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Research Paper

Influence of tillage and nutrient management on productivity and profitability of wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2012–13 to 2015–16 at Pantnagar, Uttarakhand, to study the effects of tillage and nutrient management on performance of wheat (*Triticum aestivum* L.). The experiment was laid out in a strip-plot design with 3 tillage treatments, conventional tillage (CT) without chiseling, chiseling followed by CT and chiseling followed by rotavator) and 3 nutrient-management options [100% recommended dose of fertilizer (RDF), combined application of 100% RDF along with FYM @ 15 tonnes/ha and 125% RDF combined with FYM). Results showed that, inclusion of chiseling either before disk harrowing or rotavator in tillage along with application of 125% RDF of nutrients and FYM efficiently improved the soil properties, viz. decrease in bulk density (by 0.14 Mg/m^3), penetration resistance (by 1.05 MPa) and *p*H (by 0.15) and increase in infiltration rate (by 0.8 cm/h), organic carbon (by 0.06%), available P_2O_5 and K_2O content (by 3.2 kg/ha and 45.8 kg/ha and dehydrogenage activity (by 116 units) compared with the initial status. This tillage and nutrient management combination resulted in superior growth attributes, viz. plant height, dry-matter, leaf-area index (LAI), crop-growth rate (CGR), leaf chlorophyll content, tillering along with higher grain yield (5.4 t/ha). Similarly, treatments 100% RDF + FYM and 125% RDF + FYM recorded 114 and 128% higher grain yield, respectively, over application of only RDF.

Key words: Growth and yield, Nutrient management, Soil properties, Tillage, Wheat

Rice–wheat cropping system occupies about 13.5 million ha area in Indo-Gangetic Plain (Tripathi *et al*., 2015). Puddling is the popular tillage operation by which soil structure is deliberately destroyed and dispersed by repeatedly ploughing and harrowing in a flooded or saturated state to render it impervious (Mousavi *et al*., 2009). The well-known agronomic benefits of puddling are: reduced draft requirements for tillage, weed control, easy transplanting, conservation of rain and irrigation water, increase in nutrient availability etc. It ultimately results in better crop growth and yield in rice. About 12 million ha area of Asian countries including India, Pakistan, Bangladesh, Shrilanka, Philippines, China, Indonesia, South and North Korea is under submerged condition for about 15–25 weeks of a year. Hence, direct seeding is become annoying along with poor emergence due to the anaerobic condition. The morpho-physiological structure of rice crop is also favourably respond to it and results in better grain yield. However, the succeeding upland crops cultivated after rice are adversely affected by the deterioration of soil properties and declining yield trend is observed; particularly in wheat crop grown after puddled rice (Kalhapure *et al*., 2015). Formation of hard pan below the puddled depth, soil compaction, disintegration of soil structure, reduced condition, increased bulk density, decreased infiltration, aeration, water and nutrient movement and microbial activities are reported after such lowland rice cultivation; due to which succeeding wheat growth and yield is suffered considerably.

Tillage practices improve the rhizospheric environment in terms of soil physical, chemical and biological properties of soil for better growth and yield of wheat after lowland rice cultivation (Zhou *et al*., 2014). Zero tillage, minimum tillage, reduced tillage and deep tillage have been reported to revoke the soil condition after rice harvesting. However, each tillage system suggested by researchers has its own limitations as per the locality and resource availability (Meena *et al*., 2016). In zero and minimum tillage system of wheat after rice harvesting, it is very difficult to manage crop residue and seed sowing to maintain proper plant population. Deep tillage is described to successfully break-

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ing of hard pan and detracts soil from reduced condition. However, the mechanical impedance created by it is another side of the coin which leads to increase soil compaction in surface soil layer. Inclusion of organics in the form of FYM, compost, green manuaring etc. are also described for rejuvenation of soil physico-chemical and biological environment of crop (Ghimire *et al.*, 2017). However, many researchers reported that, only application of organics is not the solution for revoking soil condition in lowland rice– wheat cropping system and it need to be combined with tillage-management practices for better results (Yadav *et al.*, 2017). Therefore, the main goal of this study was to investigate the best tillage and nutrient-management system for wheat under lowland rice–wheat cropping system to rejuvenate rhizospheric environment after harvesting of puddled rice to enable wheat for proper growth and increased yield.

MATERIALS AND METHODS

The field experiment was conducted at the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (28° 582 123 N, 79° 242 363 E and 244 meters above mean sea level) Uttarakhand, India for 4 consecutive years from 2012–13 to 2015–16 in wheat under puddled rice–wheat cropping system. The climate of the site was humid subtropical, characterized by hot summers and cool winters, with an average annual rainfall of 1433 mm. Soil characteristics at the time of initiation of experiment is given in Table 1.

Experiment was laid out in strip-plot design on fixed plot with 3 replications. Vertical strips consisted of 3 tillage treatments, viz. conventional tillage (CT) without chiseling, chiseling followed by CT and chiseling followed by rotavator. Three nutrient-management treatments, viz. 100% recommended dose of fertilizer (RDF), combined application of 100% RDF along with FYM @ 15 tones/ha and 125% RDF combined with FYM, were applied in horizontal plots. The chiseling was done at the depth of 45 cm. with chisel plough. Conventional tillage consisted of 2 times disc harrowing; while rotary tillage was performed with rotavator for twice. RDF used for treatments as 150 : 60 : 40 kg/ha of N, P_2O_5 : K_2O; while in 125% RDF 188 : 75 : 50 kg/ha of N: P_2O_5 : K_2O was applied through urea, muriate of potash and mixed fertilizer grade 12 : 32 : 16 (N, P_2O_5 : K_2O). Out of total fertilizer dose, one-third N and whole P_2O_5 and K_2O were applied at the time of sowing, whereas the remaining N was applied again in 2 split doses as one-third at 25 DAS (around crown root initiation stage) and last one-third at jointing in each year of the experiment. A well decomposed FYM @ 15 t/ha was applied in the plots of scheduled treatments before tillage operations. Other crop-cultivation practices of irrigation, plant protection, harvesting etc. were followed in similar manner for all the treatments.

Physico-chemical and biological assessment of soil with estimation of texture, pH, EC, organic carbon, available N, P_2O_5 and K_2O, dehydrogenage activity, bulk density, infiltration rate, penetration resistance was carried out at initiation of the experiment and after harvesting of crop during all the 4 years with standard methods. Plants were also analyzed for N, P and K uptake, and leaf-chlorophyll content at different stages of crop growth.

Radiation-use efficiency was calculated on the basis of total radiation energy received during entire crop-growth period (MJ/m^2) and wheat grain yield obtained (g/m^2). Following conversions were applied for this calculation.

$$\text{Radiation energy received } (MJ/m^2) = \text{Total sunshine hours during entire crop growth period} \times \text{Solar constant } (4.92\ MJ/m^2/hour)$$

$$\underset{(g/m^2/MJ)}{\text{Radiation use efficiency}} = \frac{\text{Grain yield } (g/m^2)}{\text{Solar energy received during crop growth period } (MJ/m^2)}$$

Table 1. Initial status of physico-chemical and biological properties of soil at the experimental site

Soil parameters	Value obtained	
Soil texture	Sand: 35%, Silt: 52% and Clay: 13% (Silty loam)	
Infiltration rate (cm/h)	2.3	
Penetration Resistance (MPa)	3.3	
	0–15 cm depth	15–30 cm depth
*p*H	7.51	7.55
Electrical conductivity (dS/m)	0.156	0.171
Organic carbon (%)	0.71	0.67
Available N (kg/ha)	230	223
Available P (kg/ha)	12.46	11.13
Available K (kg/ha)	188	171
Dehydrogenage activity (µg TPF formation/g soil/24 hs)	323	292
Bulk density (Mg/m^3)	1.51	1.56

Crop water-use efficiency is a ratio between grain yield and water used by the crop in evapotranspiration which was calculated as per Asseng *et al*., (2001)

$$\text{WUE (kg/ha.mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Evapotranspiration (mm)}}$$

Partial factor productivity (PFP) was calculated for different nutrients, viz. N, P, K and FYM in terms of grain yield production per unit application of that particular nutrient as:

$$\text{PFP for N or P or K or FYM = per kg of N or P or K or FYM applied)} \quad \frac{\text{Grain yield (kg/ha)}}{\text{N or P or K or FYM applied (kg/ha)}}$$

All the observation parameters in this study were analyzed with ANOVA as suggested by Gomez and Gomez (1983) and results are mentioned at 5% level to the differences among the treatment means.

RESULTS AND DISCUSSION

Various morpho-physiological characters, yield and input-use efficiency in wheat crop along with soil properties were found to be affected with different tillage and nutrient management options.

Physiological attributes in wheat

Tillage systems significantly affected different growth parameters and nutrient uptake in wheat (Table 2). Conventional tillage (CT) with chiseling recorded taller plants along with higher dry matter, leaf-area index and crop growth rate. Primary nutrient uptake, viz. nitrogen, phosphorus and potash, was also higher in this tillage option; however, all these growth attributes except crop-growth rate (CGR) were statistically at par with chiseling followed by rotary tillage (RT). The CT without chiseling recorded all these characters at significantly lower side. Similarly, higher content of chlorophyll– *a*, *b* and total chlorophyll in leaf along with higher green seeker reading were observed with the inclusion of chiseling during preparatory tillage followed by either CT or RT at 60 days after sowing (DAS).

The positive manipulation in soil physico-chemical and microbial properties of soil with inclusion of chiseling in tillage operations provided more sophisticated rhizospheric environment for plant establishment and further its physiological growth. In lowland rice–wheat cropping system, the growth and yield of wheat crop cultivated after puddled rice has been reported to reduce from its normal range because of soil sickness created in terms of destruction of soil structure, formation of hard pan, decreased soil aeration and hydraulic conductivity, increased bulk density and penetration resistance, decreased availability of macro- and micro-nutrients etc. by Kumar *et al.* (2012). Similar factors might be responsible for lower growth and yield of wheat under conventional tillage system without chiseling during this experiment. However, all these soil-sickness effects were avoided by including chiseling operation which was found to be effective in improving these entire soil parameters, viz. infiltration rate, penetration resistance, bulk density, organic carbon and available NPK content and dehydrogenage activity, as earlier reported by Tripathi and Singh (2007). The effect of chiseling on all these soil physico- chemical and biological properties might be reflected into the higher NPK uptake by wheat, which was responsible of higher plant height, leaf area, dry-matter

Table 2. Effect of tillage and nutrient management on growth attributes in wheat (mean of 4 years from 2012–13 to 2015–16)

Treatment	Plant height (cm)	Dry matter (g/m^2)	LAI at 90 DAS	CGR at 60–90 DAS (g/m^2/day)	N uptake at harvest time (kg/ha)	P uptake at harvest time (kg/ha)	K uptake at harvest time (kg/ha)	Chloro-phyll-a	Chloro-phyll-b	Total chlorophyll	Green seeker reading
Tillage (T)											
CT without chiseling	82.4	932	3.1	15.4	92.5	13.2	95.8	2.11	1.10	3.20	0.76
CT with chiseling	94.9	1352	4.2	22.8	128.5	18.4	133.3	2.40	1.27	3.66	0.82
RT with chiseling	93.4	1270	4	21.4	124.5	17.8	129.6	2.42	1.26	3.68	0.80
SEm±	1.9	37.7	0.1	0.3	2.05	0.21	5.1	0.06	0.05	0.10	0.01
CD (P=0.05)	5.6	113.2	0.3	0.87	6.05	0.62	14.9	0.16	0.15	0.29	0.04
Nutrient (N)											
RDF	84.0	986	3.3	16.4	94	13.4	96.5	2.10	1.10	3.19	0.75
RDF+ FYM	91.1	1149	3.7	19.2	113.9	16.3	116.7	2.28	1.18	3.45	0.79
RDF 125% + FYM	95.5	1420	4.3	24.0	137.7	19.7	145.6	2.55	1.35	3.90	0.85
SEm±	1.15	34.3	0.09	0.27	1.1	0.24	4.0	0.04	0.02	0.04	0.02
CD (P=0.05)	3.3	103	0.26	0.8	3.3	0.71	11.8	0.11	0.05	0.12	0.05

LAI, Leaf-area index; CGR, crop-growth rate; DAS, days after sowing; CT, conventional tillage; RT, rotary tillage; RDF, recommended dose of fertilizer; (Unit for chlorophyll content is (mg/g of fresh leaf weight) production along with increased crop-growth rate in the treatments of chiseling followed either by conventional or rotary tillage as compared to conventional tillage without chiseling. The effect of chiseling on accelerated growth parameters has been reported by several scientists, viz. Nunes *et al.* (2015) studied root activities under chiseling, Murillo *et al.* (2004) reported higher NPK uptake with chiseling and Mueen-Ud-Din *et al.* (2015) studied the chiseling effect on germination count, number of tillers, plant height and dry-matter production.

All these growth parameters along with higher NPK uptake respectively, and chlorophyll content and green seeker reading were recorded, being significantly superior in nutrient-management option of jointly applied 125% recommend dose of fertilizers and FYM to rest of the treatments. This was followed by application of 100% RDF along with FYM, whereas the lowest values of these attributes were recorded with RDF alone. However, in case of green seeker reading an application of RDF alone and its combination with FYM were found to be at par with each other. Our results confirm the findings of Mishra *et al.* (2008) in integration of organic and inorganic sources of nutrients; which might be due to the induced nutrient uptake and metabolism of wheat crop and its further reflectance into the increased growth attributing characters of crop *viz.* plant height, number of tillers, dry matter production, leaf area and crop growth rate.

Yield and economics in wheat

The conventional tillage (CT) with chiseling and rotary tillage (RT) with chiseling resulted in 5.4 and 5.2 t/ha grain yield, respectively, which was higher over CT without chiseling along with higher number of effective tillers (Table 3). The chiseling effect was also reflected in higher grain yield in wheat during all the years. Alijani *et al.* (2012) also reported the increase in yield attributing characters and wheat yield-as the function of various growth-attributing characters triggered with adopting chiseling operation in preparatory tillage of wheat under rice–wheat cropping system.

The grain yield of 5.5 t/ha was recorded in integration of 125% RDF and FYM, which was 129 and 108% higher than that obtained with the application of only RDF and its combination with FYM, respectively, along with maximum number of effective tillers. Increased dose of chemical fertilizers by 125% integrated with FYM provided a strong base for development of morpho-physiological characters in field crops; it was ultimately reflected in yield-attributing characters during this experiment and resulted in higher grain yield. Kumar *et al.* (2015) reported the increased shoot and root growth, yield- contributing characters and finally yield and nutrient uptake in wheat with increased doses of nutrients. Kumar *et.al* (2019) also reported similar response of wheat yield to nutrient-management practices in wheat. The highest net return and benefit: cost ratio were obtained from tillage treatment CT with chiseling which was followed by RT with chiseling. However, the lowest net return and B : C ratio (0.68) were recorded in CT without chiseling. similarly, amongst nutrient-management options, the highest net return was observed in treatment 125% RDF + FYM, whereas, higher B : C ratio (1.19) was recorded in application of only RDF.

Rhizospheric environment in wheat

After completion of 4 years experimentation, significantly lower soil *p*H, penetration resistance and bulk den-

Table 3. Effect of tillage and nutrient management on different yield characters and economics in wheat (mean of four 4 years from 2012-13 to 2015-16)

Treatment	Effective tillers/m^2	Grain yield (t/ha)	Cost of cultivation (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
Tillage (T)					
CT without chiseling	341	4.1	55.1	37.5	0.68
CT with chiseling	432	5.4	56.4	64.9	1.15
RT with chiseling	420	5.2	56.6	60.0	1.06
SEm±	11.2	0.09	--	--	--
CD (P=0.05)	32.9	0.26	--	--	--
Nutrient (N)					
RDF	360	4.3	44.2	52.1	1.18
RDF+ FYM	399	4.9	61.9	48.8	0.79
RDF 125% + FYM	435	5.5	62.9	61.6	0.98
SEm±	6.1	0.08	--	--	--
CD (P=0.05)	17.8	0.2	--	--	--
Interaction	SIG	SIG	--	--	--

CT, conventional tillage; RT, rotary tillage; RDF, recommended dose of fertilizer sity were recorded in chiseling followed either by CT or RT compared with CT without chiseling along with higher infiltration rate organic carbon content, dehydrogenage activity and available P_2O_5 and K_2O content. Electrical conductivity and N content in soil were not affected with adoption of different tillage systems in wheat during the experimentation period (Table 4).

The modification in soil-particle aggregation due to the chisel ploughing after puddled rice cultivation, which further resulted in decreased bulk density and increased infiltration rate was earlier reported by McDonald *et al.* (2006). Alam *et al.* (2014) correlated the structural modifications of soil caused by deep tillage operation with increased soil aeration, moisture-holding capacity and hydraulic conductivity. The improvement in soil-nutrient status in terms of organic carbon, available N, P_2O_5 and K_2O due to chiseling observed during the experiment might be owing to the increased oxidative potential of microorganisms in soil which are responsible for decomposition of organic matter (present in the form of crop residue, roots, weed biomass etc.) and accelerated mineralization processes. Gomez *et al.* (2001) and Qin *et al.* (2010) also reported this correlation between chiseling and chemical-biological properties of soil.

Among the nutrient-management options integration of FYM along with either 100% RDF or 125% RDF resulted in lower soil *p*H, penetration resistance and bulk density and higher infiltration rate, organic carbon and dehydrogenage activity as compared to application of RDF alone. Significantly higher soil available N, P_2O_5 and K_2O after completing 4 crop cycles were observed in the integrated application of 125% RDF and FYM which was followed by 100% RDF and FYM.

Input-use efficiency

Numerically higher energy, radiation and water-use efficiency along with higher partial factor productivity for N, P, K and FYM in terms of grain yield per unit consumption of these inputs was recorded with either CT or RT followed after chiseling over CT without chiseling (Table 5). Among the nutrient management treatments higher use efficiency for these inputs were recorded under the application of 125% RDF and FYM which was followed by RDF + FYM. Higher partial factor productivity of N (33.0), P (82.4) and K (123.7) was recorded in application of 100% RDF along with FYM and it was followed by 125% RDF with FYM. Numerically higher partial factor productivity of FYM (0.55) was found in 125% RDF along with FYM application.

Interaction effect

Among the interaction effects, significantly higher plant

Table 4. Effect of tillage and nutrient management in wheat on various soil properties at different depths after completing four cycles of crop

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		*p*H		EC (dS/m)		OC (%)		Bulk density (Mg/m^3)		DHA (µg TPF formation/g soil/24 h)		Infiltration rate (cm/hr)	Penetration resistance (MPa)
	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm		
Tillage (T)																		
CT without chiseling	281.5	250.5	15.4	12.2	230.2	179.8	7.55	7.60	0.167	0.167	0.71	0.63	1.52	1.55	368	285	2.6	3.40
CT with chiseling	289.2	257.4	16.6	13.4	251.1	199.5	7.35	7.40	0.152	0.151	0.78	0.72	1.39	1.41	410	338	3.1	2.25
RT with chiseling	286.1	254.8	16.3	13.1	246.5	195.7	7.35	7.45	0.169	0.165	0.79	0.73	1.39	1.41	431	347	3.1	2.30
SEm±	3.4	3.2	0.35	0.3	5.55	4.5	0.04	0.12	0.005	0.005	0.02	0.02	0.02	0.01	14	5	0.1	0.03
CD (P=0.05)	NS	NS	1.0	0.85	16.2	13.0	0.10	NS	NS	NS	0.04	0.05	0.04	0.03	40	15	0.2	0.10
Nutrient (N)																		
RDF	267.7	237.6	14.3	11.4	215.0	167.6	7.60	7.65	0.162	0.161	0.68	0.61	1.49	1.51	326	259	2.7	2.80
RDF + FYM	280.3	249.4	15.7	12.5	235.7	184.9	7.35	7.40	0.161	0.160	0.79	0.73	1.40	1.44	425	337	3.1	2.55
RDF 125% + FYM	308.8	275.8	18.2	14.8	277.1	222.6	7.45	7.45	0.165	0.162	0.80	0.74	1.41	1.42	457	374	3.2	2.60
SEm±	4.3	3.9	0.3	0.3	4.8	4.7	0.06	0.05	0.003	0.004	0.02	0.02	0.03	0.02	8	10	0.1	0.11
CD (P=0.05)	12.5	11.3	0.85	0.8	14	13.9	0.15	0.15	NS	NS	0.04	0.05	0.08	0.06	24	30	0.2	0.10
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

EC, Electrical conductivity; OC, organic carbon; DHA, dehydrogenase activity; CT, conventional tillage; RT, rotary tillage, RDF, recommended dose of fertilizer

Table 5. Effect of tillage and nutrient management on use efficiency and partial factor productivity of different inputs in wheat (mean of 4 years)

Treatment	Energy-use efficiency	Radiation use efficiency (g/ m²/MJ)	Crop water use efficiency (kg/ha.mm)	Partial factor productivity of different inputs				
				N (kg grain yield/ kg N applied)	P (kg grain yield/ kg P applied)	K (kg grain yield/ kg K applied)	FYM (kg grain yield/ kg FYM applied)	Tillage (kg grain yield/ rupee invested on tillage)
Tillage (T)								
CT without chiseling	4.45	0.15	12.1	25.5	63.8	95.8	0.40	1.10
CT with chiseling	5.8	0.19	15.8	33.3	83.2	124.9	0.55	1.15
RT with chiseling	5.55	0.18	15.3	32.1	80.3	120.4	0.50	1.00
Nutrient (N)								
RDF	5.45	0.15	12.6	28.6	71.6	107.4	0.00	0.90
RDF+ FYM	5.1	0.17	14.4	33.0	82.4	123.7	0.50	1.05
RDF 125% + FYM	5.35	0.19	16.2	29.5	73.7	110.6	0.55	1.20

CT, Conventional tillage; RT, rotary tillage, RDF, recommended dose of fertilizer

Table 6. Interaction effect of tillage vs nutrient-management on growth and yield characters of wheat (mean of 4 years)

Interaction	Dry matter (g/m²) at 60 DAS	N uptake by crop (kg/ha) at 90 DAS	P uptake by crop (kg/ha) at 60 DAS	K uptake by crop (kg/ha) at 60 DAS	Tillers/m² at harvest time	Grain yield (t/ha)
CT without chiseling × RDF	208	63.9	5.3	30.0e	281	3.6
CT without chiseling × RDF with FYM	245	78.7	6.6	37.0	343	4.2
CT without chiseling × RDF 125% with FYM	294	98.4	8.2	46.5	402	4.6
CT with chiseling × RDF	297	97.6	7.9	44.6	405	4.6
CT with chiseling × RDF with FYM	352	116.9	9.9	56.1	434	5.5
CT with chiseling × RDF 125% with FYM	436	152.7	12.7	71.9	459	6.1
RT with chiseling × RDF	285	93.1	7.6	43.0	394	4.6
RT with chiseling × RDF with FYM	324	111.6	9.2	52.0	422	5.1
RT with chiseling × RDF 125% with FYM	408	142.6	11.8	66.7	446	5.9
SEm±	14.4	5.5	0.27	2.1	5.8	0.12
CD (P=0.05)	43.5	16.2	0.8	6.2	17.6	0.34

CT, Conventional tillage; RT, rotary tillage, RDF, recommended dose of fertilizer, DAS, days after sowing

dry matter and P and K uptake at 60 DAS, N uptake at 90 DAS and number of tillers at harvesting along with higher grain yield were recorded in CT with chiseling under the application of 125% RDF combined with FYM (Table 6). However, it was found to be on a par with RT with chiseling under 125% RDF and FYM application. All these crop characters were observed significantly lower in CT without chiseling under the application of RDF alone.

It can be concluded from the 4 years field experimentation that chiseling operation before the conventional or rotary tillage in wheat and integrated nutrient management with application of 125% RDF and 15 t/ha FYM resulted in higher grain yield in wheat with superior growth and yield-attributing characters. These tillage and nutrient-management options are also responsible for the improvement in soil physico-chemical and biological properties in wheat under rice–wheat cropping system along with higher monetary benefit and input-use efficiency.

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