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Effects of conservation tillage and nitrogen management on soil properties, crop productivity and nitrogen use efficiency of irrigated rice under North West India

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Abstract
Management practices that simultaneously improve soil properties and yield are crucial to sustain high crop production and minimize detrimental impact on the environment. The objective of this study was to determine the influence of tillage and crop nitrogen management on crop yield, N uptake and nutrient use efficiency. Rice is predominant in *Typic Ustochrept* soil of North West India. A two year field experiment was conducted to assess the effect of three tillage systems [conventional tillage (CT), furrow irrigated raised beds (FIRB) and reduced tillage (RT) and five rates of fertilizer N (0, 80, 120, 160 and 200kgNha^{-1}) in rice crop was laid out in split plot design with three replication. Results indicated that the productivity of rice was significantly different in tillage systems. Response of fertilizer N was influenced by tillage systems, and crop response to fertilizer N was generally observed up to 160 kg N ha^{-1}. Amount of N uptake in rice generally increased with N rate, but tillage had no consistent effect. An improvement in selected soil physical properties like bulk density, stable aggregate size classes, infiltration rate, electrical conductivity and soil penetration resistance was recorded in FIRB, and RT than in CT. The size distributions of aggregates were also significantly influenced by tillage practices. Small macro-aggregates comprised the greatest proportion of the whole soil, followed by aggregates <0.106 mm in the 10–20 cm soil layer. Subsurface soil (10–20 cm depth) had 34% lower macro-aggregates than micro-aggregates. The percentage of water-stable aggregates of the largest size class (>2 mm) in FIRB plots at depth of 0 to 10, 10 to 20, and 20 to 30 cm was approximately twice the percentage under CT but significant only below the 10-cm soil layer indicating less potential for soil erosion when tillage was omitted. It is concluded that furrow irrigated raised beds i.e. wide raised beds systems with 160 kg N ha^{-1} would be a suitable practice for sustainable production of rice crop in *Typic Ustochrept* soil of North West India.

Keywords: conservation tillage, nitrogen fertilization, soil physical properties, productivity

Introduction
The world entered in the 21st century facing many challenges, often in an agricultural context. Prominent still is the concern for feeding an ever growing population with safe and healthy food and management of natural resources such as land, water, nutrients and energy etc. Rice occupying 163.20 million hectare of area, producing 719.73 million tonnes of rough rice with an average productivity of 4.41 tonnes ha^{-1}. Its cultivation is of immense importance to food security of Asia, where more than 90% of the global rice is produced and consumed. In India, it is cultivated on an area of 42.75 million hectare which is maximum among all rice growing countries having annual production about 105.24 million tonnes and productivity of 2.46 tonnes ha^{-1} and contributes to 15% of annual GDP (Anonymous, 2013-14) [3]. India's rice demand is estimated to rise to 122 million tons in 2020, which is equivalent to an overall increase of 22% in the next 10 years. Scented rice (*Oryza sativa* L.) cultivation is emerging as a new economic pursuit for the paddy farmers in some localities of Uttar Pradesh.

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al*., 2006, Naresh *et al*. 2015) [16, 19, 20] and affects the sustainable use of soil resources through its influence on soil properties (Lal and Stewart, 2013) [18]. Reducing tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al*., 2005) [4]. Conventional tillage practices cause change in soil structure by modifying soil bulk density and soil moisture content. In addition, repeated disturbance by conventional tillage gives birth to a finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact (Naresh *et al*., 2016) [21]. With time, conservation tillage, on the other hand, improves soil quality indicators (Cook and Trlica. 2016) [6].

Soil (land) health degradation is another such problem, especially in intensive agriculture including in North West India. Physical and biological deteriotion of land with associated fertility depletion occurs due to poor agronomic management, water logging, acidification, salinization, alkalinisation etc. Nitrogen is a key component of many organic compounds. Without applied nitrogen, the crop yield should be limited by the available nitrogen within the soil. Nitrogen application can improve the root system, so that water and nutrient absorption are facilitated. Nitrogen also plays an important role in developing yield capacity and maintaining the photosynthetic activity during grain filling stage of the crop. Hence, an efficient use and management of nitrogen in crop production is critical for obtaining optimum crop productivity, quality, environmental safety and economic returns.

The application of nitrogen under furrow irrigated raised beds and conventionally transplanted rice along with varying levels of irrigation needs to be studied and standardized for sustainable yield of the crop. Along with the proper water management, appropriate amount of plant nutrient also strongly affect plant growth, crop water productivity, and nutrient use efficiency. Among the mineral nutrients, nitrogen (N) is the key element in achieving consistently high yield in cereals (Shafi *et al*. 2011; Weih 2014) [25, 31]. Depending upon the soil condition and socioeconomic status, farmers of northern India apply anywhere between 80 to 150 kg N ha^{-1}, thus optimum N rate under different water management is still a promising management recommendations in order to increase profit for rice farmers of the region (Kar *et al.* 2013) [15]. On this background, the objectives of this study were to evaluate the effects of tillage and nitrogen management on soil properties, productivity and nitrogen use efficiency of irrigated rice under North West India.

Materials and Methods

Experimental site

The field experiment was established in 2016 at Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut research farm (290 04', N latitude and770 42' „E longitude a height of 237m above mean sea level) U.P., India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8^{0}C. The highest mean monthly temperature (38.9^{0}C) is recorded in May, and the lowest mean monthly temperature (4.5^{0}C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The predominant soil at the experimental site is classified as *Typic Ustochrept*. Soil samples for 0–15 cm depth at the site were collected and tested prior to applying treatments and the basic properties were low available nitrogen, low organic carbon, available phosphorus, available potassium medium and alkali in reaction.

Table 1: Physico-chemical properties of the experimental field

Soil parameters/characteristic	Value obtained		Methods adopted
	2016	2017	
A. Physical properties			
Sand (%)	54.21	53.61	Hydrometer method (Piper, 1966)
Clay (%)	18.32	17.46	
Silt (%)	27.47	28.93	
Textural class	Sandy loam	Sandy loam	Triangular basis
B. Physical constants			
Field capacity (%)	27.80	27.03	Field method (Dastane, 1967)
Permanent wilting point (%)	11.80	11.32	
Bulk density (Mg/m^3)	1.51	1.56	Core sampler method (Piper,1966)
C. Chemical composition			
Available N (kg ha^{-1})	242.7	244.5	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	12.0	12.3	Olsen's method(Jackson, 1973)
Available K (kg ha^{-1})	201.3	202.2	1 N NH_4OAC extraction method (Jackson, 1973)
Organic Carbon (%)	0.50	0.51	Walkley and Blak wet oxidation method (Jackson, 1973)
pH(soil: water, 1:2.5)	8.0	7.9	Electrode pH meter Suspension method (Page *et al*., 1982)
Electrical conductivity (dSm^{-1})	0.23	0.22	Conductivity meter Suspension method (Page *et al*., 1982)

Experimental design and management

A detailed description of different tillage systems is necessary to compare the influence of tillage practices on environmental performance (Derpsch *et al*., 2014) [11]. Four tillage crop establishment methods T_1- RT-TPR, transplanted rice after reduced tillage;T_2- N Bed-TPR, transplanted rice on narrow raised beds; T_3- W Bed-TPR, transplanted rice on wide raised beds; T_4- CT-TPR, conventional tillage puddled transplanted rice in main plots and five nitrogen management practices were N_1-Control ($N_0P_0K_0$); N_2- 80 kg N ha^{-1}; N_3-120 kg N ha^{-1}; N_4-160 kg N ha^{-1}; N_5-200 kg N ha^{-1} allotted to sub-plots in a split-plot design and replicated thrice. The gross and net plot sizes were 8 m×3.2 m and 6.0 m×2.0 m, respectively and treatments were superimposed in the same plot every year to study the cumulative effect of treatments. The tillage and crop establishment methods comprised of (i) conventional tillage (CT): In conventional tillage there were three tillage operations. The first tillage was performed in the pre-monsoon season (April/May) and the second one was performed in May/June, some 20–25 days after the first tillage. The third tillage was conducted during June at deeper depth (>15cm) using a tractor drawn cultivator. Nitrogen was applied as per treatments. 60- 40- 25 kg P K and Zn ha^{-1} were applied in all treatments, except N_1 through soil application in the form of Di-ammonium phosphate, Sulfate of potash and 21% Zinc sulphate, respectively. Whole amount of phosphorus (P), potash (K) and zinc (Zn) with 1/3 of nitrogen (N) was applied at the time of transplanting and at seed bed preparation. Remaining dose of nitrogen fertilizer was applied in two equal splits at the time of booting (3 weeks after transplanted) and panicle initiation stage, (6 weeks after transplanted) treatment wise. Nursery seedlings of 21 days older was uprooted manually from nursery plots and then transplanted in the main field on Ist forth night of July by keeping row to row distance of 20 cm, respectively. Irrigation was withheld about two week before harvesting when physiological maturity appeared and then crop was harvested.

Weed management

The plots would be then kept weed-free throughout the growing season. Butachlor @ 1300 g a.i.ha^{-1} at 2 days after transplanting (DAT) followed by a spray application of bispyribac sodium (Nomne gold) @ 25 g a.i.ha^{-1} at 25-30 DAT for narrow and broad leaf weeds. Additionally, 1 hand-weeding in transplanted rice was done to keep the plots weed-free.

Nitrogen use efficiency

Nitrogen harvest index (NHI) represents the crop ability in partitioning the total N uptake between the different plant organs (Anderson *et al*., 1984) [1]. Therefore, nitrogen harvest index (NHI) was defined as the ratio of seed nitrogen uptake to total biomass nitrogen uptake. There are different definitions that describe the nitrogen utilization efficiency. By using the total N uptake by seed and straw and the amount of applied N as fertilizer, the apparent N recovery (NUE) for different N treatments are calculated by Eq. I).Nitrogen yield efficiency (NYE) or agronomic nitrogen efficiency is used to describe the utilization of N inputs in relation to the level of N applied (Fageria and Baligar, 2005) [12]. Therefore, by using the applied N as fertilizer and seed yield, the NYE in different N treatments was calculated by Eq. (II) (Craswell and Godwin, 1984) [7]. The physiological N efficiency (NPE) was also determined by Eq. (III).

$$\mathrm{NUE} = \frac{\mathrm{Nui}-\mathrm{Nuc}}{\mathrm{Nfi}-\mathrm{Nfc}} \quad \text{(I)}$$

$$\mathrm{NYE} = \frac{\mathrm{Yi}-\mathrm{Yc}}{\mathrm{Nfi}-\mathrm{Nfc}} \quad \text{(II)}$$

$$\mathrm{NPE} = \frac{\mathrm{Yi}-\mathrm{Yc}}{\mathrm{Nui}-\mathrm{Nuc}} \quad \text{(III)}$$

Where NUE is the apparent N recovery or nitrogen use efficiency, Nui and N_{uc} are the total N uptake by seed and straw in different N treatments and control, respectively (kg ha^{-1}), and N_{fi} and N_{fc} are the applied N as fertilizer in different N treatments and control, respectively (kg ha^{-1}). Y_i and Y_c defined as the seed yield indifferent N treatments and control, respectively (kg ha^{-1}).

Statistical analysis

Statistical analysis was performed by the Windows-based SPSS program (Version 10.0, SPSS, 1996, Chicago, IL). The SPSS procedure was used for analysis of variance to determine the statistical significance of treatment effects. Duncan's Multiple Range Test (DMRT) was used to compare means through least significant difference (LSD).The 5.0% probability level is regarded as statistically significant.

Results and Discussion

Plant height (cm)

Plant height is an important parameter which can be used to study the effect of different treatments on crop growth. Rice transplanted under puddled conventional tillage (T_4) obtained higher plant height followed by rice transplanted on wide raised beds (T_3) treatment. However, the differences among T_1 and T_2 treatments were non- significant during experimentation. Nitrogen management at harvest maximum height of plants was obtained under treatment N_5 being significantly taller than those for the rest of the nitrogen treatments except N_4 and least under N_1 'control without fertilizer'. Treatment N_4 was significantly superior remaining of the treatments. The difference in plant height between N_2 and N_3 was at par with each other during experimentation [Table 2]. The growth at higher level of nitrogen application i.e.200kg Nha^{-1}applied was increased significantly and it was maximum in 200kg Nha^{-1} of chemical fertilizer. This indicates that the organic sources have supplied the nitrogen to the crop plant slowly and their availability may also be less than the recommended dose of chemical fertilizer which is readily available. These results corroborate the findings of Singh and Yadav, 2006, Habib 2012.

Dry matter accumulation (qha^{-1})

Dry matter accumulation indicates towards the photosynthetic left behind after respiration. So it is the best indicator of growth of a crop. Among different tillage crop establishment methods CT-TPR [conventional till with puddled transplanted rice, (T_4)] accumulated more dry matter q ha^{-1} which was statistically at par with rice transplanted under wide raised beds W Bed-TPR (T_3). However, the differences among T_1, and T_2 treatments were non-significant [Table 2]. The increase in dry matter accumulation was found maximum under treatment N_5 being statistically at more than those for the rest of the nitrogen treatment except N_4 and least under N_1 "control". The difference in dry matter accumulation between N_4 and N_3 was at par during the years of experimentation. In the present study the fact was further elucidated as more dry matter accumulation were recorded in all those treatment where nitrogen supply was more. This low growth in these treatments may be due to low availability of plant nutrient which are necessary for the normal growth. Nitrogen being the basic constituent of chlorophyll, protein and cellulose required for the process of photosynthesis and tissue build up for proper growth.

Table 2: Effects of different planting techniques and nitrogen strategies on growth and yield attributes in rice crop

Treatments	Plant height (cm)	Dry matter accumulation (qha^{-1})	Total tillers m^{-2}	Effective tillers m^{-2}	Panicle length (cm)
T_1 RT-TPR	95.9	178.55	292.9	244.9	24.2
T_2 NBed-TPR	94.6	172.56	283.6	241.8	23.7
T_3 WBED-TPR	96.9	185.77	306.9	276.2	26.2
T_4 CT-TPR	98.6	189.62	311.2	283.5	25.5
C D (P=0.05)	2.05	6.29	9.86	7.64	0.87
Nitrogen strategies					
N_1 (Control)	76.9	66.53	267.7	231.7	23.3
N_2 80kg Nha^{-1}	94.1	141.29	299.6	246.8	24.8

N_3 120kg Nha^{-1}	97.9	157.99	312.6	291.7	25.8
N_4 160kg Nha^{-1}	101.1	178.62	309.8	308.2	26.2
N_5 200kg Nha^{-1}	102.9	173.21	306.1	282.9	24.9
C D (P=0.05)	3.65	7.62	9.46	27.52	2.45

Total tillers m^{-2}

Table 2 revealed that CT-TPR (T_4) treatment significantly increased total tillers m^{-2} over all other treatments during the study but was statistically at par with T_3. However, the differences among T_1, and T_2 treatments were non-significant. Nitrogen treatment of N_3 (120kgN ha^{-1}) produced significantly more productive tillers m^{-2} over N_1 (control) treatment but statistically at par with N_4 (160 kg N ha^1) and N_5 (200 kg N ha^1). In the treatments of nitrogen management, all the treatments proved significantly higher than control.

Effective tillers m^{-2}

The number of effective tillers m^{-2} with fertile panicle is an important yield attribute accounts for major variation in grain yield of the cereal crop like rice. Table 2 revealed that effective tillers m^{-2} varied with different tillage practices and significantly higher effective tillers m^{-2} were recorded with CT-TPR conventional till puddle transplanted rice (T_4) treatment which was at par with transplanted rice on wide raised beds W Bed-TPR (T_3) during the study and gave 13.6,14.7 and 11.3,12.5 per cent more effective tillers m^{-2} as compared to reduced till transplanted rice RT-TPR (T_1) and transplanted rice on narrow raised beds N Bed-TPR (T_2), during experimentation, respectively [Table 2]. Among nitrogen level treatment N_5 produced significantly more number of effective tillers m^{-2} in all treatments except N_4 treatment during experimentation. Treatments N_3 and N_2 were statistically at par among themselves with respect to number of effective tillers m^{-2} during the years of study.

Panicle length (cm)

Panicle length is directly related to the number of spikelet and kernel panicle^{-1} and hence this is an important determinant of grain yield. Panicle length may also serve as one of the criteria for assessing the grain yield in cereal crops. Table 2 revealed that N_4 treatment significantly increased panicle length over N_5 treatment during experimentation. Treatments N_3 and N_2 were statistically at par among themselves with respect to panicle length during the years of study.

Significantly longer panicles were obtained with W Bed-TPR (T_3) as compared to CT-TPR (T_4) and this level of tillage was significantly superior to rest of the treatments. However, RT-TPR and N Bed-TPR were at par with each other during experimentation.

No. of spikelet's panicle^{-1}

Number of spikelet's panicle^{-1} is one of the most yield attribute. Table 3 advocated that the maximum number of spikelet's panicle^{-1} was recorded significantly superior in T_3 treatment as compared to all other treatments except T_4. Treatments T_4 and T_1 were at par with each other; however, they recorded significantly more number of spikelet over T_2 treatment which recorded minimum number of spikelet's panicle^{-1}. Nitrogen management differences with respect to the average number of spikelet's spike^{-1} were also found to be significant. N_1 and N_2 produced significantly lower average number of spikelet's panicle^{-1} as compare to rest of the nitrogen management. Nitrogen level N_4 produced significantly greater number of spikelet's panicle^{-1} as compared to all treatments except N_3.

Table 3: Effects of tillage crop establishment techniques and nitrogen strategies on yield attributes and yield of rice.

Treatments	No. of spikelet's panicle^{-1}	No. of grains panicle^{-1}	1000 grain weight (g)	Grain yield (qha^{-1})	Straw Yield (qha^{-1})
Tillage crop establishment methods					
T_1 RT-TPR	71.3	134	20.48	41.64	57.07
T_2 NBed-TPR	68.4	131	19.72	40.04	51.85
T_3 WBED-TPR	73.4	140	22.05	44.68	62.55
T_4 CT-TPR	72.9	137	21.85	47.38	68.69
C D (P=0.05)	1.84	3.62	3.29	6.92	9.69
Nitrogen strategies					
N_1 (Control)	65.9	119	16.43	30.65	36.78
N_2 80kg Nha^{-1}	70.1	128	18.83	33.57	42.78
N_3 120kg Nha^{-1}	72.7	140	20.75	44.33	58.35
N_4 160kg Nha^{-1}	73.8	143	21.95	50.15	67.70
N_5 200kg Nha^{-1}	71.1	137	20.20	47.55	66.57
C D (P=0.05)	2.46	7.98	4.39	5.18	8.84

No. of grains panicle^{-1}

The grain is fertilized; fully ripened ovule of spikelet in a panicle that ultimately contributes to grain yield. This excludes sterile spikelet's panicle^{-1}.Table 3 exhibited that transplanted of rice on wide raised beds (T_3) techniques produced significantly more grains panicle^{-1} over all other treatments but was statistically at par with transplanted of rice on flat beds conventional till puddled technique (T_4), respectively. The differences in number of grains panicle^{-1} among the treatments T_1 and T_4 were non-significant but significantly superior over T_2. Nitrogen management differences with respect to the average number of grains panicle^{-1} were also found to be significant. N_1 and N_2 produced significantly lower average number of grains panicle^{-1} as compare to rest of the nitrogen management. Nitrogen level N_4 produced significantly greater number of grains panicle^{-1} as compared to all treatments except N_3 and N_5.

Test weight (g)

The weight of individual grain calculated from 1000 grain weight (test weight) is an important yield attribute which provides information regarding the efficiency with grain filling process took place. Thousand grain weight (1000 grain weight), as it is called the test weight of the desired output, is referred to be considered as one of the most significant agronomic parameters ever trusted that contributes in having a reconnaissance over the possible production of a lot (grain yield). Table 3 revealed that T_3 treatment of sowing techniques significantly increased 1000 grain weight over all other treatments but was statistically at par with T_4 and T_1 treatments. However, T_1 treatment produced significantly higher grain weight as compared toT_2, respectively. Nitrogen management differences with respect to the average test weight were also found to be significant. Treatment N_1 produced significantly lower average test weight as compare to rest of the nitrogen management. Nitrogen level N_4 produced significantly highest test weight as compared to all treatments except N_2, N_3 and N_5.

Grain yield (qha^{-1})

Grain yield is a function of various parameters like crop dry matter accumulation, number of tillers, number of grains panicle^{-1} and grain weight etc. Grain yield is the most important criteria for evaluating the effects of applied treatments. Crop productivity is the rate at which a crop accumulate biomass which depends primarily on the photosynthesis and conversion of light energy into chemical energy by green plants. Grain yield was significantly influenced by different levels of nitrogen application. Significantly higher grain yield of (50.15 q ha^{-1}) were obtained in N_4 treatment which remained statistically at par with N_5 treatment. N_3 (120 kg Nha^{-1}) recorded significantly higher grain yield over N_2 (80 kg Nha^{-1}) and N_1 "control" treatments. N_1 which recorded minimum grain yield (30.65 qha^{-1}) during experimentation. The higher growth finally resulted into significant increase in grain yield through yield attributes namely number of effective tillers, number of grains per panicle and test weight [Table 3]. This increase was because of increased the number of grains per panicle. Similar results have been reported by Dhaka *et al*.; 2007 [10]; Ingle, 2007 [13] and Ali *et al*., 2012 [2].

Straw yield (qha^{-1})

The straw yield is a function of crop biomass developed during the crop growth period and also makes important contribution to the overall crop residues as it is used as feed for the cattle. Table 3 revealed that the straw yield increased significantly with the every successive increase in moisture supply by moisture retention and land configuration. TreatmentsT_3 and T_4 were at par with each other, however, they recorded significantly higher straw yield over rest of the treatments. Treatment T_2 (rice transplanted on narrow raised beds) recorded minimum straw yield 51.85 q ha^{-1}. The percentages increased in straw yield due to various modes of tillage crop establishment treatments over narrow raised beds practices were 24.5, 17.1 and 9.1 per cent during experimentation at T_4, T_3 and T_1, respectively.

Nitrogen uptake by basmati rice

Table 4 indicated that T_4 treatment of conventional tillage puddled transplanted rice significantly increased N uptake in grains and straw over all other treatments but was statistically at par with T_3 transplanted rice on wide raised beds during experimentation. Nitrogen applications of N_2 (80kg Nha^{-1}) did not have any significant effect on nitrogen uptake by grains and straw as compared to control (N_1). N_3, N_4 and N_5 treatments of nitrogen application significantly increased nitrogen uptake as compared to control and were statistically at par with each other during the period of study. The higher nitrogen uptake by basmati rice grains and straw with tillage crop establishment and nitrogen strategies might due to higher nitrogen content in grains and straw with corresponding treatments.

Table 4: Effect of tillage and nitrogen strategies on grains and straw nutrient uptake under rice crop

Treatments	Grain			Straw		
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Tillage crop establishment methods						
T_1 RT-TPR	71.4	15.2	18.3	25.1	9.4	96.7
T_2 NBed-TPR	66.5	12.8	16.2	20.7	7.5	84.8
T_3 WBED-TPR	77.5	17.1	21.2	28.8	10.9	107.6
T_4 CT-TPR	80.1	15.2	19.7	28.2	10.3	114.1
C D (P=0.05)	6.35	NS	NS	3.79	1.64	8.79
Nitrogen strategies						
N_1 (Control)	54.1	11.5	12.1	14.3	3.9	49.1
N_2 80kg Nha^{-1}	61.3	13.2	13.6	17.6	4.7	59.6
N_3 120kg Nha^{-1}	88.2	19.9	19.8	24.5	7.6	93.2
N_4 160kg Nha^{-1}	92.1	20.2	20.5	28.5	7.7	93.7
N_5 200kg Nha^{-1}	83.3	18.7	18.4	28.8	7.9	92.5
C D (P=0.05)	10.58	NS	NS	9.25	NS	19.29

Phosphorus uptake by basmati rice

The data is respect of phosphorus uptake (kg ha^{-1}) by basmati rice grains is presented in Table 4revealed that phosphorus uptake was not affected significantly with tillage crop establishment, and nitrogen level treatments during both the period of study.

Potassium uptake by basmati rice

Table 4 revealed that T_3 treatment of tillage crop establishment technique significantly increased potassium uptake in straw over all other treatments but was statistically at par withT_4 treatment to basmati rice during both the year of study. However, potassium uptake in grains due to planting techniques was non-significant during experimentation. Among different nitrogen level treatment N_3 significantly increase potassium uptake over control and other nitrogen treatments but was statistically at par with N_3 and N_5 treatments. But N_5 treatment increased potassium uptake significantly over other treatments of nitrogen level and control but was statistically at par with N_3 treatment. The higher potassium uptake by basmati rice grains and straw with tillage crop establishment practices and nitrogen level treatments might due to higher potassium content in grains and straw with corresponding treatments. The higher uptake of NPK in grain under higher dose of N (160 kg Nha^{-1}) and straw dose of N (200 kg Nha^{-1}) was because of more availability of these nutrients, which encouraged the crop growth and finally higher grain and biomass yield. Similar result has been reported by Sharma *et al*., 2005 [26], Kumar *et al*., 2007 [17] and Verma *et al*., 2008 [29].

Nitrogen Use Efficiency

Agronomic N use efficiency (ANUE) ranged from 13.7 to 22.9% under different tillage and N treatments. Average over the N treatments, significantly higher ANUE was recorded under 80 kg N ha^{-1} treatment (N_2) than that of the control ($N_0P_0K_0$ (N_1) treatment and not at higher doses of N (14.9% at 200 kg N ha^{-1}). Among different nitrogen level treatment N_3 significantly increase NHI per cent over control and other nitrogen treatments but was statistically at par with N_4 and N_5 treatments. However, N_5 treatment increased NHI per cent significantly over N_2 (80 kg N ha^{-1}) and N_1 'control' treatments. The physiological N use efficiency (PNUE) values ranged from 28.9 to 46.3 kg grain/kg N uptake with decreasing values as the N doses increased [Table 5]. The PNUE values tend to decrease with increasing N doses due to higher N uptake and higher N concentrations in both the grain and straw. Values of AR ranged from 27.1 to 56.9% among different N and tillage treatments. The higher AR was recorded under 160 kg N ha^{-1} (N_4) due to higher grain yield. This was because of the more difference of grain yield between the zero N (N_1) and N_4 treatments (about 1.95 t ha^{-1}).

Table 5: N efficiency parameters under different planting methods and nitrogen management practices

Treatments	NHI (%)	PNUE	ANUE (%)	AR (%)
Tillage crop establishment methods				
T_1 RT-TPR	57.4	41.7	15.9	40.1
T_2 NBed-TPR	55.9	38.7	13.2	37.9
T_3 WBED-TPR	64.3	46.3	20.2	56.3
T_4 CT-TPR	61.1	45.1	18.9	56.9
C D (P=0.05)	6.99	4.76	4.78	6.16
Nitrogen strategies				
N_1 (Control)	38.3	28.9	13.7	27.1
N_2 80kg Nha^{-1}	39.1	45.1	22.9	35.9
N_3 120kg Nha^{-1}	53.8	44.6	22.1	45.3
N_4 160kg Nha^{-1}	58.1	38.8	19.1	54.6
N_5 200kg Nha^{-1}	57.6	33.9	14.9	53.8
C D (P=0.05)	4.48	6.49	3.97	9.48

NHI= Nitrogen harvest index, PNUE= Physiological nitrogen use efficiency, ANUE= Agronomic nitrogen use efficiency, AR = Apparent recovery of applied nitrogen

Bulk density

In general, the upper 10 cm (0-5 and 5-10 cm) layer contributed about 23.2 and 24.1 per cent of total bulk density of the soil and the second 10-20 and 20-30 cm about 25.9 and 26.8 per cent during experimentation. Thus the higher bulk density recorded from top 0-10 cm depth i.e. 47.3 per cent, whereas the contribution of bulk density to 10-20 and 20-30 cm soil layers was about 25.9 and 26.8 per cent. It was observed that under T_4 treatment recorded higher bulk density and more contribution was from top layer 47.6 per cent and less from deeper layer 24.2 and 25.7 per cent. Treatment T_2 recorded lower bulk density and less contribution was from top layer 46.9 % and higher from deeper layer 53.1 per cent during the years of study. Among tillage crop establishment methods, plots under conventional till puddled plot T_4 had about 9% higher soil bulk density (1.69 Mgm^{-3}) than T_3 plots [Table 6]. Unlike land configuration, tillage had greater impacts on soil bulk density. Plots under T_2 and T_3 had ~ 9% less soil bulk density as compared with T_4 treated plots [Table 6].The bulk density did varied significantly due to planting techniques and it was significantly reduced under reduced and raised beds planting techniques compared to conventional tillage puddled transplanting. Similar results have been reported by Dalal *et al*., 2011 [8]; Chauhan *et al*., 2011 [5].

Table 6: Effects of different planting methods on soil physical properties in rice crop

Treatments	Bulk density (Mgm^{-3})				Infiltration rate (hr cm^{-1})	Ec (dSm^{-1})	p^H	Soil Penetration Resistance (Mpa)		
	0-5 cm	5-10 cm	10-20 cm	20-30 cm				0-5 cm	5-15 cm	15-30 cm
Tillage crop establishment methods										
T_1 RT-TPR	1.51	1.57	1.72	1.77	0.26	0.24	7.8	1.2	3.3	3.3
T_2 NBed-TPR	1.43	1.47	1.60	1.65	0.36	0.21	7.6	1.3	3.4	2.9
T_3 WBED-TPR	1.46	1.53	1.63	1.68	0.31	0.22	7.5	1.5	3.3	3.1
T_4 CT-TPR	1.58	1.63	1.73	1.80	0.19	0.25	7.9	1.6	3.6	3.4
C D (P=0.05)	0.11	0.08	0.07	0.07	8.87	0.010	0.049	0.06	0.08	0.09

Infiltration rate

Among the various planting techniques treatment T_2 was found to be significantly superior to all the treatments, except T_3 also recorded highest infiltration rate (0.36; 0.31 cm hr^{-1}). The difference in infiltration rate due to tillage practices treatments proved significant. Treatment T_3 was significantly superior to the remaining treatments.T_1 and T_4 were at par with each other. However, T_4 treatment recorded lowest infiltration rate (0.19 cm hr^{-1}), during the year of study, respectively. Similarly after two years, the highest increase (32.1%) was found in T_2 followed by T_3 (27.7%) and T_1 (23.2%), whereas T_4 showed decreasing trend after two years [Table 6]. Tillage plays a vital role in improve the soil condition by altering the mechanical impedance to root penetration, hydraulic conductivity and water holding capacity. Increases in the bulk density usually result in large decreases in water flow through the soil and land configuration on the soil surface with conservation tillage would reduce evapo-transpiration and increase infiltration rate.

Soil electric conductivity

The electric conductivity was recorded maximum 0.25 dSm^{-1} under conventional till puddled transplanting technique (T_4) treatment and minimum values 0.21dSm^{-1} also obtained under furrow irrigated raised beds (T_2), respectively.

Soil pH

Perusal of data presented in [Table 6] revealed that pH was registered lowest values (7.5 and 7.6) under transplanted rice on raised beds (T_2) and (T_3) land configuration treatments and highest under conventional till puddled transplanting technique (T_4) treatment during both the year of study.

Soil penetration resistance

The soil penetration resistance increased with the decreased in moisture supply and depth up to 15 cm and their after a decreasing trend were observed. The crop retained more moisture i.e. land configuration treatment during both the years, respectively [Table 6].

Distribution of Aggregates in different size

Table 7 revealed that in all the treatments, the proportion of macro-aggregates in the size class of 0.25 to >2 mm was higher as compared to micro-aggregate in the size class 0.11 - 0.25 mm. Among the macro-aggregates, 0.25 - 0.50 mm fraction constituted the greatest proportion followed by 0.5 - 1.0, 1.0 - 2.0, and >2 mm fraction constituted the least proportion in 0 – 10, 10-20 cm and 20 - 30 cm soil layers under FIRB, RT and CT system. Aggregate size distribution in different soil depths were significantly impacted by tillage management practices [Table 7]. Macro aggregates accounted for >66% of total aggregates. In topsoil (0–10 cm soil layer), these were the dominant water-stable aggregates (WSA). Significantly higher (70%) water-stable macro-aggregates were recorded in FIRB plots compared with CT in the topsoil, with a concurrent decrease in micro aggregates in the RT plots. A similar trend also was recorded in sub-surface soil [Table 7]. Small macro-aggregates were the greatest proportion of the whole soil, followed by aggregates <0.106 mm in topsoil. Plots under FIRB had significantly more large and small micro-aggregates than RT plots in 0-10 and 10-20 cm soil layers. The FIRB plots had significantly more large macro-aggregates, with a concomitant decrease in 'silt + clay' sized aggregates (<0.106 mm) compared with RT plots in the topsoil.

Table 7: Soil stable aggregate size classes for reduced till (RT), furrow irrigated raised beds (N Beds & W Beds) and conventional tillage (CT), treatments in the 0- to 30-cm soil depth in rice crop.

Depth (cm)	Treatments	Aggregate size distribution						Macro-aggregates (>0.25 mm)	Micro-aggregates (<0.25 mm)
		>2 mm	2-1mm	1-0.5 mm	0.5-0.25 mm	0.25-0.11mm	<0.11mm		
		----------%----------							
0-10	T_1 RT-TPR	6.45	9.73	8.09	8.95	12.83	31.66	33.44	66.57
	T_2 NBed-TPR	5.98	7.95	6.88	8.28	25.15	42.70	30.26	69.34
	T_3 WBED-TPR	5.31	6.06	5.67	7.60	35.45	53.73	31.89	67.11
	T_4 CT-TPR	2.13	4.26	5.59	5.33	13.08	66.91	19.01	79.99
C D (P=0.05)		1.16	1.93	2.44	1.64	6.87	11.31	4.85	2.84
10-20	T_1 RT-TPR	6.68	5.69	4.05	14.98	11.07	27.55	35.56	64.44
	T_2 NBed-TPR	5.58	5.65	4.56	18.62	24.89	43.50	33.67	66.21
	T_3 WBED-TPR	4.36	5.62	5.22	20.23	36.90	57.47	32.06	68.24
	T_4 CT-TPR	2.90	3.57	4.17	5.53	12.34	72.08	15.59	84.42
C D (P=0.05)		2.33	2.02	1.14	5.45	12.47	14.13	4.33	4.91
20-30	T_1 RT-TPR	4.70	4.14	3.52	8.70	21.06	61.84	17.10	82.90
	T_2 NBed-TPR	6.92	7.35	6.98	11.86	18.90	53.70	35.79	63.81
	T_3 WBED-TPR	7.82	8.55	8.43	13.96	16.36	41.55	38.89	61.11
	T_4 CT-TPR	3.55	4.10	3.14	4.10	11.90	76.76	13.81	88.76
C D (P=0.05)		1.26	1.37	1.91	4.84	5.16	15.36	3.49	5.96
0-30	T_1 RT-TPR	6.41	6.96	6.53	10.30	13.82	40.35	28.70	71.64
	T_2 NBed-TPR	6.35	7.18	6.31	13.21	23.98	47.63	33.24	66.55
	T_3 WBED-TPR	5.92	6.92	4.86	14.17	30.47	51.92	34.28	65.48
	T_4 CT-TPR	2.96	4.24	4.25	4.79	12.44	71.85	16.47	84.39
C D (P=0.05)		1.36	1.61	1.88	4.63	7.39	13.39	6.19	7.93

In the sub-surface soil, size distributions of aggregates were also significantly influenced by tillage practices. Small macro-aggregates comprised the greatest proportion of the whole soil, followed by aggregates <0.106 mm in the 10–20 cm soil layer. Subsurface soil (10–20 cm depth) had 34% lower macro-aggregates than micro-aggregates [Table 7]. The percentage of water-stable aggregates of the largest size class (>2 mm) in FIRB plots at depth of 0 to 10, 10 to 20, and 20 to 30 cm was approximately twice the percentage under CT but significant only below the 10-cm soil layer. The comparison between RT and CT did not produce significant results until a depth of 20 cm. In contrast, the soil in all layers of the CT treatment had the highest percentage of water-stable aggregates of the smallest size class (<0.106 mm) compared with both the FIRB and RT treatments. Aggregate data revealed that the macro-aggregates increased by 39% and micro-aggregates decreased by 9% in FIRB plots compared with CT plots. Decrease in micro-aggregates and increase in macro-aggregates with application of conservation tillage might have enhanced soil aggregation processes. Our study revealed that the conservation tillage treatments produced significantly higher amounts of >2 mm macro-aggregates compared with CT. This was because conservation tillage practices decreased tillage times (Wang *et al*., 2013) [30], and reduced the mechanical destruction to soil aggregates. CT with frequent tillage operations disturb soil, and increase the effect of drying–rewetting and freezing–thawing, which increase macro-aggregate susceptibility to disruption (Tian *et al*., 2010) [28].

Conclusion

The data acquired from the 02-year, rice experiment revealed that tillage and nutrient management practices had significant effects, of varying magnitude, on growth and yield attributes and yield. Small macro-aggregates were the greatest proportion of the whole soil, followed by aggregates <0.106 mm in topsoil. Plots under FIRB had significantly more large and small micro-aggregates than RT plots in 0-10 and 10-20 cm soil layers. Likewise, soil penetration resistance (SPR) was highest at the 30-cm depth in puddled treatments and lowest in furrow irrigated raised beds treatments. Infiltration was higher (0.34 cm h^{-1}) in FIRB treatments than puddled treatments (0.19 cm h^{-1}). The findings suggest that conservation tillage would improve soil quality and productivity, and may also be better for the environment. N fertilization, although improving crop production under intensive agriculture. In conclusion, Nitrogen plays a significant role in building-up/restoring soil health and productivity in *Typic Ustochrept* soil inherently low in organic matter and nutrients.

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