkably low in conventional till plots crop (T_5) than FIRB, zero and reduced till crop plots (T_4, T_1 & T_2) during the year of study. The maximum water productivity was registered (1.68kg m^{-3}) under FIRB (T_4) land configuration, followed by ZTW (T_1) > RT (T_2), CT (T_5)> RTW (T_3), treatments during the year of study. Increase in water productivity under FIRB based on the fact that the proportionate increases in grain yield with lesser number of irrigation water during experimentation (Fig.4a).



(a) (b)

Fig 4: Moisture depletion pattern, total water applied and water productivity (a) as influenced by tillage crop establishment methods and precision nitrogen practices on profitability (b) of wheat crop

Profitability

The cost of cultivation of wheat crop increase with precision nitrogen practices and increase was very nominal during the year of study (Fig.4b). Among the tillage practices the cost of cultivation was highest in T_5 conventional tillage followed by FIRB (T_4) and it was lowest in zero tillage practices plots. Among the different tillage practices the highest net profit and B: C ratio was recorded in (T_1) wheat sown with zero till practice. This may be because of higher water use efficiency than other tillage practices as well as comparatively higher increase in grain yield than in other treatment except FIRB plots. The minimum net profit, gross income, B: C was observed in (T_3 & T_5) roto till and conventional tillage treatments during experimentation. From the above results it is clear that increase in nitrogen level increased the available nutrient in soil, which may be attributed to increase the cost of cultivation, gross income, net profit and B:C ratio because of more increase in grain yield and gross income in comparison to increase in cost of cultivation. Similar results were also reported by Kumar *et al.* (2014) [14]; Ashish *et al.* (2017) [3].

The data acquired from the wheat experiment revealed that efficient planting techniques and precision nitrogen management had significant effects, of varying magnitude, on yield attributes and yield, nutrient efficiencies, grain quality, water productivity and profitability. Furrow irrigated raised beds and Zero tillage resulted in markedly higher yield attributes and yield, nutrient efficiencies, grain quality, water productivity and profitability than the conventional tillage, and it could be a suitable management strategy to improve or restore crop-water productivity. Under the efficient planting techniques and precision nitrogen management system, targeted yield practice was most effective for improving yield attributes and yield and grain quality, followed by SPAD based nitrogen management, and then LCC and recommended nitrogen management practices. Thus, application of nitrogen fertilizer in optimum amounts and inclusion of efficient planting strategy in the precision nitrogen schedule could maintain the crop-water productivity under intensive agriculture. In conclusion, Nitrogen plays a significant role in productivity with co-benefits of improved grain quality and profitability in *inceptisol* soil inherently low in organic matter and nutrients.

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