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Research Communication

Influence of rice straw incorporation and integrated nutrient management on growth, yield, and nutrient uptake in potato (*Solanum tuberosum*) and onion (*Allium cepa*) under rice (*Oryza sativa*)–potato-onion cropping system

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ABSTRACT

A field experiment was conducted during 2019–20 at the Punjab Agricultural University, Ludhiana, to study the influence of rice (*Oryza sativa* L.) straw incorporation and integrated nutrient management on growth, yield and nutrient uptake of potato and onion (*Allium cepa* L.) in direct-seeded rice (DSR)-potato (*Solanum tuberosum* L.)–onion cropping system. The experiment was laid out in a split-plot design, consisting of 4 rice residue and nutrient-application treatments in potato in main plots and 4 nutrient application treatments in onion in subplots, replicated 4 times. Results showed that, growth and yield-attributing characters of potato increased significantly with the incorporation of rice residue and application of FYM. Tuber yield (34.0 t/ha) as well as nutrient uptake was significantly higher when rice residue was incorporated with 100% recommended dose of fertilizer (RDF) + 50 t/ha FYM in potato. Growth and yield attributes of onion were significantly higher with the application of 100% (RDF) + 50 t/ha FYM along with the incorporation of rice residue in preceding potato and among the nutrient application treatments in onion, 100% RDF + 50 t/ha FYM treatment was significantly superior to rest of the treatments. Significantly higher bulb yield was also obtained under these treatments. The interaction between rice residue and nutrient-management treatments in potato and nutrient-application treatments in onion was significant for bulb yield of onion, which was significantly higher with the combination of 100% RDF + 50 t/ha FYM treatment in onion when rice residue was incorporated with 100% RDF + 50 t/ha FYM in preceding potato (35.8 t/ha) than all other treatment combinations, but it was statistically at par with the application of 100% RDF alone in onion when preceding potato received the same level of nutrients. Thus, in DSR-potato–onion cropping system, 50 t FYM/ha could be saved in onion crop when previous potato crop was supplied with 100% RDF + 50 t/ha FYM along with rice–residue incorporation without any yield reduction.

***Key words*:** Nutrient uptake, INM, Onion, Potato, Residue management

Rice (*Oryza sativa* L.) is a dominant staple food crop in India and rice-based cropping systems are source of livelihood for about 50 million households. Nowadays, direct-seeded rice (DSR) is fast replacing transplanted rice, the continuous adoption of which has led to destruction of soil aggregates, reduction of subsurface-layer permeability and hard-pan formation (Sharma *et al*., 2003). Since vegetables like potato (*Solanum tuberosum* L.) and onion (*Allium cepa* L.) enhance the profitability of the cereal-based cropping systems (Saini *et al*., 2020; Rajpoot *et al*., 2021), the predominant rice–wheat (*Triticum aestivum* L.) cropping system in North-West India can be diversified by inclusion of these crops, which can prove fruitful not only for the land but also the growers. Inorganic chemical fertilizers are an integral part of modern agricultural systems but their excessive use deteriorates the soil and do not necessarily benefit the crop. Potato, being a short-duration crop, does not utilize the applied nutrients fully and leaves a substantial residual effect on subsequent crops like onion (Singh *et al*., 2010). Of late, management of rice straw has also gained importance owing to the large-scale production of straw annually and loss of nutrients and environmental pollution due to burning of the straw. *In-situ* management of straw includes either mulching or incorporation. Residue incorporation results in improvement of aggregate stability (Keller *et al*., 2007), enhanced water-holding capacity, infiltration and water availability (Jemai *et al*., 2013; Harish

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et al., 2022) besides improvement in carbon sequestration, soil organic matter (SOM) content and soil fertility, when practiced on long-term basis. In the present agricultural scenario, integrated nutrient management (INM) in DSR-based diversified cropping system is quintessential for sustaining the productivity of crops as well as fertility of land. Thus, current investigation was carried out with the objective of studying the influence of rice straw incorporation and integrated nutrient management on growth, yield and nutrient uptake of potato and onion under DSR-potato–onion cropping system.

The experiment was conducted during 2019–20 at the Punjab Agricultural University, Ludhiana (30° 54' N, 75° 48' E, 247 m above mean sea-level). The soil at the experimental site was sandy loam, low in available N (252 kg/ha), while medium in available P (20 kg/ha) and available K (171 kg/ha). During the potato-growing season (2019–20), weekly mean maximum and minimum temperature fluctuated between 10.4 and 30.5°C and 5.5 and 16.2°C, respectively, and weekly mean relative humidity ranged from 60.0 to 84.0%. While during the onion-growing season (2020), weekly mean maximum and minimum temperature ranged from 17.5 to 35.5°C and 4.9 to 21.8°C, respectively, and weekly mean relative humidity varied from 48.0 to 77.0%. The rainfall during potato- growth period (2019–20) and onion-growth period (2020) was 115.4 mm and 119.8 mm, respectively. The experiment was laid out with 4 nutrient application treatments in potato crop, viz. rice residue removal with 100% recommended dose of fertilizer (RDF); rice-residue removal with 100% RDF+ 50 t/ha FYM; rice-residue incorporation with 100% RDF and rice-residue incorporation with 100% RDF + 50 t/ha FYM, in the main plots and 4 nutrient application treatments in onion crop, viz.75% RDF; 75% RDF+ 50 t/ha FYM; 100% RDF and 100% RDF + 50 t/ha FYM, in the subplots (RDF for potato - 187.5 kg N/ha + 62.5 kg P_2O_5/ha + 62.5 kg K_2O/ha and onion - 100 kg N/ha + 50 kg P_2O_5/ha + 50 kg K_2O/ha). The experiment was conducted in a split-plot design with 4 replications.

Potato tubers of variety 'Kufri Pukhraj' were planted manually on ridges prepared with the tractor mounted ridger at a spacing of 60 cm × 20 cm on 25 October 2019 using 4.5 t seed tubers/ha. Whole straw load (7.6 t/ha) was incorporated in the residue-incorporation treatments, while whole straw was removed in residue-removal treatments. Onion nursery for the variety 'Punjab Naroya' was sown on 2 November 2019 in lines 5 cm apart on beds using 10 kg seed/ha. Transplanting of the nursery was done on 24 January 2020 on the beds maintaining row-to-row spacing of 15 cm, while plant-to-plant distance was kept at 7.5 cm. All the recommended agronomic practices such as fertilizer application, weed management, pest and disease management were followed for potato and onion crops. For growth and yield attributes, 5 random plants were selected from each plot for both potato and onion. Nutrient uptake of potato (tuber + haulm) and onion (bulb) was worked out from their respective nutrient content and yield on dry-weight basis (Rana *et al*., 2014). Rice-equivalent yield (system productivity) and net returns (gross returns-cost of cultivation) were calculated by using the prevailing prices of various inputs and outputs. Statistical analysis of the data recorded in onion was carried out using analysis of variance technique as applicable to split-plot design. The difference between the treatment means were tested as to their statistical significance with appropriate critical difference (CD) value at 5% level of probability.

Results revealed that, rice-residue incorporation and integrated nutrient management had a significant influence on the growth characters of potato (Table 1). Emergence was the highest (93.5%) when rice residue was incorporated along with application of 100% RDF + 50 t/ha FYM in potato. The maximum plant height (46.7 cm), dry-matter accumulation (68.5 g/plant) and leaf-area index (LAI, 3.35) at haulm cutting were recorded under rice-residue incorporation with 100% RDF+ 50 t/ha FYM treatment. The increase in growth parameters might be attributed to the increased availability of nutrients and enhanced organic carbon content and activity of beneficial micro-organisms. It might also have synthesized growth-promoting substances that led to increased meristematic activity promoting rapid initiation and boost in plant height thereby, increasing the dry-matter accumulation because of the enhanced rate of photosynthesis and translocation of photosynthates from source to sink (Koroto, 2019; Varatharajan *et al*., 2022).

The yield attributes, viz. tuber yield/plant (547.8 g) and tuber number/plant (13.8) were also significantly higher with the application of 100% RDF + 50 t/ha FYM along with rice residue incorporation (Table 1). Total tuber yield increased significantly by 34.9% under rice-residue incorporation with 100% RDF + 50 t/ha FYM treatment over 100% RDF alone. Integration of 50 t/ha FYM and 100% RDF along with rice-residue incorporation resulted in 9.3% higher yield of potato than 100% RDF + 50 t/ha FYM without residue incorporation, thus indicating the beneficial effect of incorporating rice-residue. Similar trend was followed by haulm yield, which was maximum under rice residue incorporation with 100% RDF + 50 t/ha FYM treatment (12.2 t/ha). Significantly higher total N, P and K uptake by potato was recorded with the same treatment. The probable reason for increment in nutrient uptake might be attributed to augmented supply of nutrients that leads to increased tuber and haulm yields owing to favourable impact of concurrent use of organic manures with fertilizers

Table 1. Effect of rice-residue and nutrient-application treatments in potato on growth, yield attributes and yield, and nutrient uptake of potato

Treatment	Plant height (cm)			Dry-matter accumulation (g/plant)	LAI	Tuber yield/ plant (g)	Tubers/ plant	Tuber yield (t/ha)	Haulm yield (t/ha)	Total nutrient uptake (kg/ha)		
	30 DAS	60 DAS	At haulm cutting							N	P	K
Rice-residue removal with 100% RDF (NPK)	15.4	32.3	32.8	51.8	2.12	367.0	8.55	25.2	9.79	82.0	21.5	97.4
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	18.9	37.2	39.2	63.0	3.15	469.3	11.5	31.1	11.2	106.2	28.6	132.8
Rice-residue incorporation with 100% RDF (NPK)	18.1	35.8	38.7	61.6	3.08	446.8	10.7	30.2	10.9	102.2	27.4	127.5
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	21.9	42.4	46.7	68.5	3.35	547.8	13.8	34.0	12.2	124.6	34.6	155.6
SEm±	0.67	0.68	0.80	1.63	0.06	23.6	0.66	0.85	0.19	2.61	0.67	2.71
CD (P=0.05)	2.16	2.18	2.55	5.20	0.19	75.6	2.11	2.72	0.62	8.35	2.15	8.67

LAI, Leaf-area index; RDF, recommended dose of fertilizer

on the plant height, leaf area, dry-matter production and its partitioning within the plant parts (Babu, 2019).

The growth and yield attributes of onion, viz. plant height, leaves/plant, bulb diameter and bulb weight at maturity were significantly higher under rice-residue incorporation with 100% RDF + 50 t/ha FYM treatment in preceding potato than rest of the treatments. Among the nutrient application treatments in onion, an application of 100% RDF+ 50 t/ha FYM in onion resulted in significantly higher growth and yield attributes in onion. Gererufael *et al*. (2020) also found increase in bulb diameter and bulb weight with integration of organic and inorganic nutrient sources.

Bulb yield of onion was significantly influenced by rice-residue and nutrient- management treatments in both potato and onion and their interaction. Among the nutrient- management treatments in preceding potato, an application of 100% RDF + 50 t/ha FYM with rice-residue incorporation resulted in 22.8% higher bulb yield than the application of 100% RDF alone without residue. Application of 100% RDF + 50 t/ha FYM in onion resulted in enhancement in bulb yield by 21.5% over sole application of 75% RDF and 7.8% over application of 100% RDF. Rice residue and nutrient application in potato × nutrient application in onion interaction (Table 3) revealed that, bulb yield of onion (35.8 t/ha) was significantly higher under the application of 100% RDF + 50 t/ha FYM in onion when preceding potato received the application of 100% RDF + 50 t/ha FYM along with incorporation of rice residue as compared to other treatment combinations but remained statistically at par with the 100% RDF treatment in onion when preceding potato was supplied with same level of nutrients (34.7 t/ha). Nutrient uptake by bulbs showed the similar trend as the bulb yield since, it is the product of nutrient content and yield on dry- weight basis (Table 2). Increase in bulb yield with rice-residue incorporation and FYM treatments is attributed largely to increased biomass input that enriched the soil quality in terms of biotic activity and organic carbon content (Rajpoot *et al*., 2021) that might have led to increased porosity and improved root proliferation. Also, the growth characters, viz. plant height, bulb weight and bulb diameter, are known to increase the crop yield (Nasreen *et al*., 2007).

Rice-equivalent yield of the system (39.2 t/ha) was significantly higher with the application of 100% RDF + 50 t/ha FYM to onion where preceding potato crop was supplied with 100% RDF, FYM and rice-residue incorporation (Table 4) which was statistically at par with 100% RDF application in onion when preceding potato crop was supplied with 100% RDF and FYM along with rice-residue incorporation (38.6 t/ha). Among the various combinations of nutrient application in potato and onion, significantly

Table 2. Effect of rice-residue and nutrient-application in preceding potato and nutrient application in onion on plant height, leaves/plant, bulb diameter, bulb weight and nutrient uptake in bulbs at maturity in onion

Treatment	Plant height (cm)	Leaves/ plant	Bulb diameter (cm)	Bulb weight (g)	Bulb yield (t/ha)	Nutrient uptake (kg/ha)		
						N	P	K
Rice-residue and nutrient-application in preceding potato								
Rice-residue removal with 100% RDF (NPK)	63.7	5.47	3.94	45.6	27.6	93.5	4.71	75.4
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	69.9	6.68	4.42	62.1	31.0	108.2	6.47	92.3
Rice-residue incorporation with 100% RDF (NPK)	68.8	6.44	4.29	60.1	30.2	104.9	6.03	87.7
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	75.3	8.07	4.94	71.9	33.9	120.7	7.89	109.2
SEm±	0.46	0.08	0.07	0.76	0.40	1.46	0.16	1.47
CD (P=0.05)	1.46	0.26	0.22	2.43	1.26	4.69	0.53	4.71
Nutrient-application in onion								
75% RDF (NPK)	63.5	5.39	3.90	48.0	27.4	93.1	4.60	74.2
75% RDF (NPK) + FYM 50 t/ha	70.4	6.73	4.40	61.7	31.1	108.4	6.45	93.5
100% RDF (NPK)	69.9	6.75	4.40	61.7	30.9	107.4	6.35	92.1
100% RDF (NPK) + FYM 50 t/ha	74.0	7.80	4.89	68.4	33.3	118.3	7.70	104.8
SEm±	0.43	0.12	0.05	0.84	0.24	1.43	0.14	1.01
CD (P=0.05)	1.22	0.34	0.14	2.40	0.70	2.71	0.40	2.89

RDF, recommended dose of fertilizer

Table 3. Interactive effect of rice-residue and nutrient-application in preceding potato and nutrient-application in onion on bulb yield (t/ha) of onion

Rice-residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	24.6	27.7	26.8	31.2	27.6
Rice residue removal with 100% RDF (NPK) + FYM 50 t/ha	27.2	31.2	31.6	34.0	31.0
Rice-residue incorporation with 100% RDF (NPK)	26.9	31.4	30.4	32.3	30.2
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	31.1	34.0	34.7	35.8	33.9
Mean	27.4	31.1	30.9	33.3	
SEm±			0.49		
CD (P=0.05)			1.41		

higher net returns (431.8 × 10^3 ₹/ha) were obtained with 100% RDF application in onion when the previous potato crop was supplied with 100% RDF, FYM along with rice-residue incorporation (Table 5) and was found to be statistically at par with the application of 100% RDF + FYM 50 t/ha where preceding potato crop received the application of 100% RDF + FYM 50 t/ha along with rice-residue incorporation (426.5 × 10^3 ₹/ha).

Based on the present study, it can be concluded that in DSR–potato–onion cropping system, the highest bulb yield of onion (35.8 t/ha) was obtained with application of 100% RDF and 50 t/ha FYM which remained statistically at par with 100% RDF, when previous potato crop was supplied with 50 t/ha FYM and 100% RDF along with rice–residue incorporation. Thus, rice–residue incorporation along with 50 t FYM/ha and 100% RDF applied to previous potato crop is sufficient for the following onion crop with sole application of 100% RDF without any yield reduction.

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Table 4. Effect of rice-residue and nutrient-application in potato and nutrient-application in onion on rice-equivalent yield (t/ha)

Rice residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	29.7	31.3	30.8	33.0	31.2
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	33.6	35.6	35.8	37.0	35.5
Rice-residue incorporation with 100% RDF (NPK)	33.0	35.3	34.8	35.7	34.7
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	36.8	38.3	38.6	39.2	38.2
Mean	33.3	35.1	35.0	36.2	
SEm±	Rice-residue and nutrient-application treatments in potato : 0.5 Nutrient-application in onion : 0.12 Interaction : 0.23				
CD (P=0.05)	Rice-residue and nutrient-application treatments in potato : 1.5 Nutrient-application in onion : 0.35 Interaction : 0.70				

Selling price, DSR, 18,150 ₹/t; potato, 8,000 ₹/t; onion, 9,000 ₹/t
RDF, Recommended dose of fertilizer

Table 5. Effect of rice-residue and nutrient-application in potato and nutrient-application in onion on net returns (× 10^3 ₹/ha) of the system

Rice-residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	287.4	300.9	305.7	330.4	306.1
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	344.9	366.1	382.6	389.5	370.8
Rice-residue incorporation with 100% RDF (NPK)	344.9	371.4	375.1	378.0	367.3
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	400.1	412.1	431.8	426.5	417.6
Mean	344.3	362.6	373.8	381.1	
SEm±	Rice-residue and nutrient-application treatments in potato : 8.87 Nutrient-application in onion : 2.11 Interaction : 4.23				
CD (P=0.05) for interaction	Rice residue and nutrient-application treatments in potato : 26.6 Nutrient-application in onion : 6.33 Interaction : 12.7				

RDF, recommended dose of fertilizer

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