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IMPACT OF CONSERVATION AGRICULTURE ON YIELD, NUTRIENT UPTAKE AND QUALITY OF WHEAT CROP IN CALCIORTHENT

Vijay Kumar, Mukesh Kumar, Santosh Kumar Singh and Shree Krishna Chandra

Department of Soil Science, Rajendra Agricultural University, Pusa, Samastipur - 848 125 (Bihar), India.

Abstract

Conservation agriculture (CA) practices were established during *kharif* 2006 in calcareous soil of Bihar in Randomized Block Design with eight combinations of tillage, crop establishment and residue management under rice-wheat cropping systems. The treatments involved different CA practices *viz*., puddled transplanted rice-conventional tillage wheat ($\mathbf{T_1}$); system of rice intensification-system of wheat intensification ($\mathbf{T_2}$); zero tillage rice-zero tillage wheat on beds ($\mathbf{T_3}$) with residues; zero tillage rice-conventional tillage wheat ($\mathbf{T_4}$) without residues; zero tillage rice-zero tillage wheat ($\mathbf{T_5}$) without residues; zero tillage rice-zero tillage wheat ($\mathbf{T_6}$) with residues; unpuddled transplanted rice-zero tillage wheat ($\mathbf{T_7}$) only rice residues; zero tillage rice with brown manuring-zero tillage wheat ($\mathbf{T_8}$) without residues. Grain, straw yield and nutrient uptake by wheat crop (cv HD 2733) during 2013-14 were significantly influenced by different treatments and the maximum increment of 24.49% was recorded in system of wheat intensification ($\mathbf{T_2}$). The corresponding increase in protein yield was 928.80 kg ha^{-1}. Among the yield attributes *viz*. number of effective tillers, number of grains per spike, 1000 grain weight were found to be maximum for treatment $\mathbf{T_2}$. Treatments $\mathbf{T_3}$, $\mathbf{T_5}$, $\mathbf{T_6}$ and $\mathbf{T_8}$ improved the grain and straw yield by 8.52-22.13% and 6.74-15.14%, respectively over conventional tillage ($\mathbf{T_1}$). However, in treatment $\mathbf{T_2}$ the straw yield reduced by 2.85% over conventional tillage wheat ($\mathbf{T_1}$). Nutrient uptake by wheat grain and straw followed the yield trends. The highest N, P and K uptake of 148.70, 12.00 and 11.12 kg ha^{-1}, respectively, by wheat grain was recorded in treatment $\mathbf{T_2}$, which was significantly superior over treatments $\mathbf{T_1}$ & $\mathbf{T_5}$ and all other treatments *viz*., $\mathbf{T_3}$, $\mathbf{T_4}$, $\mathbf{T_6}$, $\mathbf{T_7}$ and $\mathbf{T_8}$ were found to be at par. However, in case of wheat straw the highest N, P and K uptake of 67.47, 1.24 and 75.57 kg ha^{-1} was recorded in treatment $\mathbf{T_3}$, which was significantly superior over measurements $\mathbf{T_1}$ & $\mathbf{T_2}$ and all treatments were at par. The lowest uptake of N, P and K by wheat straw was recorded in treatment $\mathbf{T_2}$ *i.e.* 56.77, 1.04 and 63.59 kg ha^{-1}, respectively. Highest protein yield of 928.80 kg ha^{-1} was also observed in treatment $\mathbf{T_2}$. Results from this investigation suggest that system of rice intensification followed by system of wheat intensification *i.e.* treatment $\mathbf{T_2}$ proved best in improving wheat grain and protein content in calcareous soil owing to better soil-crop environment.

Key words : Calcareous soil, conservation agriculture (CA), wheat crop, uptake, yield.

Introduction

Rice and wheat in sequence are cultivated in two contrasting soil environments. Rice requires soft, puddled and water saturated soil conditions, while wheat requires well aggregated and well aerated soil with fine tilth. Puddling is the most common technique of land preparation for rice in South Asian countries, which creates soil conditions ideal for rice cultivation and also eliminates the weed growth, but unsuitable for upland crops which follow rice (Sharma *et al*., 2003). After rice harvest puddled soils, upon drying shrink, become compact and hard and develops surface cracks of varying sizes and shapes. The draft power requirement for tilling such soils is very high, sometimes beyond the reach of local ploughs and small tractors. Nevertheless, when tilled, these soils often break into larger clods, having high breaking energy (Sharma and Bhagat, 1993). Inspite of spending significant time and energy, it is often difficult to obtain seedbeds with the desired tilth for sowing of wheat. Wheat planted in seedbeds with coarse tilth, results in poor seedling emergence and unsatisfactory crop stands mainly due to poor seed soil contact. These problems are faced in soil under rice-wheat cropping system of Bihar having low organic carbon content and poor water retention ability. Crop production removes varying amounts of mineral nutrients from the soil, depending on production and nutrient-supplying capacity of the soil, which in turn is influenced by soil type, soil organic matter content, amount of nutrients applied and removal or recycling of crop residues in the soil. Rice and wheat are heavy feeders of nutrients. The rice-wheat system has not only resulted in mining of major nutrients (N, P, K and S) from the soil, but also has created a nutrient imbalance, leading to deterioration in soil quality and lowered the wheat productivity. The conventional wheat planting system involves repeated dry tillage to prepare the field followed by broadcasting of wheat seeds which also leads to further delay in wheat seeding by almost a week compared to zero tillage planting. Because of the shorter growing period coupled with its delayed planting, wheat grain filling stage coincides with high temperature (terminal heat) leading to large yield penalty. Though, the application of irrigation water at grain filling stage helps in adapting to terminal heat, most farmers in eastern Indo Gangetic Plain do not have economical access to irrigation water and hence wheat suffers with high temperature stress at grain filling with yield losses upto 30% (Jat *et al*., 2014). Conservation agriculture (CA) play an important role in respect of problem associated with intensive agriculture. Wheat yields with CA practices are either equal or even better than those obtained with conventional practices because of timely planting of wheat, efficient use of fertilizers and weed control. In addition, CA is fuel and energy efficient (Jat *et al*., 2014). Thus, CA technologies involving zero or reduced tillage in wheat improved water and nutrient-use efficiency. Use of green manure especially legumes in a cropping pattern could help restore soil nutrient and crop productivity and allow farmers to reduce inputs, maximize yields, conserve the natural resource base, and reduce risk due to both environmental and economic factors. Thus, farmers are shifting increasingly to direct seeding because of its similar or even higher yields (Sharma *et al*., 2003; Bhusan *et al*., 2007 and Farooq *et al*., 2009). Therefore, a long-term trial was established in 2006 to evaluate the tillage, crop establishment and residues management on growth and productivity of wheat in rice-wheat rotation.

Materials and Methods

An experiment on conservation agriculture (CA) was established at research farm of Rajendra Agricultural University, Pusa, Samastipur, Bihar (25.58510 N, 85.40313 E), during monsoon 2006 (*Kharif*) to study the influence of conservation agriculture (CA) practices involving various combinations of tillage, crop establishment and residue management in rice-wheat cropping system. The crop reported here is wheat (cv HD 2733) for *rabi* 2013-14. The soil of the experimental site was sandy loam in texture with alkaline pH (8.6), medium in organic carbon content (0.68%) and available N, P and K (111.96, 14.02 and 60.49 ppm), respectively. The average maximum and minimum temperature during experimentation (November, 2013-March, 2014) were 24.32^{O}C and 11.61^{O}C, respectively; average rainfall, humidity, evaporation, sunshine and wind speed were 4.57 mm, 71.60%, 1.95 mm, 4.62 and 6.73 km hrs^{-1}, respectively. The experiment was laid out in Randomized Block Design, replicated thrice within a block and involved eight treatments *viz*., puddled transplanted rice-conventional tillage wheat (**T$_1$**); system of rice intensification-system of wheat intensification (**T$_2$**); zero tillage rice-zero tillage wheat on beds having 50% rice residue retained in wheat cycle and 25% wheat residues retained in rice cycle (**T$_3$**); zero tillage rice-conventional tillage wheat without residues (**T$_4$**); zero tillage rice-zero tillage wheat without residues (**T$_5$**); zero tillage rice-zero tillage wheat having 50% rice residue retained in wheat cycle and 25% wheat residues retained in rice cycle (**T$_6$**); unpuddled transplanted rice-zero tillage wheat with 25% rice residues retained in wheat cycle (**T$_7$**); zero tillage rice with sesbania brown manure-zero tillage wheat without residues (**T$_8$**). The seed rate for treatments like conventional tillage wheat, system of wheat intensification, zero tillage with bed planting and zero tillage were 150, 30, 70 and 100 kg ha^{-1}, respectively. Both rice and wheat crops were fertilized at the rate of 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in all the treatments except for **T$_2$** which received 75 kg N, 30 kg P_2O_5 and 20 kg K_2O ha^{-1} along with 3000 kg ha^{-1} of organic manures. Yield attributing characters, *i.e.* effective tillers per meter square, numbers of grains per spike and 1000-grain weight (at 12% moisture content) were recorded. The crops were harvested manually from 5 m^2 randomly selected 3 quadrate from each plot and recorded the grain and straw yields. To determine the root biomass, three quadrants of 1 × 1 ft were laid down randomly in each plot during the grain filling stage. Metallic cores (10 cm internal diameter and 15 cm height) were used for taking samples for root studies from each treatment. The sample cores were kept in water overnight and then soil was removed from the roots by washing them with a fine jet of water. The roots were collected on fine sieves for final washing with a micro jet tap and were dried in oven at 60 ± 5^{0}C for 48 hours and subsequently their weight was taken to determine the root biomass. The results were expressed on dry weight basis (t ha^{-1}). Harvest index was calculated with the help biological and economical yield. The nutrient uptake by the crop was calculated by multiplying the nutrient content with dry matter yield. The nutrient content in grain and straw were determined as per the standard procedure (Tondon, 2005). Protein content in grain and straw were calculated with multiplying the N content with

6.25 and protein yield was determined by calculating the protein content with their respective yield. Statistical analysis was performed using the SPSS statistical package.

Results and Discussion

Yield attributes and yield

The adoption of SWI and zero tillage with residue retention significantly increased effective tillers, no. of grains per spike and 1000 grain weight (table 1). The effective tillers, no. of grains per spike and 1000 grain weight increased due to system of wheat intensification (**T_2**) by 21.13, 62.50 and 20.56%, respectively compared to the conventional tillage. It might be due to the addition of vermicompost, wider space and mechanical weeding facilitate the aeration in the root zone leads to more tiller formation. Similarly, zero tillage with residue retention (**T_3**, **T_6** and **T_7**) increased the effective tillers, no. of grains per spike and 1000 grain weight by 13.96-20.75, 41.67-58.33 and 15.14-20.21%, respectively, over conventional tillage, because of potentially improved physical, chemical and biological properties of soil after decomposition of crop residues as compared to conventional tillage.

Growth of the crop also depends upon the proper growth of the root (root biomass) and it was significantly influenced with different combination of tillage, crop establishment and residue management (table 1). Highest root biomass of wheat was observed for treatment **T_3** (2.34 t ha^{-1}), which was statistically at par with **T_6** (2.30 t ha^{-1}), **T_2** (2.24 t ha^{-1}), **T_4** (2.24 t ha^{-1}), **T_5** (2.16 t ha^{-1}) and **T_7** (2.21 t ha^{-1}) and significantly superior over **T_1** (1.98 t ha^{-1}). Per cent increment in root biomass under CA practices varied from, 7.52-18.18 and in system of wheat intensification by 13.13% over conventional practice. The crop residue retention in treatment **T_3** and **T_6** resulted in better equilibrium between macro and micro-porosity leading to increased root biomass in the surface soil layer, a finding supported by Bonfil *et al.* (1999). Restricted root growth under conventional tillage resulted from puddling which formed compacted layers in plow pan and restricted the root penetration and growth of succeeding crop after rice. The results are in conformity with the findings of Jha *et al.* (2011).

Grain yield of wheat was significantly influenced by different tillage, crop establishment and residue management practices. The maximum yield of wheat was obtained under **T_2** (6.19 Mg ha^{-1}), which was at par with **T_3** (6.07 Mg ha^{-1}), **T_6** (5.99 Mg ha^{-1}) and **T_7** (5.78 Mg ha^{-1}). Other treatments like **T_8** (5.72 Mg ha^{-1}), **T_4** (5.61 Mg ha^{-1}) and **T_5** (5.40 Mg ha^{-1}) also recorded higher yield as compared to **T_1** (4.97 Mg ha^{-1}). The data further indicate that the highest increment of 24.49% in wheat grain yield was recorded in treatment **T_2** followed by **T_3**, **T_6**, **T_7**, **T_8**, **T_4** and **T_5** *i.e.* 22.13, 20.47, 16.30, 14.98, 12.85 and 8.52%, respectively, over treatment **T_1** *i.e.* conventional practice. Highest grain yield in treatment **T_2** may be attributed to better root development owing to priming action of wheat seed and use of organic manures resulting in better physical, chemical and biological environment for crop growth. Better grain yield obtained in treatments **T_3**, **T_6** & **T_7** may be attributed to crop residues management and least soil disturbance in the preceding rice crop. These findings are in conformity with the findings of Sharma *et al.* (1990), Gupta *et al.* (1990) and Singh *et al.* (2014).

Higher residues retention resulted in more proliferation of root system and higher organic carbon, improved soil porosity, enhanced microbial population and infiltration rate which provided more favourable conditions for the crop, leading to higher productivity (Jat *et al.*, 2009). These results are also conformity with Pandey (2012) and Rathod *et al.* (2012). Conventional tillage had obtained the lowest wheat yield because wheat crop suffered the ills of puddling in preceding rice crop resulting in poor rooting due to soil compaction and poor aggregation as reported by other researchers in the region (Jat *et al.*, 2009; Kumar and Ladha, 2011 and Gathala *et al.*, 2011).

Maximum yield of wheat straw was recorded in treatment **T_3** (7.18 Mg ha^{-1}), which was statically at par with **T_6** (7.04 M ha^{-1}), **T_8** (6.96 Mg ha^{-1}), **T_4** (6.90 Mg ha^{-1}), **T_7** (6.87 Mg ha^{-1}) and **T_5** (6.65 Mg ha^{-1}), whereas, lowest yield was recorded in treatment **T_2** (6.06 Mg ha^{-1}). Per cent increase in straw yield to the tune of 15.14, 12.92, 11.65, 10.70, 10.25 and 6.74 was recorded by **T_6**, **T_3**, **T_8**, **T_4**, **T_7** and **T_5**, respectively, over **T_1** (6.23 Mg ha^{-1}).

Harvest index of wheat depends upon the grain and straw yield of crop. The per cent values of harvest index followed the patterns of obtaining a yield in different treatments (table 1). System of wheat intensification (**T_2**) obtained the highest per cent of harvest index (50.53%) as compared to rest of the treatment. Treatments **T_3**, **T_5**, **T_6**, **T_7** and **T_8** also recorded higher values of harvest index in the range of 44.81-45.81% as compared to conventional practice.

Nutrient uptake

Uptake of N, P and K (148.70, 12.00 and 11.12 kg ha^{-1}) respectively by wheat grain was highest under **T_2** treatment, which was statistically at par with **T_3** (146.45, 11.82 and 10.96 kg ha^{-1}), **T_6** (144.47, 11.66 and 10.81 kg

Table 1 : Impact of conservation agriculture on growth and yield of wheat under rice-wheat cropping system in Calciorthent.

Treatment	Effective tillers (m^{-2})	Number of grains ($spike^{-1}$)	1000 grain weight (g)	Root biomass (Mg ha^{-1})	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Harvest index (%)
T_1	265	24	40.02	1.98	4.97	6.23	44.38
T_2	321	39	48.25	2.24	6.19	6.06	50.53
T_3	320	38	48.11	2.34	6.07	7.18	45.81
T_4	282	29	41.65	2.24	5.61	6.90	44.84
T_5	277	28	40.98	2.16	5.40	6.65	44.81
T_6	315	35	46.93	2.30	5.99	7.04	45.97
T_7	302	34	46.08	2.21	5.78	6.87	45.69
T_8	289	32	45.89	2.13	5.72	6.96	45.11
CD (P = 0.05)	5.32	2.78	2.22	0.16	0.47	0.63	2.68

Table 2 : Impact of conservation agriculture on NPK uptake by grain and straw of wheat under rice-wheat cropping system in Calciorthent.

Treatment	Grain uptake (kg ha^{-1})			Straw uptake (kg ha^{-1})			Total uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
T_1	123.58	9.97	9.24	60.46	1.11	67.72	184.04	11.08	76.96
T_2	148.70	12.00	11.12	56.77	1.04	63.59	205.47	13.04	74.71
T_3	146.45	11.82	10.96	67.47	1.24	75.57	213.92	13.06	86.53
T_4	137.81	11.12	10.31	66.07	1.22	74.00	203.88	12.34	84.31
T_5	133.03	10.74	9.95	63.98	1.18	71.66	197.01	11.92	81.61
T_6	144.47	11.66	10.81	66.21	1.22	74.16	210.68	12.88	84.97
T_7	139.95	11.29	10.47	64.86	1.19	72.64	204.81	12.48	83.11
T_8	140.40	11.33	10.50	66.68	1.23	74.68	207.08	12.56	85.18
CD (P=0.05)	12.39	1.00	0.93	5.62	0.10	6.30	15.04	1.04	6.63

Table 3 : Impact of conservation agriculture on protein yield of wheat under rice-wheat cropping system of Calciorthent.

Treatment	Protein content in grain (%)	Protein content in straw (%)	Protein yield (kg ha^{-1})
T_1	15.37	6.06	774.08
T_2	14.96	5.88	928.80
T_3	14.96	5.88	915.05
T_4	15.12	6.00	863.00
T_5	15.79	6.00	829.94
T_6	14.87	5.88	902.55
T_7	15.12	5.88	874.98
T_8	15.46	6.00	879.30
CD (P=0.05)	NS	NS	77.45

ha^{-1}), $\mathbf{T_8}$ (140.40, 11.33 and 10.50 kg ha^{-1}), $\mathbf{T_7}$ (139.98, 11.29 and 10.47 kg ha^{-1}) and $\mathbf{T_4}$ (137.81, 11.12 and 10.31 kg ha^{-1}) and these treatments were significantly superior to $\mathbf{T_5}$ (133.03, 10.74 and 9.95 kg ha^{-1}) and $\mathbf{T_1}$ (123.58, 9.97 and 9.24 kg ha^{-1}). Highest net uptake in treatment $\mathbf{T_2}$ may be accounted for wider spacing of plants resulting in better light and air utilization. Moreover, mechanical weeding applied in treatment $\mathbf{T_2}$ not only loosened the soil and helped in aeration but also helped to control weeds. Similar observations were also made by Shekher *et al.* (2009). Higher uptake of N, P and K in treatment $\mathbf{T_8}$ was perhaps due to more dry matter production (wheat grain) by crop and less nutrient depletion due to better management practices and subsequently more availability of nutrients to crop. These findings corroborate with those of Mukherjee (2008) and Gupta *et al.* (2007).

Uptake of N, P and K by wheat straw was also significantly influenced with combinations of tillage, crop establishment and residue management practices. Higher N, P & K uptake was recorded under the treatment of T_3 (67.47, 75.57 and 1.24 kg ha^{-1}, respectively), which was at par with T_8 (66.68, 74.68 and 1.23 kg ha^{-1}), T_6 (66.21, 74.16 and 1.22 kg ha^{-1}), T_4 (66.07, 74.00 and 1.22 kg ha^{-1}), T_7 (64.86, 72.64 and 1.19 kg ha^{-1}) and T_5 (63.98, 71.66 and 1.18 kg ha^{-1}). Whereas, lowest uptake of N, P and K were recorded with treatment T_2 (56.77, 1.04 and 63.59 kg ha^{-1}, respectively).

Similarly, highest total uptake of N, P and K was obtained for treatment T_3 *i.e.* 213.92, 13.06 and 86.53 kg ha^{-1}, respectively. The highest nutrient uptake recorded under treatment T_3 may be due to the better soil environment, high seed rate, and better root growth conditioned by better moisture supply, favorable soil temperatures and less impedance to root proliferation which resulted in better translocation of absorbing nutrients from soil and its translocation to plant and seed translating into higher plant growth, grain and straw yields and ultimately increased the uptake of nutrient. Other studies also suggested that the presence of organic residues on the surface induced more root growth and resulted in increased removal of nutrients by crops (Thiagalingam *et al.*, 1991). These results are in conformity to those reported by Dwivedi and Thakur (2000) under silt-clay loam soil that incorporation of rice straw increased the nutrient uptake. Similarly, findings were also reported by Das *et al.* (2001) in rice.

Protein yield

The data on protein content in grain and straw are presented in table 3. Maximum protein yield was observed in treatment T_2 (928.80 kg ha^{-1}), which was statistically at par with T_6 (902.55 kg ha^{-1}), T_3 (915.05 kg ha^{-1}), T_8 (879.30 kg ha^{-1}), T_7 (874.98 kg ha^{-1}) and T_4 (863.00 kg ha^{-1}) and was superior over T_1 (774.08 kg ha^{-1}). Overall increase in protein yield was 19.99% in treatment T_2, whereas, the variation for treatments T_3, T_5, T_6, T_7 and T_8 ranged from 13.03-18.21% over conventional tillage. The increase in protein yield owing to nitrogen addition, through the addition of vermicompost in T_2 and decomposition of residues in treatment T_3, T_5, T_6, T_7 and T_8 might be attributed to its involvement in N metabolism (Singh and Kumar, 2014). Residues which nitrify rapidly and release greater amounts of available nitrogen during the growing season result in higher yields and protein content of wheat than those residues, which nitrify, slowly and release smaller amounts of available nitrogen. These results are in agreement with those reported by Najafinezhad (2007), who found that residue retention is more effective in increasing protein content.

Based on the study, it may be concluded that system of rice intensification for rice crop followed by system of wheat intensification in wheat crop *i.e.* treatment T_2 proved best for improving grain yield of wheat crop. Other management practices involving zero, reduced or minimum tillage and residues retention (T_3, T_5, T_6, T_7 and T_8) also proved beneficial in improving wheat grain yield. In other words the ill effect of puddling in succeeding of wheat crop can be mitigated by using conservation agriculture along with crop residues/ organic manure management.

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