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Effect of nutrients with GA_3 and residual effect of rice residue, FYM and nutrients applied to preceding potato on growth, yield and quality of wheat (*Triticum aestivum*) in rice (*Oryza sativa*)-potato (*Solanum tuberosum*)–wheat cropping system

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ABSTRACT

A field experiment was conducted during winter (*rabi*) and rainy (*kharif*) season of 2020–21 and 2021–22 at Punjab Agricultural University, Ludhiana, Punjab to enhance the productivity of wheat (*Triticum aestivum* L.) in rice (*Oryza sativa* L.)-potato (*Solanum tuberosum* L.)-wheat cropping system. The experiment was laid out in factorial randomized block design (F-RBD) with two factors, Factor A [Two nutrient management treatments (rice straw incorporation + 100 RDF + FYM @25 t/ha and without rice straw incorporation + 100 RDF + FYM @50 t/ha)] and Factor B [Nine nutrient with GA_3 treatments (75% recommended N and P, 75% recommended N, 50% recommended N and P, 50 % recommended N, 200 ppm gibberellic acid (seed treatment) + 75% recommended N and P, 200 ppm gibberellic acid (seed treatment) + 75% recommended N, 100 ppm gibberellic acid (seed treatment) + 50% recommended N and P, 100 ppm gibberellic acid (seed treatment) + 50% recommended N and water soaking (seed treatment) + 50% recommended N]. Application of FYM @50 t/ha + 100 RDF without rice residue to preceding potato crop showed significant improvement on growth character, viz. plant height, tillers and dry matter accumulation of succeeding wheat crop as compared to rice straw incorporation (RSI) + 100 RDF + FYM @25 t/ha during both the year. Similarly application of FYM @50 t/ha +100 RDF without rice residue to preceding potato crop showed significant maximum yield attributing characters and yield of succeeding wheat crop during both the year. The application of no rice residue with FYM @50 t/ha +100% RDF recorded 12.8 and 14.9% increased grain yield of wheat than rice straw incorporation (RSI) + 100% RDF + FYM @25 t/ha during first and second year of experimentation, respectively. The application of GA_3 irrespective of nutrients levels increased the germination percentage significantly as compared to no GA_3 application treatments at 10 and 12 DAS during both the years. The application of GA_3 advanced the germination by 2 days as compared to no GA_3 application. The maximum growth, yield attributing character andyield in wheat recorded with 75% RDN and P + GA_3 @200 ppm which at par with GA_3 @200 ppm + 75% RDN, GA_3 @100 ppm + 50% RDN and P, 75% RDN and P, 75% RDN and 50% RDN and P while significantly higher than other treatments during both the years.

Keywords: FYM, GA_3, Nutrients, Rice, Rice straw, Yield, Quality

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system plays a vital role in global food security as it provides staple foods to the world's population (Lalik *et al.* 2014 and Banjara *et al.* 2021). In India, pre-dominant rice-wheat system covers an area about 9.2 Mha, thus playing a key role in the nation's food security (Jat *et al.* 2020). The availability of irrigation, mechanization and higher economic returns of the system are the main reasons for the farmers to stick to the rice-wheat system. Continuous adoption of the RWCS has resulted stagnation in the productivity and thus facing challenges for sustainable production of rice wheat cropping system. Several emerging problems, such as the exhausting nutrient pool in soil, deteriorating soil health, ground water depletion, escalating production cost, labour scarcity, environmental pollution due to crop residue burning and enhanced greenhouse gas emissions, climatic vulnerabilities, and herbicide resistance in weed species are a few major threats to its sustainability. During the recent decade, the yields and land productivity of rice-wheat system in South Asia and particularly in the north-west IGPs have either stagnated or decreased due to declining groundwater table (Bhatt 2020), deteriorated soil health, micro-nutrients deficiencies (Ladha *et al.* 2009) frequent and widespread insect-pest infestation and climate change

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(Saini and Bhatt 2020). Rice residue burning contributes to air pollution, also leads to loss of approximately 80–90% N, 25% of P, 20% of K and 50% of S present in crop residues in the form of different gases and particulate matter and also depriving soils of organic carbon (Krishna *et al.* 2004 and Jain 2014). Modern concepts in crop production such as crop diversification with short duration crops varieties, conservation agriculture, integrated nutrient management, residue management, precision farming and different farming techniques has been developed to solve these issues and increased the production level, without hampering the natural resources (Singh *et al.* 2015). Hence, present study aimed to enhance the productivity of wheat in rice-potato-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) and rainy (*kharif*) season of 2020–21 and 2021–22 at Punjab Agricultural University, Ludhiana, Punjab. The meteorological data was recorded at meteorological observatory of Punjab Agricultural University, Ludhiana, Punjab during wheat growing seasons are depicted in Fig. 1 and 2. During the wheat growing period the weekly mean maximum air temperature range from 14–37.5ºC and 13.5–39.9ºC while weekly mean minimum temperature ranged from 6.3–23.0ºC and 7.2–25.7ºC during 2021 and 2022, respectively. During the wheat growing period, weekly maximum temperature was 37.5 in 18th week and minimum 6.3ºc in the 5nd week during 2021 and the corresponding figures were 39.7 in 17th week and 7.2 in 7th week during 2022. Relative humidity ranged from 30–83% during the first year and 30–89% during the second year. Maximum of 52 mm and 56.4 mm evaporation was recorded during 18th and 18th standard meteorological weeks of the year 2021 and 2022 respectively. Mean weekly sunshine hours ranged from 0.5–9.9 during 2021 and from 0.1–10.7 during 2022 of crop growing season. The total rainfall received was 52.7 mm and 157.7 mm during the growing season of first and second years respectively.The experiment was laid out in factorial randomized block design (F-RBD) with two factors. Factor A contains two nutrient management treatments (rice straw incorporation + 100 RDF + FYM @25 t/ha and without rice straw incorporation + 100 RDF + FYM @50 t/ha) and factor B contains nine nutrient with GA_3 treatments (75% recommended N and P, 75% recommended N, 50% recommended N and P, 50 % recommended N, 200 ppm gibberellic acid (seed treatment) + 75% recommended N and P, 200 ppm gibberellic acid (seed treatment) + 75% recommended N, 100 ppm gibberellic Acid (seed treatment) + 50% recommended N and P, 100 ppm gibberellic acid (seed treatment) + 50% recommended N and water soaking (seed treatment) + 50% recommended N. All the 18 treatment combination were randomized and replicated three times. Potato was planted as preceeding crop to wheat with recommended doses of fertilizers i.e. 187.5 N, 62.5 P_2O_5 and 62.5 K_2O kg/ha. After harvesting of potato, late wheat was sown on second week of January during both the years of experimentation. The fertilizes were applied as per the treatment. The recommended dose of fertilizers in wheat were125 N and 62.5 P_2O_5 kg/ha. The soil of experimental station was normal in *p*H (7.8), low in organic carbon (0.38%), low in available nitrogen

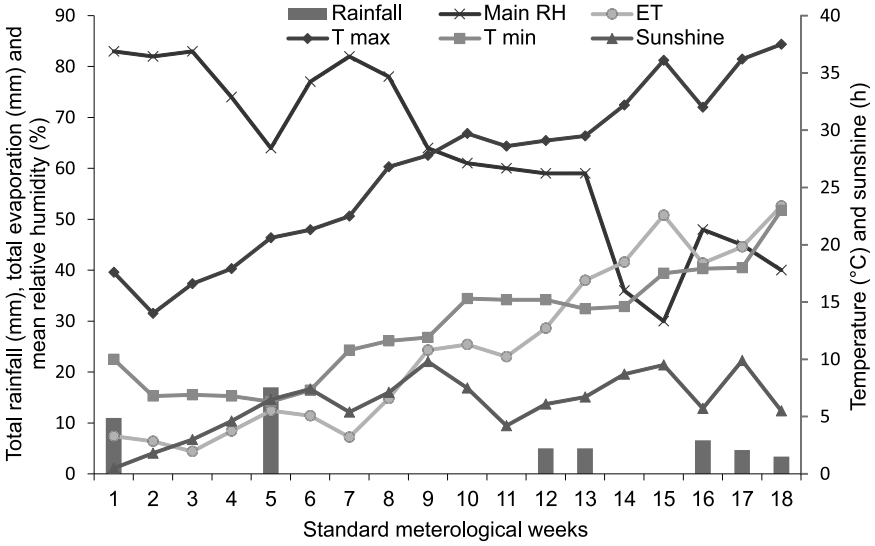

Fig. 1 Standard meteorological weather data for wheat during 2021.

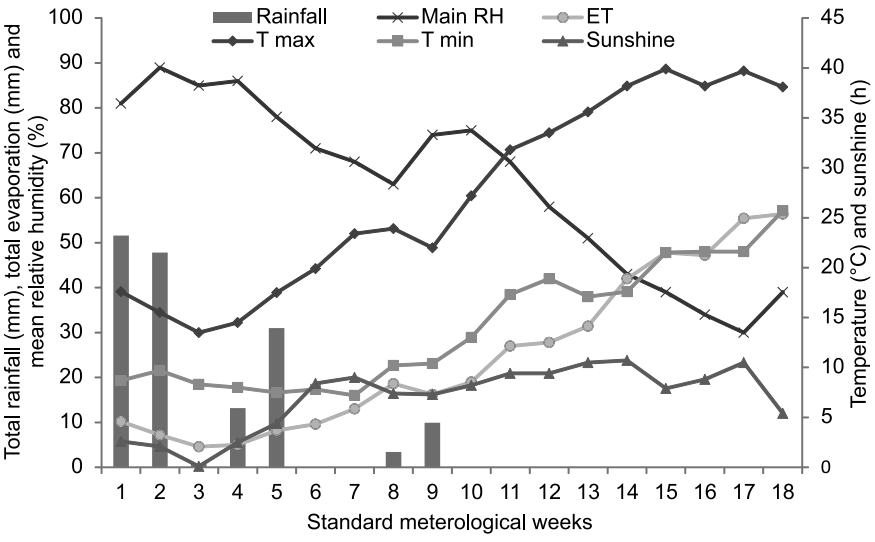

Fig. 2 Standard meteorological weather data for wheat during 2022.

(134.5 kg/ha) and medium in available phosphorus (15.8 kg/ha) and potassium (150.2 kg/ha). The growth parameters were taken at periodical interval and yield was calculated on net plot basis and expressed in kg/ha. "Infratech 1241 (FOSS)" was used to estimate the protein and glutin content of wheat grains.

RESULTS AND DISCUSSION

Growth characters: The first factor which affect the extablishment of crops is germination. Rice straw incorporation (RSI) + 100% RDF + FYM @25 t/ha and without rice straw incorporation (WRSI) + 100% RDF + FYM @50 t/ha treatments showed non-significant results on germination percentages during both the year of study (Table 1). The application of GA_3@100 and 200 ppm irrespective of nutrients levels increased the germination percentage significantly as compared to no GA_3 application treatments at 10 and 12 days after sowing during both the years. Seed treatments with GA_3 @100 and 200 ppm completed the germination percentage of wheat within 12 days after sowing while water soaked and without GA_3 seed treatment complete the germination up to 14 DAS during both the year. Application of different nutrient levels, viz. 75% RDN and P, 75% RDN, 50% RDN and P and 50% RDN resulted non–significant effect on germination percentage of wheat during both the years of study. Similar results that the application of 200-ppm gibberellic acid was found as the best for germination of wheat but it was

Table 1 Effect of rice residue, FYM and nutrients application to preceding potato and nutrients with (GA_3) application to wheat on growth characters in wheat

Treatment	Germination (%) 2021			Germination (%) 2022			Plant height at harvest (cm)		Dry matter accumulation at harvest (/g^2)	
	10 DAS	12 DAS	14 DAS	10 DAS	12 DAS	14 DAS	2021	2022	2021	2022
Rice residue, FYM and nutrient application to preceding potato										
RSI + 100 RDF + FYM @ 25 t/ha	28.0 (29.7)	78.5 (66.9)	98.4 (83.3)	28.1 (29.8)	77.0 (65.6)	97.6 (83.2)	88.4	85.2	826.0	813.1
WRSI + 100 RDF + FYM @50 t/ha	30.2 (32.0)	76.6 (65.3)	97.7 (83.9)	29.4 (31.2)	79.0 (67.3)	97.8 (83.4)	91.7	87.2	863.0	877.8
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	2.6	1.8	19.5	14.6
Nutrients with gibberellic acid application in wheat										
75% RDN and P	20.4 (21.6)	58.8 (50.1)	98.2 (83.7)	18.2 (19.3)	54.2 (46.2)	97.5 (83.1)	90.5	87.1	873.5	861.4
75% RDN	22.5 (23.9)	56.2 (47.9)	97.2 (82.8)	20.5 (21.8)	54.6 (46.5)	98.2 (83.7)	89.2	86.1	855.0	851.3
50% RDN and P	24.5 (26.0)	56.5 (48.2)	97.2 (82.8)	22.5 (23.9)	52.4 (44.7)	97.5 (83.1)	89.5	86.7	868.5	860.8
50% RDN	22.5 (23.9)	54.6 (46.5)	98.2 (83.7)	20.5 (21.8)	54.6 (46.5)	97.6 (83.2)	84.5	81.9	785.5	787.6
200 ppm GA_3 (seed treatment) + 75 % RDN and P	38.6 (41.0)	98.5 (84.0)	98.5 (84.0)	38.2 (40.5)	97.8 (83.4)	97.8 (83.4)	98.1	92.3	890.0	880.0
200 ppm GA_3 (seed treatment) + 75% RDN	37.5 (39.8)	97.6 (83.2)	97.5 (83.1)	35.8 (38.0)	95.6 (81.5)	97.5 (83.1)	97.3	90.4	877.8	879.7
100 ppm GA_3 (seed treatment) + 50% RDN and P	35.6 (37.8)	98.2 (83.7)	98.3 (83.8)	35.6 (37.8)	97.5 (83.1)	97.5 (83.1)	96.7	90.8	878.7	880.2
100 ppm GA_3 (seed treatment) + 50% RDN	35.6 (37.8)	98.5 (84.0)	99.0 (84.4)	36.5 (38.7)	97.5 (83.1)	98.2 (83.7)	86.7	80.1	816.5	817.5
Water soaking (seed treatment) + 50% RDN	24.5 (36.0)	60.2 (51.3)	98.4 (83.9)	22.8 (24.2)	97.8 (83.4)	97.2 (82.8)	86.1	80.0	754.0	790.6
CD (*p*=0.05)	8.9	19.6	NS	13.5	21.6	NS	5.0	3.6	47.5	38.5
Interaction	NS	NS	NS	NS	NS	NS	90.5	87.1	NS	NS

RSI, Rice straw incorporation; WRSI, Without rice straw incorporation; RDN, Recommended dose of N; RDN and P, Recommended dose of N and P. Figures in parentheses are arcsine transformed value.

statistically similar with 100-ppm gibberellic acid reported by Islam *et al.* (2013). Ghobadi *et al.* (2012) also reported significant improvement in germination of wheat cultivars due to soaking of seed in GA_3.

Rice straw incorporation (RSI) + 100% RDF + FYM @25 t/ha and without rice straw incorporation (WRSI) + 100% RDF + FYM @50 t/ha treatments showed significant results on plant height and dry matter accumulation during both the year of study (Table 1). The treatment WRSI + 100% RDF + FYM @50 t/ha recorded significantly higher plant height and dry matter accumulationthan RSI + 100% RDF + FYM @25 t/ha of crop growth during both the year of study. Dhar *et al.* (2014) reported similar results the residual effect of crop residues along with green manure, microbial culture and inorganic fertilizer on growth of wheat grown after rice. Gawali and Shila (2018) also reported similar findings that the application of nitrogen 217 kg/ha, phosphorus (P_2O_5) 164 kg/ha, potassium (K_2O) 118 kg/ha, Sulphur 6 kg/ha, zinc 0.7 kg/ha, manganese 0.6 kg/ha and boron 0.3 kg/ha was found remunerative and suitable for maintaining the residual status of the soil after harvest of wheat crop. Application of 75% RDN and P +GA_3 @200 ppm resulted significantly higher plant height and dry matter accumulationthan GA_3 @100 ppm + 50% RDN,water soaking + 50% RDN and without GA_3application treatments (75% RDN and P, 75% RDN, 50% RDN and P and 50% RDN) which was at par with GA_3 @200 ppm + 75% RDN and GA_3 @100 ppm + 50% RDN and P during both the years. The increased nutrients levels without GA_3 also improved the plant heightand dry matter accumulation of crop growth during both the years. Application of 75% RDN and P resulted in significantly higher plant height than 50% RDN which was at par with75% RDN and 50% RDN and P of crop growth during both the years. The results suggest that using GA_3 seed treatment in combination with 75% RDN and P is the most effective treatment for enhancement in plant height and dry matter accumulation of wheat. GA_3 is known to stimulate plant growth and development and its combination with nutrients could potentially enhance the uptake and utilization of these nutrients by the plant. Ghobadi *et al.* (2012) and Islam *et al.* (2013) also reported that there was significant improvement in seedling growth parameters of wheat cultivars due to soaking treatment with GA_3.

Yield attributing character: Application of rice residue, FYM and nutrient to preceding potato recorded significant carryover effect on yield attributing characters of succeeding wheat crop during both the years (Table 2). Rice straw incorporation (RSI) + 100 RDF + FYM @25 t/ha and

Table 2 Effect of rice residue, FYM and nutrients application to preceding potato and nutrients with GA_3 application to wheat on yield attributing characters of wheat

Treatment	No. of spikes (/m^2)		Spike length (cm)		No of spikelet (/spike)		No. of grains (/spike)		1000-grain weight (g)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Rice residue, FYM and nutrient application to preceding potato										
RSI + 100 RDF + FYM @25 t/ha	282.3	276.5	8.4	8.0	16.3	15.7	35.9	35.7	38.4	36.5
WRSI + 100 RDF + FYM @50 t/ha	304.5	298.9	9.4	9.2	17.0	16.3	41.1	40.9	40.7	34.1
CD (p=0.05)	10.2	13.5	0.5	0.8	0.5	0.4	1.3	1.2	2.9	1.7
Nutrients with gibberellic acid application in wheat										
75% RDN and P	310.0	302.5	9.2	8.9	17.2	16.4	43.0	36.3	40.0	36.4
75% RDN	296.6	290.3	8.9	8.4	16.4	16.0	38.8	36.1	38.9	34.9
50% RDN and P	300.5	298.5	9.0	8.7	16.6	16.2	39.7	36.6	39.2	35.6
50% RDN	268.4	265.3	7.8	7.6	15.0	14.3	35.8	33.6	36.7	33.9
200 ppm GA_3 (seed treatment) + 75% RDN and P	316.0	312.2	9.8	9.5	18.1	17.6	40.7	38.8	43.0	37.0
200 ppm GA_3 (seed treatment) + 75% RDN	300.2	292.6	9.6	9.1	17.7	16.5	38.5	37.0	41.2	36.3
100 ppm GA_3 (seed treatment) + 50% RDN and P	305.0	298.5	9.8	9.4	18.0	17.2	39.6	37.3	42.0	36.4
100 ppm GA_3 (seed treatment) + 50% RDN	272.5	265.3	8.0	7.8	15.7	15.7	35.9	33.6	37.5	33.6
Water soaking (seed treatment) + 50% RDN	271.4	264.1	8.0	8.0	15.7	15.0	34.5	32.0	37.4	33.2
CD (p=0.05)	19.6	24.5	0.8	1.0	1.0	1.8	2.7	2.5	4.2	2.6
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RSI, Rice straw incorporation; WRSI, Without rice straw incorporation; RDN, Recommended dose of N; RDN and P, Recommended dose of N and P.

without rice straw incorporation (WRSI) + 100 RDF + FYM @50 t/ha treatments recorded significant results on yield attributing characters, viz.number of spikes/m^2, spike length, number of spikelet/spike, number of grains/spike and 1000-grain weight during both the year. Dhar *et al.* (2014) reported similar results the residual effect of crop residues along with green manure, microbial culture and inorganic fertilizer on yield attributing characters of wheat grown after rice. The second factor involved applying nutrients with gibberellic acid (GA_3) to wheat crops. Significantly higher yield attributing character in wheat recorded with 75% RDN and P +GA_3 @200 ppm which was significantly higher than GA_3 @100 ppm + 50 % RDN, water soaking + 50% RDN and 50% RDN while at par with GA_3 @200 ppm+75% RDN, GA_3@100 ppm+50% RDN and P, 75% RDN and P, 75% RDN and 50% RDN and P during both the years. In nutrient application treatments without GA_3, the application of 75% RDN and P result significantly higher yield attributing character in wheat than 50% RDN while at par with75% RDN and 50% RDN and P during both the years.

Yield: The treatment WRSI + 100% RDF + FYM @50 t/ha resulted in significant higher grain and straw yield of wheat than RSI + 100% RDF + FYM @25 t/ha during both the year (Table 3). Application of no rice residue with FYM @ 50 t/ha +100 % RDF enhanced 12.8 and 14.9% increase in grain yield of wheat than rice straw incorporation (RSI) + 100% RDF + FYM @25 t/ha, respectively. Addition of soil organic matter (SOM) improved soil chemical, physical, and biological properties, which can then positively impact nutrient cycling and provide an enhanced environment for vegetation growth of crop which increased the photosynthesis and reflected in the yield (Wu *et al.* 2013). Ali *et al.* (2020) reported similar results that rice residue retention with 25% additional N + recommended NPK or rice residue retention + *Sesbania* green manuring with recommended NPK fertilizer under rice-wheat cropping system resulted higher yield and benefits from wheat on sustainable basis. Significantly higher grain and straw yield yield of wheat recorded with 75% RDN and P + GA_3 @200 ppm which was significantly higher than GA_3 @100 ppm + 50 % RDN, water soaking + 50 % RDN and 50% RDN while at par with GA_3 @200 ppm + 75% RDN, GA_3 @100 ppm + 50% RDN and P, 75% RDN and P, 75% RDN and 50% RDN and P during both the years. The application of 75% RDN and P + GA_3 @200 ppm resulted 18.8 and 21.8% increase in yield over GA_3 @100 ppm + 50 % RDN, 20.5 and 22.1% over water soaking

Table 3 Effect of rice residue, FYM and nutrients application to preceding potato and nutrients with GA_3 application to wheat on grain yield, straw yield and harvest index of wheat

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		Harvest Index (%)		Protein content (%)		Gluten content (%)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Rice residue, FYM and nutrient application to preceding potato										
RSI + 100 RDF +FYM @25 t/ha	4362.2	3986.1	6497.2	6007.2	40.2	39.9	10.2	10.1	8.2	8.0
WRSI + 100 RDF + FYM @50 t/ha	4919.7	4580.4	6691.5	6381.5	42.4	41.8	10.4	10.2	8.3	8.4
CD (p=0.05)	356.5	385.6	183.5	352.6	0.6	0.8	NS	NS	NS	NS
Nutrients with gibberellic acid application in wheat										
75% RDN and P	4832.6	4558.0	6836.3	6551.4	41.4	41.4	10.3	10.5	8.2	8.7
75% RDN	4670.0	4368.2	6759.8	6330.2	40.9	40.8	10.0	10.2	8.0	8.3
50% RDN and P	4694.3	4358.0	6738.2	6252.6	41.1	41.1	10.3	10.3	8.3	8.5
50% RDN	4083.0	3833.3	6012.5	5712.6	40.4	40.2	9.7	9.9	7.9	8.0
200 ppm GA_3 (seed treatment) + 75% RDN and P	5093.6	4690.3	7018.5	6436.0	42.1	42.2	10.9	10.5	8.7	8.7
200 ppm GA_3 (seed treatment) + 75% RDN	4923.0	4455.5	6883.6	6281.9	41.7	41.5	10.5	10.5	8.4	8.1
100 ppm GA_3 (seed treatment) + 50% RDN and P	4959.8	4611.5	6887.6	6376.8	41.9	42.0	10.7	10.3	8.6	8.4
100 ppm GA_3 (seed treatment) + 50% RDN	4287.2	3851.0	6118.0	5426.3	41.2	41.4	9.8	10.1	7.9	7.8
Water soaking (seed treatment) + 50% RDN	4225.2	3842.2	6094.5	5481.2	40.9	41.2	9.8	9.6	7.8	8.1
CD (p=0.05)	525.5	502.6	754.2	965.5	0.9	1.0	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RSI, Rice straw incorporation; WRSI, Without rice straw incorporation; RDN, Recommended dose of N; RDN and P, Recommended dose of N and P.

+ 50% RDN and 24.7 and 22.3% over 50% RDN during first and second years of experimentation respectively. In nutrient application treatments without GA_3, application of 75% RDN and P result significantly higher grain and straw yield of wheat than 50% RDN while at par with 75% RDN and 50% RDN and P during both the years. 75% RDN and P resulted 18.4 and 18.9% increase in yield over 50% RDN during first and second years of experimentation respectively. WRSI + 100% RDF + FYM @50 t/ha resulted significantly higher harvest index of wheat than RSI + 100% RDF + FYM @25 t/ha during both the years. Significantly higher harvest index of wheat recorded with 75% RDN&P + GA_3 @200 ppm which was at par with GA_3@200 ppm + 75% RDN, GA_3@100 ppm + 50% RDN &P, 75% RDN&P, 75% RDN and 50% RDN&P during both the years. Anwar *et al.* (2016) also reported similar results that maximum growth, yield attributing characters, grain yield and harvest index of wheat were observed with increased level of nitrogen (125 kg/ha) and phosphorus (90 kg/ha).

Quality parameters: Application of rice residue and nutrients to preceding potato had non-significant carryover effect on grain protein and gluten content of succeeding wheat crop during both the years (Table 3). WRSI + 100% RDF + FYM @50 t/ha resulted higher protein and gluten content of wheat than RSI + 100% RDF + FYM @25 t/ha, although the difference was non–significant during both the year. Significantly higher protein and gluten content of wheat recorded with 75% RDN&P + GA_3 @200 ppm which was at par with GA_3 @100 ppm + 50% RDN, water soaking + 50 % RDN, 50% RDN, GA_3 @200 ppm + 75% RDN, GA_3 @100 ppm + 50% RDN and P, 75% RDN and P, 75% RDN and 50% RDN and P during both the years.

It is concluded that the treatment WRSI + 100% RDF + FYM @50 t/ha applied to preceding potato crop results significantly more growth parameter, yield attributing characters and yield than RSI + 100% RDF + FYM @25 t/ha during both the year.The maximum yield attributing character and yield in wheat occurred with GA_3 @200 ppm + 75% RDN and P which was significantly higher than GA_3 @100 ppm + 50% RDN, water soaking + 50% RDN and 50% RDN while at par with GA_3 @200 ppm + 75% RDN, GA_3 @100 ppm + 50% RDN and P, 75% RDN and P, 75% RDN and 50% RDN and P during both the years.

REFERENCES

Ali M N, Alam M P , Ahmad E and Sah A. 2016. Effect of different residue management practices of rice on growth and yield of wheat and soil health in rice-wheat system. *International Journal of Bio-resource and Stress Management* **7**(4): 567–57.

Anwar S, Israeel, Iqbal B, Khan S, Faraz M, Ali N, Hussain S and Anjum M M. 2016. Nitrogen and phosphorus fertilization of improved varieties for enhancing yield and yield components of wheat. *Pure and Applied Biology* **5**(4): 727–37.

Banjara T R, Bohra J S, Kumar S, Singh T, Shori A and Prajapat K. 2021. Sustainable alternative crop rotations to the irrigated rice-wheat cropping system of Indo-Gangetic plains of India. *Archives of Agronomy and Soil Science* **67**: 1–18.

Bhatt R. 2020. Tensiometers for rice water footprints. *Current Applied Science and Technology* **30**: 11–27.

Dhar D, Datta A, Basak N, Paul N, Badole S and T Terence. 2014. Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice-wheat cropping system. *The Indian Journal of Agricultural Research* **48**: 373–78.

Gawali R and Shila P K. 2018. Integrated nutrient management approach on wheat (*Triticum aestivum* L.) in Vertisols. *International Journal of Current Microbiology and Applied Sciences* **7**(4): 3144–53.

Ghobadi M, Abnavi M S, Honarmand S J, Ghobadi M E and Mohammadi G R. 2012. Effect of hormonal priming (GA_3) and osmopriming on behaviour of seed germination in wheat (*Triticum aestivum* L). *Journal of Agricultural Science* **4**: 244–50.

Islam M M, Akhter S, Nik M M, Ferdous J and Alam M S. 2013. Integrated nutrient management for potato (*Solanum tuberosum*) in grey terrace soil (*Aeric Albaquipt*). *Austrialan Journal of Crop Science* **9**: 1235–41.

Jain N, Bhatia A and Pathak H. 2014. Emission of air pollutants from crop residue burning in India. *Aerosol Air Quality Research* **14**: 422–30.

Jat M L, Chakarborty D, Ladha J K, Rana D S, Gathala M K and Mc Donald A. 2020. Conservation agriculture for sustainable intensification in South Asia. *Nature Sustainability* **3**: 336–43.

Krishna G M, Misra A K, Kuntal M H, Kali K B, Ghosh P K and Mohanty M. 2004. Rice residue management options and effects on soil properties and crop productivity. *Journal of Food, Agriculture and Environment* **1**: 224–31.

Ladha J K, Kumar V, Alam M M, Sharma S, Gathala M and Chandna P. 2009. *Integrating Crop and Resource Management Technologies for Enhanced Productivity, Proftability, and Sustainability of the Rice-Wheat System in South Asia,* pp. 395. Ladha J K, Yadvinder Singh, O Erenstein and B Hardy (Eds). International Rice Research Institute, Los Banos, Philippines.

Lalik R, Sharma S, Idris M, Singh A K, Singh S S and Bhatt B P. 2014. Integration of conservation agriculture with best management practices for improving system performance of the rice-wheat rotation in the eastern Indo-Gangetic Plains of India. *Agriculture Ecosystems Environment* **195**: 68–82.

Saini J and Bhatt R. 2020. Global warming: Causes, impacts and mitigation strategies in agriculture. *Current Journal of Applied Science and Technology* **7**: 93–107.

Singh C B, Singh S, Arora V K and Sekhon N K. 2015. Residue mulch effects on potato productivity and irrigation and nitrogen economy in a subtropical environment. *Potato Research* **58**: 245–60.

Wu Y, Li Y, Zheng C, Zhang Y and Sun Z. 2013. Organic amendment application influences soil organism abundance in saline alkali soil. *European Journal of Soil Biology* **54**: 32–40.