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Research Article

Growth and yield performance of zero tillage wheat (*Triticum aestivum* L.) under varying rice residue load and nutrient management options

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Abstract

Conservation Agriculture (CA) based rice-wheat system improve overall productivity and profitability with improved production efficiencies and better environmental quality. Under CA it is very crucial to retain the residues, but to what extent? - still it is unanswered. There is an opportunity to manage nutrients in a more precise way under varying rice residue retained- wheat cultivation in sub-Himalayan plains of West Bengal. Keeping these in backdrop, a field experiment was conducted during the *rabi* season of 2021-2022 and 2022-2023 at Conservation Agriculture Block, Instructional Farm, Uttar Banga Krishi Viswavidyalaya, West Bengal to assess the impact of varying rice residue retention and nutrient management options on the growth and yield performances of subsequent zero tillage wheat. The experiment was laid out in split plot design having four main plot treatments of various heights of rice residue (rice straw kept at various heights after harvesting *i.e.,* R_0 – at ground level *i.e.,* 0 cm, R_1 - 15 cm, R_2 - 30 cm and R_3 - 45 cm) and five nutrient management options as sub-plot treatments (N_1 - Control, N_2 - Recommended dose of fertilizer (RDF), N_3 - Nutrient Expert® (NE), N_4 - RDF + Bio and N_5 - NE + Bio), each replicated thrice. The wheat variety used in the experiment was DBW 187. Results revealed that rice residue retention did not show any significant effect on overall growth parameters, yield attributes and yield of wheat crop. However, higher grain yield (4.48 and 4.16 t ha^{-1}) was obtained under the treatment R_2 in which the rice straw was retained at 30 cm height. Nutrient management options had a significant impact on all growth parameters, yield attributes and yield of wheat. Results highlighted that management of nutrients in a balanced way as guided by NE® and seed inoculation with bio-fertilizers (N_5) significantly improved spike no. m^{-2} (277 and 268), filled grains spike^{-1} (43.40 and 46.73), spike length (11.13 and 11.70 cm), 1000-grain weight (40.70 and 40.67 g) *vis-a-vis* higher grain yield (5.27 and 4.64 t ha^{-1}) as compared to other treatments. Lower values of growth, yield attributes and yield were obtained under the treatments where no above ground residues were kept (R_0) and without any application of fertilizers (N_1). It can be concluded that retention of residues at 30 cm height (R_2) and nutrient management as guided by NE® along with seed inoculation with *Azotobacter* and *PSB* could increase the productivity of zero tillage wheat cultivation under this zone.

Key Words: Bio-fertilizers, conservation agriculture, Nutrient Expert®, nutrient management, rice residue

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple food grain crops in the world and stands next to rice in India. It contributes nearly 30 % to the food basket of the country (Shiferaw *et al.*, 2013). India is the second leading producer of wheat after China in the world. In India, wheat was grown in about 31.13 M ha with the production of 109.59 MT and the average productivity of 3421 kg ha^{-1} during 2021-2022 (USDA, 2023). In Indo-Gangetic plains, rice-wheat cropping system is one of the major agriculture production system which was practiced in about 14 M ha of area (Alam *et al.*, 2016). It is also a common cropping sequence in sub-Himalayan plains of West Bengal where rice is grown mostly under rainfed puddle condition and wheat is grown after harvesting rice in tilled land. The sowing of wheat mostly gets delayed due to presence of high soil residual moisture even after harvesting of medium-long duration rice varieties (Mitra and Das, 2015; Mitra and Patra, 2019). Intensive tillage practices coupled with residue burning are quite common in the country which adversely affects the soil quality and in turn results in low levels of soil organic carbon, yield stagnation, low farm profitability, poor soil biota and low factor productivity (Lal, 2006). To reverse the situation, Conservation agriculture (CA) play an important role in respect of problems associated with intensive agriculture which could meet the ever-increasing food demand worldwide with sustainable intensification of crops and various resources (Lal, 2015). CA is characterized by three major principles: i) minimum soil disturbances; ii) maintaining and managing crop residues (at least 30% of the total crop load) and iii) diversification of crop species (may be spatial or temporal) including legumes (FAO, 2019). Many researches carried out over the Indo-Gangetic plains (IGP) in recent years confirmed the claim that CA can improve overall productivity and profitability of rice-wheat system with increased yields, reduced production cost, improved efficiencies of resource use with better environmental quality (Gathala *et al.*, 2011; Hossen *et al.*, 2018; Jat *et al.*, 2019). Even under sub-Himalayan plains of West Bengal, it was observed that wheat yields with CA practices are either equal or even better than those obtained with conventional practices (Mitra *et al.*, 2014; Mondal *et al.*, 2018; Mitra *et al.*, 2019).

Under CA system, many a times the residue load itself is a determining factor. Still we are searching the answer of the question that how much residues are to be retained for getting higher productivity and soil health benefits in CA based rice-wheat rotation. Along with the CA practices there is need for precise management of N fertilizer in wheat for both economic and environmental prospective. Static fertilizer recommendations based on average response lead to excessive and inadequate fertilizer application with high N losses. Inappropriate nutrient management is one of the major factors causing such yields gaps in wheat (Majumdar *et al.,* 2013). In sub-Himalayan plains of West Bengal, decision support tools like Nutrient Expert® following the principles of 4R nutrient stewardship (right source, right rate, right time and right method) (Pampolino *et al.*, 2012) might be used in a precise way for balanced fertilization. The beneficial effect of such a user-friendly nutrient decision support tool has already been proved in wheat nutrient management under both zero tillage as well as conventional tillage systems (Mondal *et al.*, 2018; Mitra *et al.*, 2019). Moreover, under CA system with varying loads of rice residue retention, nutrient management in wheat will become a crucial issue. Thus, there is an opportunity to manage nutrients in a more precise way in varying rice residue retained- wheat cultivation. Apart from chemical fertilizers recommended through any decision support system, we may adopt environment friendly and sustainable nutrient management package through use of bio-fertilizers also (Yasin *et al.*, 2012). Keeping this in backdrop a field experiment was conducted with varying rice residue load and nutrient management options to assess its impact on growth and yield performances of zero tillage wheat.

2. Materials and Methods

The field experiment was conducted during the *rabi* seasons of 2021-2022 and 2022-2023 at Conservation Agriculture Block, Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal, located at 26°24'02.2"N latitude, 89°23'21.7"E longitude and at an elevation of 43 meters above mean sea level (msl). The experimental site was situated in sub-tropical per humid region receiving higher monsoon and pre-monsoon rainfall with a drier winter months.The soil of the experimental site was sandy loam in texture with pH 5.53, Organic C 0.71 %, low available N (134.58 kg ha^{-1}), high available P (39.90 kg ha^{-1}) and low available K (129.46 kg ha^{-1}) . Before establishment of current experiment, the site was under continuous rice (unpuddled) - wheat (zero tillage) cropping system for past 5 years.

The experiment was laid out in split plot design with four main plot treatments comprising various heights of rice residue retention (R_0: No above ground rice residue; R_1: harvesting the preceding rice crop at 15 cm height from the ground level; R_2: harvesting the preceding rice crop at 30 cm height from the ground level; R_3: harvesting the preceding rice crop at 45 cm height from the ground level) and five nutrient management options as sub-plot treatments (N_1: No application of nutrients *i.e.*, control; N_2: Recommended dose of fertilizer (RDF) 150: 60: 40 kg ha^{-1}N: P_2O_5: K_2O; N_3: Nutrient Expert (NE) based recommendation *i.e.,* 144: 72: 72 kg ha^{-1} N: P_2O_5: K_2O; N_4: RDF + biofertilizers (*Azotobactor* and *PSB* as seed inoculants); N_5: NE + biofertilizers (*Azotobactor* and *PSB* as seed inoculants), each replicated thrice. The size of each experimental plot was 20 m × 2.2 m. Rice variety included in the experiment was MTU 1153, a short duration variety matures in 115-120 days with a yield potential of 6.5 t ha^{-1}. This rice variety was harvested manually at different heights during both the years and residue load was expressed on dry weight basis (Table 1).

Table 1. Rice residue load of various treatments

Treatments	Residue load (t ha^{-1})	
	2021-2022	2022-2023
R_1 (15 cm)	1.35	1.83
R_2 (30 cm)	2.56	3.57
R_3 (45 cm)	3.63	4.78

The wheat variety used in the experiment was DBW 187, suitable for early sown irrigated conditions of both NEPZ and NWPZ, matures in about 115-120 days exhibiting disease resistance and has the ability to adapt variable growing conditions. After harvest of preceding rice crop at varying heights, glyphosate 41% SL @ 3.5 lit ha^{-1} was sprayed 7 days prior to sowing to control the existing weed flora. Sowing was done with the help of happy seeder by maintaining the row spacing of about 20 cm with a seed rate of 120 kg ha^{-1}. A post emergence ready mix herbicides metribuzin 42 % + clodinofop propagyl 12% @ 0.75 kg ha^{-1} was applied at 4 weeks after seeding to control the broad-leaf weeds which emerged later. Spraying of boron was done twice by using Solubor (20% B) @ 0.20% at 35-40 DAS and at 55-60 DAS. Zinc was also applied at 55-60 DAS in foliar form using chelated zinc (Chelamin) @ 0.10%.

Based on the treatments seeds were treated with bio-fertilizers (*Azotobacter* + *PSB*) @ 5 g kg^{-1} of seeds before sowing. Fertilizer application was done based on the treatments. The basal application of fertilizers was done through NPK complex fertilizer (IFFCO 10: 26: 26) placed in the furrow during seeding with happy seeder. Remaining amount of N as urea was applied through topdressing in two split doses at first and second irrigation.

The data on growth attributes like number of tillers m^{-2}, leaf area index was recorded periodically at 15 days interval; while the plant height was recorded at harvest. Yield attributes like number of spikes m^{-2}, number of filled grains spike^{-1}, spike length (cm), 1000-grain weight (g) and grain yield (kg ha^{-1}) were recorded at the time of harvest. The grain yield was estimated from a net plot area of 32.4 m^2 (18 m long and 1.8 m width) excluding the border rows. After threshing, the grains were sun dried and yield was expressed in tonnes per hectare at 12% moisture content.

3. Results and Discussion

3.1 Growth Parameters

Most of the growth parameters did not show any significant effect due to various loads of rice residue during both the years (Table 2). Varying left over rice residue had no significant impact on plant height harvest and total number of tillers m^{-2} at periodic intervals. Leaf area index differed significantly due to various loads of rice residue at 45 and 75 DAS during the first year. At 45 DAS higher leaf area index (1.91) was recorded under the treatment R_2 and at 75 DAS higher leaf area index (3.02) was recorded under treatment R_3. During the second-year various rice residue load did not show any significant effect on leaf area index at all the growth stages (Table 2). Higher leaf area index under the respective residue retention treatments might be due to better soil moisture provided by the higher residues resulted in better exploration of solar radiation reflected through taller plants with more tillers. The results were in conformity with the findings of Brar *et al.* (2010), Pooniya and Shivay (2011) and Arora *et al.* (2023) who claimed that there was a significant influence on leaf area index due to retention of crop residues as compared to residual removal treatments.

However, various nutrient management practices had a significant influence on plant height during both the years. During first year highest plant height (97.17 cm) was recorded under the treatment N_2 (RDF) and during the second-year plant height was higher (94.18 cm) under the treatment N_3 (NE), respectively. The higher values of plant height with respect to the above treatments might be due to positive effect of individual and balanced plant nutrients which may have induced cell division and expansion, photosynthetic efficiency and meristematic activity resulting in better plant growth (Sekar, 2003). The results obtained were in conformity with the findings of Kumar *et al.* (2010), Mauriya *et al.* (2013) and Kumar *et al.* (2016) who concluded that nutrient recommendation through site specific nutrient management resulted in producing taller plants. During the first year at 45, 60 and 75 DAS treatment N_3 (NE) recorded the highest tiller number (317, 348 and 359 at 45, 60 and 75 DAS, respectively). This might be due to providing optimum amount of nutrients to the crop and maintaining without any nutritional stress as like in control treatment. The obtained results were in conformity with the findings of Mohanty *et al.* (2015). They found that recommendation of nutrients through SSNM significantly increases the number of tillers as compared to RDF and control plots. Addition of extra phosphorus and potassium might have a crucial role towards tiller development. During the second year at 45 DAS treatment N_3 recorded higher tiller number (287 m^{-2}) and treatment N_5 (NE + Bio) resulted in higher tiller number per square meter at 60 and 75 DAS (322 and 336 m^{-2} at 60 and 75 DAS, respectively). This might be attributed to integrated application of bio-fertilizer and inorganic sources of fertilizers which resulted in improved germination percentage, better crop stands and nutrient availability which resulted in higher tiller number. The similar results of higher tiller number were observed with the integrated application of organic and chemical fertilizers as reported by Kumar *et al.* (2013) and Kumar *et al.* (2021). Singh *et al.* (2016) reported that co-inoculation of *Azotobacter* and *PSB* along with chemical fertilizers significantly increased the tiller number in wheat over control. At 45 and 60 DAS significantly higher leaf area index (1.99 and 1.54 and 4.36 and 3.98 at 45 and 60 DAS during 2021-2022 and 2022-2023, respectively) was recorded under treatment N_5 (NE + Bio). At 75 DAS significantly higher leaf area index (3.68) was obtained under treatment N_2 (RDF) during the first year and during second year leaf area index was higher (4.25) under the treatment N_5 (NE + Bio). The significant increase in leaf area index under various nutrient management options might be attributed to better integration of bio-fertilizers and chemical fertilizers which might have provided the balance amount of nutrients especially at active crop growth stages through both the sources which helped in producing maximum leaf area index (Fazily *et al.*, 2021). The results were also in conformity with the findings of Prasad *et al.* (2010) who reported that providing optimum amount of nutrients especially nitrogen at active growing crop period results in maximum leaf area thereby higher leaf area index. Findings of Mohanty *et al.* (2015) and Kaur *et al.* (2016) also suggested that the site-specific nutrient management practices had a significant impact on leaf area index of wheat.

3.2 Yield Attributes

Various loads of rice residue did not show any significant impact on yield attributes of wheat during both the years except the 1000-grain weight during the first year. Significantly higher test weight (39.91 g) during the first year was obtained under the treatment R_3 (where residues were retained at 45cm height) (Table 3).

Nevertheless, various nutrient management practices showed significant effect on various yield attributes during both the years. Significantly higher number of spikes m^{-2} (314 and 288), number of filled grains spike^{-1} (47.00 and 49.33) and spike length (11.50 and 11.90 cm) during 2021-2022 and 2022-2023, respectively was obtained under the treatment N_5 (NE + Bio). Improved yield attributes under the above-mentioned treatments might be due to balanced fertilization which contributed to better plant growth and enhanced translocation of photosynthates to sink which resulted in producing higher values of yield components. When the application of nutrients was carried out using SSNM practice, other studies also indicated increased value of yield components (Mauriya *et al.* 2013; Mohanty *et al.* 2015; Mondal *et al.* 2018; and Mitra *et al.*, 2019). Kantwa *et al.* (2023) reported that application of chemical fertilizers along with the seed inoculation of *Azotobacter* and *PSB* had a significant impact on yield attributing

Table No 2. Growth attributes of wheat as influenced by various rice residue load and nutrient management options.

Treatments	Plant height at harvest (cm)		No. of tillers m^{-2}						Leaf area index					
			2021-2022			2022-2023			2021-2022			2022-2023		
	2021-22	2021-22	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
Residue load														
R_0	93.21	87.98	266	293	304	249	279	293	1.72	3.90	3.26	1.42	3.57	3.91
R_1	92.77	88.40	277	306	321	254	285	301	1.84	4.15	3.40	1.46	3.63	3.90
R_2	91.49	88.87	276	307	322	264	294	307	1.91	4.15	3.35	1.47	3.73	4.01
R_3	92.15	91.09	268	302	314	260	284	295	1.66	3.95	3.52	1.41	3.71	3.98
SEm (±)	2.54	0.85	4.38	8.32	7.02	7.55	10.80	5.95	0.05	0.09	0.048	0.025	0.06	0.04
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.17	NS	0.165	NS	NS	NS
Nutrient management options														
N_1	79.77	73.12	169	188	199	168	188	199	1.42	2.82	2.48	1.32	2.58	2.80
N_2	97.17	92.80	296	324	337	268	300	314	1.71	4.33	3.68	1.43	3.88	4.25
N_3	94.31	94.18	317	348	358	286	314	327	1.88	4.32	3.53	1.44	3.92	4.20
N_4	96.13	92.27	289	323	339	276	304	320	1.92	4.35	3.64	1.47	3.95	4.25
N_5	94.64	93.07	290	327	343	285	321	335	1.99	4.36	3.57	1.54	3.98	4.24
SEm (±)	2.19	1.19	7.12	10.44	10.50	10.86	12.18	10.58	0.07	0.08	0.10	0.03	0.06	0.05
CD(P=0.05)	6.32	3.44	20.53	30.08	30.26	31.30	35.10	30.49	0.20	0.24	0.28	0.08	0.17	0.15

Table 3. Yield attributes of wheat as influenced by various rice residue load and nutrient management options.

Treatments	Number of spikes m^{-2}		No. of filled grains $spike^{-1}$		Spike length (cm)		1000-grain weight (g)	
	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023
Residue load								
R_0	267	255	41.87	44.87	10.95	11.23	39.39	39.65
R_1	276	253	43.13	44.87	10.92	11.22	39.60	39.83
R_2	277	268	43.40	46.73	11.13	11.70	39.77	39.89
R_3	274	247	42.33	46.20	10.92	11.38	39.91	39.92

SEm (±)	7.26	10.50	1.261	1.08	0.13	0.17	0.07	0.07
CD(P=0.05)	NS	NS	NS	NS	NS	NS	0.26	NS
Nutrient management options								
N_1	163	168	29.50	33.92	9.65	9.81	35.93	36.51
N_2	280	268	45.17	47.42	11.13	11.63	40.48	40.60
N_3	302	278	45.83	48.58	11.27	11.72	40.60	40.65
N_4	309	277	45.92	49.08	11.36	11.78	40.63	40.69
N_5	313	288	47.00	49.33	11.50	11.98	40.70	40.67
SEm (±)	7.94	7.64	1.05	1.14	0.21	0.19	0.08	0.18
CD(P=0.05)	22.88	22.03	3.02	3.30	0.61	0.55	0.25	0.53

Table 4. Grain yield (t ha^{-1}) of wheat as influenced by various rice residue load and nutrient management options.

Treatment combinations	2021-2022					2022-2023				
	R_0	**R_1**	**R_2**	**R_3**	**Mean**	**R_0**	**R_1**	**R_2**	**R_3**	**Mean**
N_1	1.36	1.67	1.71	1.57	1.58	1.54	1.63	1.77	1.71	1.67
N_2	4.52	4.74	4.94	4.71	4.73	4.06	4.21	4.37	4.02	4.17
N_3	4.89	4.95	5.08	5.09	5.01	4.38	4.28	4.64	4.29	4.40
N_4	4.89	5.23	5.24	5.13	5.12	4.29	4.32	4.91	4.29	4.45
N_5	5.06	5.38	5.43	5.20	5.27	4.59	4.44	5.09	4.44	4.64
Mean	4.14	4.39	4.48	4.34		3.77	3.77	4.16	3.75	
	R	N	R x N	N x R		R	N	R x N	N x R	
SEm (±)	0.09	0.10	0.20	0.21		0.06	0.13	0.26	0.24	
CD(P=0.05)	NS	0.30	NS	NS		0.22	0.37	NS	NS	

characters of wheat. The highest test weight (40.70 g) was obtained under the treatment N_5 (NE+Bio) during the first year; while, N_4 (RDF+Bio) resulted in the higher test weight (40.69) during the second year, being statistically at par with the treatment N_5 (NE+Bio) having test weight 40.67 g. Being the genetic character, there was not much alteration in 1000-grain weight irrespective of treatments; though there was huge reduction in test weight under non fertilized plots. Similar findings were reported by Sanadi *et al.* (2022) who claimed that application of nutrients through site specific and balanced nutrient management produced significantly higher test weight.

3.3 Grain Yield (t ha^{-1})

Varying rice residue load did not show any significant variation in grain yield of wheat during the first year. During second year, significantly higher grain yield (4.16 t ha^{-1}) was obtained under the treatment R_2 where rice residues were retained at 30 cm height (Table 4). The results clearly highlighted that removal as well as excess amount of residues were not favorable for wheat crop grown in this region and maintaining rice residue load of around 3-3.5 t ha^{-1} was optimum for providing a better microclimate for the crop in this region. Maintaining optimum amount of residues was relatively good as compared to excess rice residues or no rice residues as the yield was less under both the treatments. Extra residues interfered with the smooth running of zero till drill for which there was reduction in overall stand count also. The results were in conformity with the findings of Sirazuddin *et al.* (2019) who found that higher residue load had detrimental effect with respect to growth and yield.

Among the different nutrient management options, significantly higher grain yield (5.27 and 4.64 t ha^{-1} during 2021-2022 and 2022-2023, respectively) was recorded in the N_5 treatment (NE + Bio). Increment in the grain yield under the mentioned treatment might be due to balanced fertilization as guided by nutrient expert and seed inoculation of bio-fertilizers which resulted in improving the activity of various microorganisms which helps in the solubilization of insoluble nutrients thereby improving crop nutrient uptake that results in better growth, yield attributes and yield of wheat. According to Rajesh *et al.* (2018) the increased grain yield in the mentioned treatment might be attributed to targeted yield techniques and capacity to manage the crop's nutrient needs more effectively and improve photosynthates translocation from source to sink. Excess P and K application resulted from NE treatments might be bringing more balanced nutrition to the crop. Similarly, Sunil *et al.* (2018) reported that SSNM based nutrient recommendation significantly improved the yield of wheat. Results were also in close conformity with findings of Singh *et al.* (2016) who claimed that integration of chemical and bio-fertilizers had statistically significant impact on grain yield of wheat.

Conclusion

It can be concluded from this 2-years trial that higher residues retention might not be beneficial for subsequent zero tillage wheat grown in sub-Himalayan plains of West Bengal. Retaining the residues at 30 cm height and nutrient management as guided by Nutrient Expert® along with seed inoculation of *Azotobacter* and *PSB* could improve growth and yield of wheat in this region.

Author contributions

Conceptualization of research (BM); Designing of the experiments (MSLR and BM); Contribution of experimental materials (MSLR and BM); Execution of field/lab experiments and data collection (MSLR and BM); Analysis of data and interpretation (MSLR and BM); Preparation of the manuscript (MSLR and BM).

Conflict of interest: No

Declaration

The authors declare no conflict of interest.

References

1. Alam MK, WK Biswas and RW Bell. 2016. Greenhouse gas implications of novel and conventional rice production technologies in the Eastern-Gangetic plains. *Journal of Cleaner Production* 112: 3977–3987.

2. Arora, K, RS Bana, S Sepat, B Phogat, P Devatwal and S Anchra. 2023. Effect of Residue Recycling on Leaf Area Index and Nutrient Uptake Pattern of Wheat Crop under Different Potassium Management Practices. *Biological Forum - An International Journal* 15(2): 414–419.

3. Brar AS and US Walia. 2010. Rice residue position and load in conjunction with weed control Treatments interference with growth and development of

Phalaris minor retz. and wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science* 42 (3&4): 163–167.

4. Fazily T, SK Thakral and AK Dhaka. 2021. Effect of Integrated Nutrient Management on Growth, Yield Attributes and Yield of Wheat. *International Journal of Advances in Agricultural Science and Technology* 8(1): 106–118.

5. FAO. 2019. Conservation Agriculture. Available online at: http://www.fao.org/conservation-agriculture/overview/what-is-conservation agriculture/en/ (accessed August 2019).

6. Gathala MK, JK Ladha, V Kumar, YS Saharawat, V Kumar, PK Sharma, S Sharma and H Pathak. 2011. Tillage and Crop Establishment Affects Sustainability of South Asian Rice–Wheat System. *Agronomy Journal* 103(4): 961-971.

7. Hossen MA, MM Hossain, ME Haque and RW Bell. 2018. Transplanting into non puddled soils with a small-scale mechanical transplanter reduced fuel, labour and irrigation water requirements for rice (*Oryza sativa* L.) establishment and increased yield. *Field Crops Research* 225:141–151.

8. Jat RK, RG Singh, M Kumar, ML Jat, CM Parihar, D Bijarniya, JM Sutaliya, MK Jat, MD Parihar, SK Kakraliya and RK Gupta. 2019. Ten years of conservation agriculture in a rice-maize rotation of eastern Gangetic plains of India: yield trends, water productivity and economic profitability. *Field Crops Research* 232: 1–10.

9. Kantwa CR, PK Saras, KG Vyas, HL Chaudhari, RR Choudhary, SA Patel, SRK Singh and BJ Patel. 2023. Effect of Wheat Varieties and Integrated Nutrient Management Practices on Nutrient Content, Uptake and Soil Nutrient Status. *Indian Journal of Agricultural Research*, pp: 1–5.

10. Kaur H, H Ram, R Sikka and H Kaur. 2016. Productivity, agronomic efficiency and quality of bread wheat [*Triticum aestivum* (L.)] cultivars in relation to nitrogen. *International Journal of Agriculture Environment and Biotechnology*, **9**: 101–106.

11. Kumar A, KD Sharma and A Yadav. 2010. Enhancing yield and water productivity of wheat (*Triticum aestivum*) through furrow irrigated raised bed system in the Indo-Gangetic Plains of India. *Indian Journal of Agricultural Sciences* 80: 198–202.

12. Kumar D, RA Singh and Y Singh. 2016. Influence of sowing dates and nitrogen scheduling on growth behavior and productivity of late sown wheat (*Triticum aestivum*) in north Indian plains. *Annals of Agricultural Research* 37: 61–65.

13. Kumar P, SD Dubey, US Tiwari, RK Pandey, K Hussain and RK Singh. 2021. Effect of VC, FYM, S, Zn, *Azotobacter* and *PSB* on Growth and Yield Attributes of Maize and Wheat. *International Journal of Current Microbiology and Applied Sciences* 10(6): 764–773.

14. Kumar V, YS Saharawat, MK Gathala, AS Jat, SK Singh, N Chaudhary and ML Jat. 2013. Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in the Indo-Gangetic Plains. *Field Crops Research* 142: 1–8.

15. Lal, R. 2006. Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degradation and Development* 17:197-209.

16. Lal R. 2015. Sequestering carbon and increasing productivity by conservation agriculture. *Journal of Soil and Water Conservation* 70(3): 55A–62A.

17. Majumdar K, ML Jat, M Pampolino, S Dutta and A Kumar. 2013. Nutrient management in wheat: current scenario, improved strategies and future research needs in India. *Journal of Wheat Research* 4(1): 1–10.

18. Mauriya AK, VK Maurya, HP Tripathi, RK Verma and S Radhey. 2013. Effect of site specific nutrient management on productivity and economics of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) system. *Indian Journal of Agronomy* 58: 282–287.

19. Mitra B and K Patra. 2019. Performance of rice wheat system under conservation agriculture based establishment techniques in eastern Indian plains. *Journal of Cereal Research* 11(3): 268–274.

20. Mitra B, K Majumdar K, SKR Dutta, T Mondal, S Das, H Banerjee, K Ray and T Satyanarayana. 2019. Nutrient management in wheat (*Triticum aestivum*) production system under conventional and zero

tillage in eastern sub-Himalayan plains of India. *Indian Journal of Agricultural Sciences* 89(5): 775–784.

21. Mitra B, S Mookherjee and S Das. 2014. Performances of wheat under various tillage and nitrogen management in sub-Himalayan plains of West Bengal. *Journal of Wheat Research* 6(2): 150–153.

22. Mitra B and S Das. 2015. Economization of irrigation schedule in wheat (*Triticum aestivum* L.) cultivation under sub-Himalayan plains of West Bengal. *Journal of Crop and Weed* 11(2): 122–126.

23. Mohanty SK, AK Singh, SL Jat, CM Parihar, V Pooniya, S Sharma, V Chaudhary and B Singh. 2015. Precision nitrogen-management practices influences growth and yield of wheat (*Triticum aestivum*) under conservation agriculture. *Indian Journal of Agronomy* 60(4): 617–621.

24. Mondal T, B Mitra and Das S. 2018. Precision nutrient management in wheat (*Triticum aestivum*) using Nutrient Expert®: Growth phenology, yield, nitrogen-use efficiency and profitability under eastern sub-Himalayan plains. *Indian Journal of Agronomy* 63(2): 174–180.

25. Pampolino M, K Majumdar, ML Jat, T Satyanarayana, A Kumar, VB Shahi, N Gupta and V Singh. 2012. Development and Evaluation of Nutrient Expert for Wheat in South Asia. *Better Crops* 96(3): 29–31.

26. Pooniya V and YS Shivay. 2011. Effect of green manuring and zinc fertilization on productivity and nutrient uptake in basmati rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* 56(1): 29–35.

27. Prasad RK, V Kumar, B Prasad and A P Singh. 2010. Long term effect of crop residue and Zn fertilizer on crop yield, nutrient uptake and fertility build up under Rice-Wheat cropping system in Calciorthents. J*ournal of Indian Society of Soil Sciences* 58(2): 205–211.

28. Rajesh V, SR Balangoudar, H Veeresh, KD Ashok and YM Ramesh. 2018. Effect of nutrient management approaches and major nutrients on dry direct seeded rice (dry-DSR) in TBP Command Area. *International Journal of Current Microbiology and Applied Science* 7(2):1239–1247.

29. Sanadi U, KK Math, BI Bidari, KD Lamani and KM Kiran. 2022. Response of wheat (*Triticum aestivum* L.) to precision nutrient management approaches in vertisol under northern transitional zone of Karnataka. *The Pharma Innovation Journal* 11(9): 650–655 .

30. Sekar A. 2003. Studies on the evaluation of sugarcane variety and production technologies for sugarcane productivity in coastal region of Tamil Nadu. *Ph.D. thesis*, Annamalai University, Annamalainagar, Tamil Nadu.

31. Shiferaw B, Smale M, Braun H J, Duveille E, Reynolds M, Muricho G. 2013. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security* 5: 291–317.

32. Singh MP, P Kumar, A Kumar, R Kumar, A Diwedi, S Gangwar, V Kumar and NV Kumar. 2016. Effect of NPK with biofertilizers on growth, yield and nutrient uptake of wheat (T*riticum aestivum* L.) in Western U.P. *Progressive Agriculture* 16(1): 83–87.

33. Sirazuddin V, P Singh, S Chandra, SP Singh, SK Guru, N Pareek, AK Sarvadamana and A Paliwal. 2019. Growth and Productivity of Wheat under Tillage Systems and Residue Loads in Tarai Region of Uttarakhand, India. *International Journal of Current Microbiology and Applied Sciences* 8(8): 11–19.

34. Sunil K, AS Panwar, RK Naresh, S Prem, NC Mahajan and C Udita. 2018. Improving rice-wheat cropping system through precision nitrogen management: A review. *Journal of Pharmacognosy and Phytochemistry* 7(2):1119–1128.

35. USDA. 2023. United States Department of Agriculture/Foreign Agriculture Service, Global market analysis, Circular series: 1-40. https://apps.fas.usda.gov/psdonline/circulars/production.pdf

36. Yasin M. 2012. Review article: Bio-fertilizers, substitution of synthetic fertilizers in cereals for leveraging agriculture. *Crop and Environment* 3(1-2): 62–66.