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Effect of INM in aromatic rice (*Oryza sativa*) under SRI and its residual effect on wheat (*Triticum aestivum*)

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ABSTRACT

The field experiment was conducted at the Agricultural Research Farm, Banaras Hindu University, Varanasi, India during two consecutive rainy (*kharif*) and winter (*rabi*) seasons of 2015-16 and 2016-17 in split plot design to study the effect of integrated nitrogen management (INM) [100% recommended dose of nitrogen (RDN: 120 kg N/ha), 75% RDN + 25% N through *Azolla microphylla*, 75% RDN + 25% RDN through NADEP compost, 75% RDN + 25% RDN through sewage sludge and 75% RDN + 25% RDN through vermicompost] in aromatic rice (*Oryza sativa* L.) varieties (HUR-4-3, HUR-105, NDR-6093 and Rajendra Kasturi) under system of rice intensification and its residual effect on productivity of succeeding wheat (*Triticum aestivum* L.). The results of the study revealed that the variety HUR-4-3 and the INM with 75% RDN + 25% N through *Azolla microphylla* were found superior in terms of enhanced growth, yield attributes, yield, nutrient uptake, milling quality and length-breadth ratio (L/B) before cooking as compared to rest of the varieties and integrated nitrogen management, respectively. It was found that soil microbial population get improved when 75% RDN was coupled with 25% N through *Azolla microphylla*. Further, higher gross income, net return and output-input ratio were attributed to the variety Rajendra Kasturi (177.47×10^3 ₹, 130.35×10^3 ₹/ha and 3.79, respectively) and the application of 75% RDN + 25% N through *Azolla microphylla* (162.21×10^3 ₹, 117.14×10^3 ₹/ha and 3.6, respectively). Moreover, varieties did not show marked effect on yield of the succeeding wheat while significant yield enhancement was evident as a result of nitrogen management in preceding rice with 75% RDN + 25% N through *Azolla microphylla*.

Key words: Aromatic rice, *Azolla microphylla*, Nitrogen management, Microbial population, Residual effect, SRI

Rice (*Oryza sativa* L.) is a staple food for more than 60% of the world's population and plays a crucial role in the economic and social stability of the world. In India, area under cultivation of rice is around 43.38 m ha having production of 104.32 million tonnes with a productivity of 2.40 tonnes/ha. Per capita availability of rice to the country's population is 66.80 kg/year with 183.00 g/day (Anonymous 2017b). Demand for rice growing is increasing each year and it is approximated that requirement would be 140 million tonnes by 2025 AD. To sustain the present food self-sufficiency and to meet the future food requirement, India has to increase the rice productivity by 3% per annum (Kumar *et al.* 2017). Aromatic rice is known for its quality, aroma and demand in the domestic as well as in the international market. The major portion of rice area is devoted to the coarse and medium slender rice varieties. However, very less area has been assigned to the fine and scented rice. Rice quality is the major factor from consumer as well as marketing point of view. Aromatic rice which has stronger aroma and kernel elongation than ordinary rice has more demand in different countries of the world (Bajpai and Singh 2010).

System of rice intensification (SRI) is much accepted method of rice cultivation but that may be suited for high yielding, hybrid varieties, this is due to characteristic profuse tillering and better yield attributing characters. Generally, aromatic rice varieties are having low tillering, less number of effective tillers, low responsive to high nutrient dose. Therefore, it is needed to refine one important practice under SRI, i.e. integrated use of organic and inorganic sources of nutrient (Dass *et al.* 2015) that might result profuse tillering and better yield attributing characters to ensure higher yield and quality of aromatic rice varieties. The use of organic manures is emphasized as they are found to give a better response. Since, the availability of organic manures are less as few farms now have cattle or grow green manure, integrated nutrient management, i.e. using both inorganic and organic manures, is currently recommended. Krupnik *et al.* (2012) suggested that integrated organic and inorganic nutrient management of soil fertility is more advantageous

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with SRI than recommended practices. Studies have been performed in the recent past comprising judicious nitrogen management in different varieties of rice under SRI but the findings are meagre and needs to be fine tuned to improve and sustain the rice productivity. Hence, a detailed study was carried out to deal with the yield attributes, yield, nutrient uptake pattern and economics of aromatic rice varieties as influenced by INM and its residual effect on productivity of succeeding wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

The field experiment was conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University Varanasi, India during the two consecutive rainy (*kharif*) and winter (*rabi*) seasons of 2015-16 and 2016-17. The soil of the experimental field was sandy clay loam in texture (typic *Ustochrepts*) with *p*H 7.45. It was moderately fertile being low in organic carbon (0.32%) and available nitrogen (195 kg N/ha), high in available phosphorus (26.8 kg P_2O_5/ha) and medium in potassium (224 kg K_2O/ha). The experiment was laid out in split plot design assigning four aromatic rice varieties (HUR-4-3, HUR-105, NDR-6093 and Rajendra Kasturi) in main plot, five INM practices [100% recommended dose of nitrogen (RDN), 75% RDN + 25% N through *Azolla microphylla*, 75% RDN + 25% RDN through NADEP compost, 75% RDN + 25% RDN through sewage sludge and 75% RDN + 25% RDN through vermicompost] made 20 treatment combinations were replicated thrice followed by the succeeding wheat (cv. PBW-502). The recommended dose of nitrogen was 120 kg N/ha. Half dose of the total nitrogen (120 kg N/ha) along with the full dose of phosphorus (60 kg P_2O_5/ha), potassium (60 kg K_2O/ha) and zinc (5.5 kg Zn/ha) as basal dose were applied just before transplanting of rice crop on puddled surface and incorporated into the top 15 cm soil manually. The source of nitrogen, phosphorus, potassium and zinc was urea, di-ammonium phosphate, muriate of potash and zinc sulphate monohydrate (33% Zn), respectively. The remaining amount of nitrogen applied through urea, fertilizer was top dressed in two equal instalments at active tillering and 5-7 days before panicle initiation. The healthy seeds of aromatic rice varieties, i.e. HUR-4-3, HUR-105, NDR-6093 and Rajendra Kasturi were sown separately as per the treatment on nursery bed @ 5 kg/ha. Raised nursery beds having a width of 1 m and length of 10 m provided with 40 cm channels all around were prepared well with a massive mixture of soil and vermicompost (2:1) before sowing of seed. Prior to sowing, seeds were soaked in water for 48 hr for quick and uniform germination and then allowed to sprout on gunny bags in shade before spreading to nursery bed. Sprouted seeds @ 20 g/m^2 were spread uniformly on moist soil of the bed in such a manner that each seed could be isolated to one another. Then the seed beds were covered with paddy straw for two days after sowing to protect seeds from birds and keeping the soil moist. After covering the seed, watering was done with rose can (*hazara*) twice (morning and evening) a day. Seedling of 14 and 15 days old along with soil were pulled from the nursery bed very carefully by a spud (*khurpi*) without damaging roots during the first and second year, respectively. The single seedlings were gently planted by using index finger and thumb at the intersection of marking 25 cm × 25 cm in puddled soil. Further, culture of *Azolla microphylla* was multiplied locally to get ample quantity of fresh *Azolla* for application. Fresh *Azolla* obtained was then released into the respective plots as per the treatment with the rate of 833 kg/ha one week after transplanting with 3-5 cm standing water. The released population of *Azolla* was allowed to grow and proliferate for 4-5 days and then water was drained out. Thus, final biomass of *Azolla* obtained was incorporated into the soil during the first cono-weeding. Well prepared NADEP compost (1.4 and 1.5% N), sewage sludge (2.8 and 3.0% N) and vermicompost (1.5 and 1.6% N) during the respective years, were incorporated in the respective plots as per the treatment just after layout of the experiment. Since, one of the objectives of this study was to quantify the residual effect of the treatments applied in the preceding rice crop on the succeeding wheat, it was fertilized with 50% recommended dose of fertilizer (60 kg N, 30 kg P_2O_5 and 30 kg K_2O/ha) and sown with the help of seed-cum-fertilizer drill machine at 20 cm apart with a seed rate of 100 kg/ha.

The Leaf-area index (LAI) was estimated by leaves of five plants taken from each penultimate rows and leaf area was recorded with a leaf area meter (Systronics 211). The LAI was worked out as: Leaf-area index = Total leaf-area (cm^2)/Land area. Yield attributes and productivity of preceding rice crop as well as succeeding wheat crop were recorded as per the standard procedure. Grain and straw samples were dried, processed and analysed for their total nitrogen content by micro-Kjeldahl's, phosphorus by Vanadomolybdo phosphoric acid-yellow colour method and potassium by flame-photometer. Nutrient uptake was quantified by multiplying the content with the oven-dry weight of biological yield. The samples were oven dried at 70°C ± 2°C till constant weight was achieved. The microbial population in the soil was estimated as per the standard procedure by Fumigation-Extraction Method (Joergensen 1995). The hulling percentage of preceding rice was recorded using weight of brown rice divided by weight of rough rice and multiplied by hundred. The milling percentage was calculated using weight of milled rice divided by weight of rough rice and multiplied by hundred. The percentage of the head rice recovery was calculated by weight of whole polished rice divided by weight of rough rice and multiplied by hundred. The physical quality parameters of rice kernels were quantified for head rice recovery, kernel length, kernel breadth, length/breadth (L/B) ratio, linear kernel elongation ratio and breadth expansion ratio using an average of 10 randomly selected kernels following the standard methods (Ghosh *et al.* 1971). All the data obtained from rice and succeeding wheat crop for consecutive two years were statistically analyzed using the F-test as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes of rice

The data pertaining to productive tillers/m^2 have been presented in Table 1. A critical analysis of data indicated that the growth and yield attributes of the aromatic rice showed significant variation due to different rice varieties as well as INM during the studies. There was a significant improvement in the growth and yield attributes of rice, *viz*. leaf-area index (3.69), shoot dry weight (57.9 g/hill), productive tillers/m^2 (188), panicle length (26.4 cm), grains/panicle (200), weight/panicle (5.10 g) and 1000-grain weight (23.1 g) with the variety HUR-4-3, which produced significantly better yield attributes than the varieties NDR-6093 and Rajendra Kasturi, but at par with HUR-105. The lowest values of yield attributes were recorded under the variety NDR-6093. The improvement in the growth and yield attributes of rice by the variety HUR-4-3 over NDR-6093 was to the tune of 18.3, 17.8, 7.3, 20.3, 25.5, 32.1 and 11.1 per cent more leaf-area index, shoot dry weight, number of productive tillers/m^2, panicle length (cm), grains/panicle, weight/panicle (g), and 1000-grain weight (g), respectively. Variations in growth and yield attributing characters among varieties may be due to their genetic makeup inherited to variably convert the photosynthetic assimilates into the economically important plant parts. Chetri *et al.* (2015) working with variable nutrient application pattern concluded significant distinct variation among growth and yield attributes of aromatic rice varieties. The INM performed in rice crop with the application of 75% RDN + 25% N through *Azolla microphylla* significantly improved the growth and yield attributes of rice, *viz*. leaf-area index (3.37), shoot dry weight (57.8 g/hill), productive tillers/m^2 (190), panicle length (25.4 cm), grains/panicle (205), weight/panicle (4.69 g) and 1000-grain weight (21.5 g), which was at par with 75% RDN + 25% RDN through sewage sludge but significantly

Table 1 Effect of integrated nitrogen management on growth parameters, yield attributes and quality parameters of aromatic rice varieties under SRI (pooled data of two years)

Treatment	Growth parameters		Yield attributes					Milling quality			Kernel quality		
	Leaf-area index at 90 DAT	Shoot dry weight at 90 DAT (g/hill)	Productive tillers/m^2 (No.)	Panicle length (cm)	Grains/ panicle (No.)	Panicle weight (g)	1000-grain weight (g)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length before cooking (mm)	Kernel breadth before cooking (mm)	Length breadth ratio before cooking
Varieties													
HUR-4-3	3.69	57.9	188	26.4	200	5.10	23.1	69.0	65.9	52.4	6.89	1.59	4.28
HUR-105	3.37	57.2	181	25.4	195	4.52	22.5	70.6	67.1	53.8	6.81	1.79	3.80
NDR-6093	3.12	49.2	175	21.9	160	3.86	20.9	73.0	69.6	55.9	6.52	1.91	3.42
Rajendra Kasturi	2.93	50.8	178	23.4	176	4.16	18.1	73.4	69.9	57.6	4.48	2.02	2.25
SEm±	0.033	0.44	2.5	0.33	2.1	0.24	0.21	0.35	0.46	0.64	0.24	0.025	0.130
LSD (*P*=0.05)	0.112	1.50	8.6	1.14	7.3	0.84	0.73	1.20	1.59	2.21	0.83	0.086	0.448
Integrated nitrogen management													
100% RDN (120 kg N/ha)	3.23	50.0	177	23.1	157	3.88	20.8	70.3	66.8	53.6	6.01	1.76	3.48
75% RDN + 25% N through *Azolla microphylla*	3.37	57.8	190	25.4	205	4.69	21.5	72.5	69.1	56.1	6.36	1.91	3.39
75% RDN + 25% N through NADEP compost	3.24	52.9	183	24.0	193	4.46	21.3	71.8	68.4	54.9	6.18	1.83	3.44
75% RDN + 25% N through sewage sludge	3.29	56.9	185	25.2	199	4.59	21.4	72.2	68.8	55.6	6.23	1.85	3.42
75% RDN + 25% N through vermicompost	3.24	51.5	179	23.8	166	4.35	21.1	70.9	67.5	54.6	6.12	1.81	3.45
SEm±	0.025	0.34	2.4	0.19	2.0	0.07	0.05	0.21	0.24	0.41	0.15	0.019	0.032
LSD (*P*=0.05)	0.069	0.95	6.7	0.53	5.7	0.20	0.15	0.59	0.68	1.16	NS	0.054	2.89

superior over rest of the treatments. The enhancement in the growth and yield attributes of rice by the application of 75% RDN + 25% N through *Azolla microphylla* over 100% RDN was to the tune of 4.3, 15.6, 7.4, 9.7, 30.4, 20.9 and 3.4 per cent more leaf-area index, shoot dry weight, number of productive tillers/m^2, panicle length (cm), grains/panicle, weight/panicle (g) and 1000-grain weight (g), respectively. Crop plants have the tendency to uptake a balanced amount of nutrient from the soil solution provided when there is better soil microclimate. The incorporation of *Azolla* added good amount of organic biomass in addition to plant nutrients that acted positively to make the nutrients easy to uptake and hence, increased the growth and yield attributes. Singh *et al.* (2013) found improved plant height, tillers/hill and effective tillers/hill of aromatic rice when organic sources of nutrient were applied in combination of inorganic sources and concluded that it is more beneficial to have integrated approach in nutrient application for better crop characters.

Rice yield

Significantly higher grain yield (4.91 t/ha) and straw yield (6.16 t/ha) of rice was recorded with the variety HUR-4-3 but found at par to HUR-105 (Table 2). The per cent increment in the grain and straw yield by the rice variety HUR-4-3 over NDR-6093 was to the magnitude of 20.6 and 15.4%, respectively during the years of study. The higher yield of the variety HUR-4-3 was attributed to the improved yield contributing parameters, *viz*. number of productive tillers/ m^2, panicle length, grains/panicle, weight/ panicle and 1000-grain weight to this particular variety. Singh *et al.* (2013) employing aromatic rice in their study found significant increment in the yield parameters with the variety Pusa 44 under integrated supply of plant nutrient which clearly indicates the varietal factor that affects the crop yield. Further, plots fertilized with 75% RDN + 25% N through *Azolla microphylla* resulted into higher grain yield (4.82 t/ha) and straw yield (6.16 t/ha) which was statistically at par to the application of 75% RDN + 25% RDN through sewage sludge and significantly superior over rest of the INM practices. The magnitude of enhancement in the grain and straw yield with the treatment 75% RDN + 25% N through *Azolla microphylla* over 100% RDN was to the tune of 15.3 and 13.9%, respectively. It could be ascribed to the gradual release of nutrients after decomposition ensuring continued availability compared with inorganic fertilizer alone. Moreover, organics, besides supplying macro and micronutrient, have also solubilizing effect on native soil nutrients due to the action of organic acids evolved during decomposition. The combination of inorganic fertilizer with *Azolla microphylla* might have gradually supplied adequate amount of nutrients during reproductive phase contributed in the expansion of leaf surface and chlorophyll content which together might have accelerated the photosynthetic rate and as a result increased the supply of carbohydrates to the plants bringing about better yield attributing characters and finally higher grain and straw yield of aromatic rice. Further, the presence of *Azolla* compels an early reduction of nitrogen losses and an increased recovery of applied nitrogen by rice. However, a substantial fraction of the applied nitrogen was trapped up by *Azolla* leading to a reduction of the *Azolla* biological nitrogen fixation (BNF). The remobilization of this conserved nitrogen is of plays the important role in the final recovery and grain yield at maturity (Kollah *et al.* 2016). *Azolla* has the ability to absorb traces of potassium at a concentration as low as 0-5 ppm from water, while rice requires at least 8 ppm of potassium for effective absorption. Hence, when the *Azolla* decomposes, indirectly it acts as a good source of potassium

Table 2 Effect of integrated nitrogen management on yield and relative economics of aromatic rice varieties under SRI (pooled data of two years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Gross income ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	Output: Input (O:I)
Varieties					
HUR-4-3	4.91	6.16	175.48	128.40	3.76
HUR-105	4.81	6.13	134.00	86.90	2.87
NDR-6093	4.07	5.34	117.80	70.66	2.52
Rajendra Kasturi	4.23	5.53	177.47	130.35	3.79
SEm±	0.036	0.044	1.79	1.96	0.23
LSD (*P*=0.05)	0.123	0.154	6.16	6.76	0.80
Integrated nitrogen management					
100% RDN (120 kg N/ha)	4.18	5.41	140.37	98.38	3.34
75% RDN + 25% N through *Azolla microphylla*	4.82	6.16	162.21	117.14	3.60
75% RDN + 25% N through NADEP compost	4.44	5.72	148.85	97.88	2.92
75% RDN + 25% N through sewage sludge	4.76	6.10	159.64	114.64	3.55
75% RDN + 25% N through vermicompost	4.31	5.56	144.86	92.36	2.76
SEm±	0.033	0.040	1.14	1.33	0.09
LSD (*P*=0.05)	0.092	0.114	3.22	3.74	0.24

for soil (Van Hove 1989). Pandey *et al.* (2007) concluded that the application of 10 t/ha of FYM could compensate the reduced quantity of recommended dose of nitrogen in terms of comparable yield in rice crop which also depicts the importance of including organics in nutrient management.

Nutrient uptake

Different varieties and INM practices significantly influenced the nutrient uptake by the rice crop (Fig 1). Among the varieties, the higher nitrogen (102 kg N/ha), phosphorus (13.67 kg P/ha) and potassium (125 kg K/ha) uptake was noted under the variety HUR-4-3 but it was statistically at par with HUR-105 and significantly superior over the varieties NDR-6093 and Rajendra Kasturi. The magnitude of increment in the nutrient uptake by the rice variety HUR-4-3 over NDR-6093 was 20.0, 26.2 and 25.0 per cent N, P and K, respectively during the course of investigation. The higher nutrient uptake by the variety HUR-4-3 might be due to enhanced growth leading to increased rate of grain filling, the highest test weight with more number of grains/panicle and grain and straw yield in comparison to the other varieties. Sharma *et al.* (2012) found the variable rate of nutrient removal by aromatic rice varieties and concluded that the significantly higher nutrients uptake was estimated with the variety Pusa Basmati-1121. The INM in rice crop with 75% RDN + 25% N through *Azolla microphylla* recorded the greater value of nutrient uptake (102 kg N, 13.73 kg P and 124 kg K/ha), which was statistically at par with the application of 75% RDN + 25% RDN through sewage sludge and significantly superior over the rest. During the experiment, the treatment 75% RDN + 25% N through *Azolla microphylla* noted 18.6, 24.3 and 21.6 per cent higher N, P and K uptake, respectively over 100% RDN. This might be due to increased supply of nutrients directly through organic and inorganic sources to the crop as well as indirectly through reducing the loss of nutrients from soil solution resulting into better growth, higher biological yield as well as more nutrient concentration. Mohanty *et al.* (2013) found that N and P uptake by grain and straw of rice was highest with the application of 1/3[rd] N each as chemical fertilizer, FYM and *Azolla*, but higher K uptake was recorded with application of 50% N as chemical fertilizer and 50% N as *dhaincha*.

Soil fertility after rice

The rice variety NDR-6093 resulted higher available NPK after the harvest of rice crop but it was statistically on par with Rajendra Kasturi in the left over nutrient status of the soil (Fig 2). It may be attributed to the comparatively lower uptake of nutrients and hence, the higher leftover or the available nitrogen (222 kg N/ha), phosphorus (29 kg P_2O_5/ha) and potassium (231 kg K_2O/ha) in the soil after the harvest of the rice variety NDR-6093. Among the various nitrogen management practices, the application of 75% RDN + 25% N through *Azolla microphylla* exhibited higher available nitrogen (219 kg N/ha), phosphorus (29 kg P_2O_5/ha) and potassium (233 kg K_2O/ha) after the harvest of rice crop but shown its statistical equality with the treatment 75% RDN + 25% RDN through sewage sludge during the experiment. Increased quantity of available N, P and K with this treatment may be due to the gradual release and lesser loss of nutrients by *Azolla* application and hence, higher available nutrients after the harvest of the rice crop. Available nutrient content is significantly correlated to oxidizable organic carbon, total organic carbon, phosphorus, potassium. Singh and Chandra (2011) obtained significantly higher available nitrogen and phosphorus after harvest of rice crop under integrated nutrient management while available potassium was recorded higher within organic nutrient management than the integrated nutrient management. Further, Shahane *et al.* (2013) also reported that one-third of RDN (120 kg N/ha) through compost along with two-third of RDN through urea recorded the highest available nitrogen content in the soil after the harvest of rice crop.

Microbial population

The variation in the population of microbes, viz,

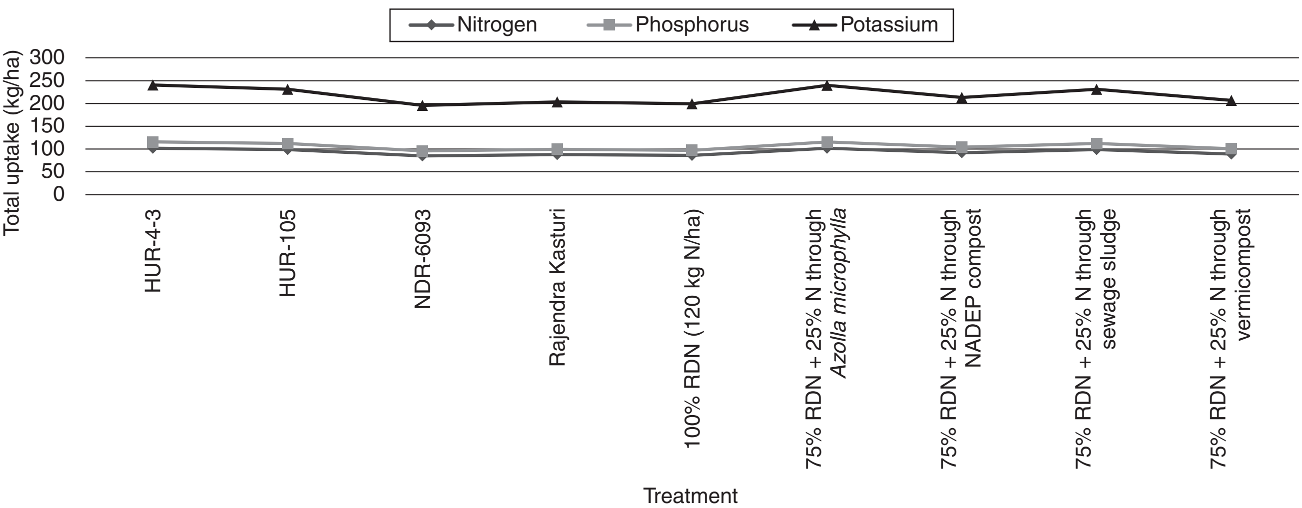

Fig 1 Effect of integrated nitrogen management on nutrient uptake by aromatic rice varieties under SRI (pooled data of two years).

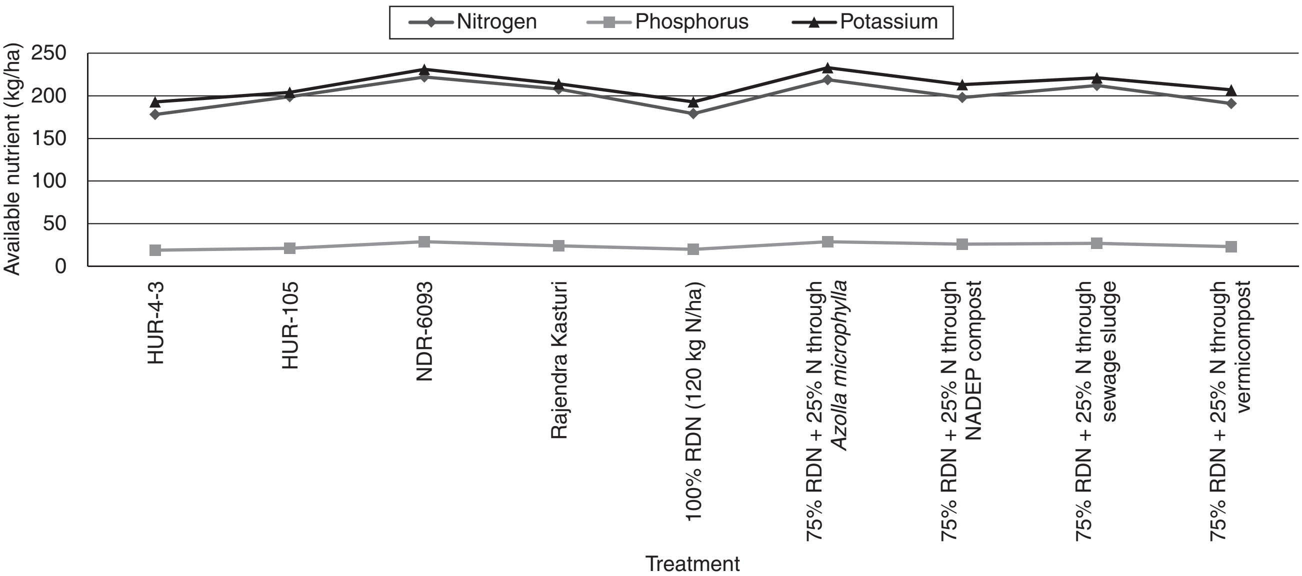

Fig 2 Available nutrient in soil after harvest of rice as influenced by integrated nitrogen management in rice varieties under SRI (pooled data of two years).

bacteria, fungi and actinomycetes in the soil as affected by different varieties of rice was found statistically unaffected during the study. However, INM practices exhibited significant variation in the soil bacterial, fungal and actinomycetes population [colony forming units (cfu)/g soil] in the rice crop (Table 3). The maximum value with respect to the population of bacteria (80.93×10^3 cfu/g), fungi (35.56×10^3 cfu/g) and actinomycetes (43.53×10^3 cfu/g) in the soil was recorded with the combination of 75% RDN and 25% N through *Azolla microphylla* applied to the rice crop. The rich organic matter added through *Azolla* build up moisture availability and revitalizes the soil micro environment as it serves as a nutritive substrate for the proliferation and multiplication of soil microbial community that might enhanced their population in the soil. Bahadur *et al.* (2013) reported the maximum bacterial population and *Azotobacter* in soil with the application of NPK Zn based on soil test + FYM @ 5 t/ha + PSB + BGA while; unaffected

Table 3 Soil microbial population in rice field, grain and straw yield of succeeding wheat and available nutrient in the soil after harvest of the wheat crop as affected by integrated nitrogen management applied in rice (SRI) varieties (pooled data of two years)

Treatment	Microbial population ($\times 10^3$) (cfu/g)			Wheat yield (t/ha)		Available nutrient (kg/ha)		
	Bacteria	Fungi	Actinomycetes	Grain	Straw	Nitrogen	Phosphorus	Potassium
Varieties								
HUR-4-3	70.6	32.0	40.1	3.51	5.30	177	19	195
HUR-105	72.3	32.7	39.4	3.48	5.26	193	20	202
NDR-6093	72.6	33.7	39.0	3.34	4.98	207	27	216
Rajendra Kasturi	72.7	33.3	39.2	3.39	5.03	203	22	209
SEm±	1.65	0.92	1.40	0.053	0.093	10.3	3.8	9.9
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nitrogen management								
100% RDN (120 kg N/ha)	67.0	30.2	37.3	3.22	4.87	205	27	217
75% RDN + 25% N through *Azolla microphylla*	80.9	35.6	43.5	3.62	5.33	180	21	196
75% RDN + 25% N through NADEP compost	73.8	34.1	40.1	3.47	5.21	193	24	210
75% RDN + 25% N through sewage sludge	70.8	32.0	38.7	3.53	5.26	186	22	204
75% RDN + 25% N through vermicompost	71.0	32.9	40.0	3.29	5.04	203	25	214
SEm±	1.32	0.43	1.03	0.049	0.039	9.7	2.6	8.6
LSD (*P*=0.05)	3.74	1.20	2.89	0.139	0.110	NS	NS	NS

Note I: Initial value (kg/ha) - N: 195, P_2O_5: 26.8 and K_2O: 224; Note II: Initial value [$\times 10^3$(cfu/g)]- Bacteria: 67.65, Fungi: 30.16 and Actinomycetes: 37.53

actinomycetes population by different nutrient management practices applied. Mishra *et al.* (2017) quantified the varied microbial biomass carbon (MBC) of soils from the lowest in control to the highest level in soils treated with 50% RDF + 50% N through *Azolla*. These results are in accordance to the findings of the current study.

Milling quality of rice

The milling quality of rice grain was also influenced significantly with subsequent varieties (Table 1). The results on hulling percentage, milling percentage and head rice recovery were statistically at par among the varieties Rajendra Kasturi and NDR-6093 but significantly superior to HUR-4-3 and HUR-105. The higher hulling percentage (73.4%), milling percentage (69.9%) and head rice recovery (57.6%) by Rajendra Kasturi can be ascribed to smaller grain size as compared to rest of the varieties. This might be the genetic makeup of the varieties that has inherited better quality characters compared within them during the course of study. The distinct grain qualities of the variety HUR-4-3 were exhibited during an evaluative study conducted with different aromatic varieties by Jaiswal and Singh (2011) that complements to the findings of the present study. Marked variation in the milling quality parameters of rice grain was evident due to various nitrogen management practices applied in the rice crop. Higher hulling percentage (72.5%), milling percentage (69.1%) and head rice recovery (56.1%) was found with the application of 75% RDN + 25% N through *Azolla microphylla* being statistically at par with 75% RDN + 25% RDN through sewage sludge. Jagannath *et al.* (2017) found that significant improvement in milling quality parameters, *viz.* hulling percentage, milling percentage and head rice recovery of grain by the combined application of RDN (150 kg N/ha) and BGA (12 kg/ha) in hybrid rice crop which depicts the fact that integrated nutrient supply system not only enhances the yield, it also improves the quality of produce.

Kernel quality of aromatic rice

The better kernel length before cooking (6.89 mm) was attributed to the variety HUR-4-3 which was found at par with HUR-105 and NDR-6093 while significantly superior over short grained variety Rajendra Kasturi (Table 1). Regarding breadth of the kernel, the highest kernel breadth before cooking (2.02 mm) was attributed to the variety Rajendra Kasturi which proved its superiority over rest of the varieties. The highest value of length/breadth (L/B) ratio before cooking (4.28) was computed with the variety HUR-4-3 which has shown its superiority among the varieties. This might be attributed to the genetic makeup of the variety HUR-4-3 which is a semi-dwarf mutant of a land race Lanjhi with inherited medium slender and distinct quality aromatic grains (Jaiswal and Singh 2011). Further, kernel quality parameters, *viz*. kernel length before cooking and length/breadth (L/B) ratio before cooking remained significantly unaffected due to various nitrogen management practices while the highest value of kernel breadth before cooking (1.91 mm) was attributed to the application of 75% RDN + 25% N through *Azolla microphylla* which has shown its superiority over rest of the treatments. Jagannath *et al.* (2017) found at par results on kernel length, kernel breadth and length/breadth (L/B) ratio before cooking by the combined application of chemical and organic sources of nitrogen in hybrid rice under SRI which supports the outcomes of this study.

Yield of succeeding wheat

The variation among the grain and straw yield of succeeding wheat crop due to different varieties grown in the preceding rice crop remained non-significant (Table 3). Further, various INM practices applied in the preceding rice crop exhibited significant residual effect on the productivity of succeeding wheat crop. Application of 75% RDN + 25% N through *Azolla microphylla* to the preceding rice crop resulted higher grain yield (3.62 t/ha) and straw yield (5.33 t/ha) of the succeeding wheat crop, being statistically at par with the treatment 75% RDN + 25% RDN through sewage sludge and significantly superior over the rest INM practices. The magnitude of enhancement in the grain and straw yield of the succeeding wheat due to the residual effect of 75% RDN + 25% N through *Azolla microphylla* over 100% RDN applied in preceding rice crop was 12.42 and 9.44%, respectively. These results indicated that organic manures supplemented nutrients and increased its availability in the soil resulted augmentation of soil fertility to exhibit higher yield attributes and yield of succeeding wheat. Higher residual effect in the form of enhanced yield of succeeding wheat was recorded with the application of 50% RDN + 50% N through FYM + *Azospirillum by* Jat *et al.* (2015). Shah *et al.* (2017) found that the grain yield traits of succeeding wheat after rice increased significantly by the application of organics, *viz. in-situ* green manure of *dhaincha* + vermicompost + mulching with *dhaincha*. These results support the finding of the current study and reveal the positive effect of judicious nutrient management performed in rice crop on succeeding wheat.

Soil fertility after wheat

Different varieties and INM practices applied to the rice crop remained statistically ineffective with respect to the available nitrogen, phosphorus and potassium in the soil after harvest of the succeeding wheat crop during the course of investigation (Table 3). This could be attributed to the dependency of the succeeding wheat crop on the residual fertility of the plots after rice. Further, applying only 50% of recommended dose of fertilizer, the crop had to thrive under a limited supply of nutrient resulting uptake of maximal share of the nutrient available in soil nutrient pool during the crop period to fulfil the crop demand. Hence, the variation in the status of available nutrient in soil after succeeding wheat crop was found non-significant. In contrast to the results of present study, Urkurkar *et al.* (2010) reported marked improvement in available N and P while non-significant increment in available K after harvest of wheat in rice-wheat system due to the application of various organics, *viz*. green manure (*Sesbania aculeata*), farmyard manure and composted rice straw in conjunction to 50% RDF to the rice crop.

Relative economics

The gross income, net return and output-input ratio (O:I) were recorded higher under the rice variety Rajendra Kasturi but statistically at par with the variety HUR-4-3 (Table 2). These increments would be attributed to higher market price of Rajendra Kasturi among the four varieties. Further, higher yield of HUR-4-3 has compensated its lesser returns and hence, the economic gain is comparable to that of Rajendra Kasturi. Among the INM practices, the treatment 75% RDN + 25% N through *Azolla microphylla* resulted higher values of gross income, net return and output-input ratio (O:I) in the rice crop but it remained statistically at par with 75% RDN + 25% RDN through sewage sludge which was due to higher grain and straw yield resulting higher economic gain. Panwar (2014) found the highest net return and benefit-cost ratio (B:C) with FYM 5 t/ha + *Azolla* dual cropping + 50% RDF applied to rice crop which supports the findings of the current study.

Conclusion

It is concluded from present study that the aromatic rice variety HUR-4-3 may be the better option in terms of yield attributes, yield, milling quality, length-breadth ratio before cooking and nutrient uptake by the crop while the variety Rajendra Kasturi may be the remunerative one regarding higher gross income, net return and output-input ratio. Moreover, the application of 75% recommended dose of nitrogen (RDN) (90 kg N/ha) through chemical fertilizers in conjunction to 25% RDN (30 kg N/ha) through *Azolla microphylla* may be the superior option for enhancing yield attributes, yield, milling quality, nutrient uptake and profitability of aromatic rice. Simultaneously, it could improve the soil microclimate to proliferate essential micro-fauna including bacteria, fungi and actinomycetes as well as ensure higher productivity of succeeding wheat.

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