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Research Article *Natural Resource Management*

Integrated Nitrogen Management Influences the Yield Performance of Rice under Different Methods of Cultivation

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Abstract

The field studies were conducted during 2012 and 2013 at Banaras Hindu University, Varanasi, Uttar Pradesh, India. The experiments were undertaken on two rice hybrids cultivated under two different establishment techniques with integrated nitrogen management to evaluate the growth dynamics, production potential and nutrient removal of rice. Results revealed that the system of rice intensification (SRI) and rice cv. Arize-6444 recorded significantly higher growth attributes *viz*., number of tillers hill^{-1}, dry matter accumulation, crop growth rate and relative growth rate with almost yield attributes and yield with nutrient harvest index and total water productivity. The corresponding increment in grain and straw yield of rice under SRI to the tune of 14.66% and 13.12% over normal transplanting and rice hybrid Arize 6444 produced 8.63% and 5.32% higher grain and straw yield over PHB 71, respectively. Among the integrated nitrogen management practices, the application of 50% RDN+50% N through FYM+*Azospirillum* recorded significantly higher growth attributes, grain yield (6942 kg ha^{-1}), protein content (7.80%), nutrient content, protein yield (542 kg ha^{-1}) total nutrient uptake, total water productivity (5.90 kg/ha-mm) and nutrient harvest index of rice. The study concluded that the conjunctive application of inorganic fertilizer and organic manure with biofertilizer to rice hybrid 'Arize-6444' cultivation under SRI method for realizing higher yield of rice in eastern Uttar Pradesh.

Keywords: Rice, Azospirillum, CGR, hybrids, nitrogen and spikelet sterility

1. Introduction

Rice cultivation is in crisis the world over and India with a shrinking area, reducing water availability, fluctuating annual production, stagnating yields and escalating input (Thakur et al., 2016). The production cost of paddy has consistently been increasing owing to the escalating costs of seeds, fertilizers, labour and other inputs. With increasing labour scarcity due to urbanization, sustaining the interest of farmers in rice cultivation has become a challenge. Amongst production resources, water and nitrogen have especial role in increasing rice production. Global availability of water was 3500 m^3 person^{-1} year^{-1} in 1950, which reduced to 1250 m^3 person^{-1} year^{-1} in 2003 and is estimated to be 760 m^3 person^{-1} year^{-1} in 2050 (Prasad and Nagrajan, 2004). Irrigated agriculture

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utilizes about 90% of fresh water and out of which >50% is used for rice cultivation (Jat et al., 2016). Water scarcity is becoming more a global concern and signal of serious water scarcity are already evident in several agricultural areas. Besides this increasing threat to productivity of irrigated rice systems due to water scarcity, rice has very low water-use efficiency under irrigated conditions. It consumes approximately 3000-5000 litre of water to produce one kg of rice. In India, rice cultivation consumes 80% of the total water available for agriculture. About 50-80% of total water applied to rice fields is lost as deep percolation, while only 30-40% is utilized consumptively. Increasing scarcity due to increasing demand for water from other sectors threatens the sustainability of irrigated rice production and calls for development of novel technologies that require less water than conventional flooded rice without experiencing yield losses (Kadiyala et al., 2012; Singh, 2013). There is clearly an urgent need to find ways to grow more rice with less water and fewer inputs. One way to address the dearth of water for rice production would be to shift from conventional methods of rice cultivation to apply the system of rice intensification (SRI). SRI has numerous advantages over the conventional system of rice production. It increases rice grain yield by at least 50% (Lin et al., 2005), save seeds by at least 80-90% (Miyazato et al., 2010), save water by at least 50% (Satyanarayana et al., 2007) or 67% (Lazaro, 2004), as well as reducing the cost of rice production. This innovative method of rice cultivation, by requiring only intermittent and light irrigations that can reduce the water demand and percolation losses from rice fields. SRI is gaining popularity in the country in recent past but so far, no specific nutrient management strategy has been developed or recommended for SRI. Continuous, imbalanced and high level use of chemical or inorganic fertilizers had led to soil degradation problems, which are proving detrimental to rice production *i.e.* declining trend in the productivity of rice even when grown under adequate N, P and K application (Jat et al., 2016; Saravanakumar, 2020). Application of inorganic fertilizers alone could not sustain the soil fertility and productivity. Integration of organic sources such as FYM and biofertilizer may also help in the restoration of soil health (Pillai et al., 2007). The conjunctive application of organics with inorganic sources of nutrient reduces the dependence on chemical inputs, and it not only acts as a source of nutrient but also provides micronutrient as well as modifies the soil physical behaviour and increases the efficiency of applied nutrients (Pandey et al., 2007). Considering above facts in view the present field experiment was planned to study the effect of integrated nitrogen management on performance of rice hybrids under different methods of cultivation for agro-climatic region of eastern Uttar Pradesh.

2. Materials and Methods

2.1. Experimental site and weather

A field experiment was conducted during 2012 and 2013 at Banaras Hindu University, Varanasi (25°18' N latitude, 83°03' E longitude and at an altitude of 75.7 m above mean sea level) in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. The crops received 691.5 mm of rainfall during 2012 and 825.0 mm in 2013. The rainfall observed to be higher in initial stage but later it was uniformly distributed throughout the crop period during the second year. The weekly mean maximum temperature varied from 29.4 to 42.6°C (average 33.13°C) and 26.7 to 38.0°C (average 31.73°C) along with minimum temperature ranged from 16.3 to 30.6°C (average 25.28°C) and 17.3 to 28.3°C (average of 25.17°C) during 2012 and 2013, respectively. The weekly mean sun-shine hours in 2012 was low (5.36 hours) as compared to 2013 (5.72 hrs.). The weekly mean rate of evaporation was less in second year (3.62 mm) over first year (4.14 mm), respectively. The soil is typic *Ustochrepts* with sandy clay loam texture (50.27% sand, 27.41% silt, and 22.32% clay), bulk density of 1.41 Mg m^{-3}, and low in available nitrogen and phosphorus with medium in available potassium status (Table 1).

Table 1: Initial soil physico-chemical properties of the experimental field (0-20 cm soil)

Year	EC^{*} (dS m^{-1})	pH	$OC^{\#}$ (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
2012	0.18	7.39	0.34	205.20	25.30	215.60
2013	0.17	7.41	0.35	213.21	25.86	219.80

*: Electrical conductivity; #: Organic carbon

2.2. Experimental details

The experiment was laid out in split-plot design replicated thrice with keeping 5.0 by 4.0 m plots. The treatments comprised two crop establishment methods (NT- Normal transplanting/traditional method and SRI- System of rice intensification) with two hybrids i.e. PHB-71 (duration 120-130 days) and Arize-6444 (duration 130-140 days) as assigned to main plots. Each main plot were further divided into six sub-plots to accommodate integrated nitrogen management treatments, *i.e.* (N_1-100% RDN, N_2-125% RDN, N_3-50% RDN+50% N through FYM, N_4-50% RDN+50% N through FYM+*Azospirillum*, N_5-100% N through FYM, N_6-Control/No fertilizer).

2.3. Crop management and observations

The experimental field was ploughed with tractor drawn mould board plough followed by two harrowing. Before laying out the experiment the field was puddled for transplanting. Nursery bed of normal transplanting (23 days old seedlings) was raised fourteen days before the SRI nursery (10 days old seedlings) to synchronize the transplanting at a same time. Seedlings were treated with biofertilizer '*Azospirillum*' by root deep in culture as per treatment. Two seedlings for normal transplanting and single seedling hill^{-1} for SRI along with soil was transplanted by using index finger or thumb and gently planted at the spacing was maintained at 20×15 cm^2 under normal transplanting and 25×25 cm^2 under SRI plots in puddled soil on 5th July, 2012 and 4th July, 2013. Recommended dose of fertilizer *i.e*. 150, 75 and 60 kg ha^{-1} N, P_2O_5 and K_2O for rice were applied as per treatments. Farmyard manure (0.51% N, 0.26% P_2O_5 and 0.50% K_2O) was manually incorporated as per the treatments. Nutrient application was done as per treatments. Irrigation was given with the help of parshall flume only on appearance of hair line cracks. Weed management was done manually under normal transplanting method and conoweeding under SRI to reduce the weed infestation and other crop management practices were followed as per the standard recommendation. The field observations on plant height, number of tillers hill^{-1}, dry matter accumulation, crop growth rate, relative growth rate, number of filled grains panicle^{-1}, number of unfilled spikelets panicle^{-1}, spikelet sterility percentage, protein contents, protein yield, grain yield, harvest index, water productivity, nutrient uptake and nutrient harvest index were recorded. The nutrient content were estimated from both seed and stover, separately during both years and its uptake were estimated with the help of total seed and stover yield multiply with respective nutrient content.

Crop growth rate and relative growth rate were computed between 30-60 and 60-90 DAT by the formulae given by (Redford, 1967).

Where, W_1, W_2 are dry matter and at time t_1, t_2, and Ln=Natural logarithm

Spikelet sterility (%) was also calculated. Irrigation water was measured using a 'parshall flume'. The irrigation was applied to rice as per requirement, but also depended on the rainfall. The quantity of water applied and the depth of irrigation were computed using standard procedure. The input water productivity was computed as the ratio of grain yield to the total water input (irrigation+rainfall) from nursery raising to harvesting of the crop and expressed as kg grain ha mm^{-1}. Protein content in grain was worked out by multiplying the nitrogen content in grain with the factor 6.25, as suggested by (AOAC, 1970). Protein yield was determined by multiplying the protein content in grain with their respective yields.

The nutrient harvest index was determined by Dass et al., 2010.

Nutrient harvest index (%)=(Nutrient uptake by grain (kg ha^{-1})/ Nutrient uptake by grain+straw (kg ha^{-1})×100

2.4. *Statistical analysis*

The experimental data of two consecutive years were pooled and analyzed statistically by applying the technique of analysis of variance (Gomez and Gomez, 1984) prescribed for the split plot design to test the significant difference among treatments by the F test and conclusions were drawn at 5% probability levels.

3. Results and Discussion

3.1. *Crop growth*

SRI planting recorded significantly higher plant height, number of tillers hill^{-1}, dry matter accumulation hill^{-1}, CGR between 30-60 DAT and RGR between 60-90 DAT over normal transplanting. However, CGR between 60-90 DAT and RGR between 30-60 DAT under both the crop establishment method could not influenced significantly (Table 2). This may be attributed under normal transplanting have 23 days old seedlings and in SRI only 10 days old seedlings were planted, consequently rapid growth of older seedling during initial stage under normal transplanting is well acknowledged thereafter at successive stage SRI produced more growth by their 10 days old tender age seedlings which obviously took more time to initiate better growth over normal transplanting (Singh, 2013). Significantly higher no. of tillers hill^{-1} was produced under SRI as compared to normal transplanting. However, tender age seedling showed better agronomic potential to produced significantly higher dry matter accumulation hill^{-1}. Similar findings were earlier reported by (Krishna et al., 2008). SRI planting significantly increased by 13.34% and 16.50% more dry matter production hill^{-1} over normal transplanting at 30 and 60 DAT. The current findings are parallel with the finding of (Chandrapala et al., 2010; Manjunatha et al., 2010). Amongst the two hybrids, no. of tillers hill^{-1} and dry matter accumulation hill^{-1} was significantly increased due to hybrid Arize-6444 over PHB-71. However, the tallest plant was recorded with PHB-71. The differences in plant height among cultivars are mainly due to their genetic build up (Singh et al., 2013). However, relatively more tillers hill^{-1}, dry matter, crop growth rateand relative growth rate were recorded with 'Arize-6444' and showed its significant superiority over 'PHB-71'. Differences have been observed in grain yield among plants or hybrids having the same amount of dry matter, because differences exist in the utilization of photosynthates among them (Hayashi, 1995). High efficient photosynthetic performance of super high-yielding rice hybrids to produce more no. of tillers hill^{-1}, resulting in to more dry matter synthesis is largely due to the increased '*cytokinin*' content in their roots (Shu-Qing et al., 2004) contributing to produced higher grain yield. Among integrated nitrogen management treatmentsthe application of 50% RDN+50% N through FYM+*Azospirillum* produced higher plant height, no. of tillers hill^{-1}, dry matter accumulation hill^{-1}, CGR and RGR though it remained statistically at par with 125% RDN but significantly superior over rest of the treatments (Table 2). This might be due to combined application of inorganic fertilizer with FYM and biofertilizer facilitating better structure, texture, soil environment for root development and increased availability of nitrogen for longer period. The additional nitrogen fixed by *Azospirillum* was made available to plants. Similar results were also reported by (Rakshit et al., 2008; Sangeetha et al.,

Table 2: Effect of crop establishment methods, hybrids and integrated nitrogen management on growth parameters of rice (Pooled data of 2 years)

Treatments	Plant height (cm)		Number of tillers hill^{-1} at		Dry matter accumulation (g hill^{-1})		CGR (g hill^{-1} day^{-1})		RGR (mg g^{-1} day^{-1})	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30-60 DAT	60-90 DAT	30-60 DAT	60-90 DAT
A. Crop establishment methods										
Normal transplanting	63.51	101.64	13.46	18.15	8.69	27.65	0.632	1.14	38.83	27.27
SRI	57.87	96.84	15.94	21.90	9.85	32.21	0.746	1.21	39.43	24.04
SEm±	0.447	0.711	0.169	0.216	0.119	0.312	0.009	0.034	0.407	0.675
CD (*p*=0.05)	1.377	2.191	0.521	0.666	0.366	0.960	0.027	NS	NS	2.080
B. Hybrids										
PHB-71	62.90	102.42	14.22	18.46	9.44	28.99	0.652	1.06	38.12	23.58
Arize-6444	58.48	96.06	15.18	21.59	9.11	30.87	0.726	1.28	40.14	27.73
SEm±	0.447	0.711	0.169	0.216	0.119	0.312	0.009	0.034	0.407	0.675
CD (*p*=0.05)	1.377	2.191	0.521	0.666	NS	0.960	0.027	0.105	1.253	2.080
C. Integrated nitrogen management										
100% RDN	61.92	103.43	15.38	20.82	10.25	33.23	0.766	1.20	38.52	24.59
125 % RDN	63.65	104.29	16.48	22.95	11.19	33.43	0.742	1.27	36.26	25.19
50% RDN+50% N through FYM	60.20	99.29	14.75	19.93	9.19	30.47	0.692	1.26	38.19	26.68
50% RDN+50% N through FYM+ *Azospirillum*	64.49	104.90	16.87	23.30	10.58	34.45	0.796	1.28	39.51	24.37
100% RDN through FYM	58.73	93.77	13.88	18.58	7.86	27.32	0.649	1.14	41.59	26.85
Control (No fertilizer)	55.17	89.78	10.84	14.58	6.05	20.69	0.488	0.89	40.68	26.25
SEm±	0.473	0.836	0.138	0.505	0.114	0.340	0.011	0.036	0.461	0.714
CD (*p*=0.05)	1.331	2.353	0.387	0.576	0.321	0.957	0.031	0.103	1.297	NS

*DAT= Day after transplanting

2010; Saravanakumar, 2020).

3.2. Yield performance and water productivity

SRI planting significantly produced 8.57%, 14.66% and 13.12% more number of filled grains panicle^{-1}, grain yield and straw yield with minimum unfilled spikelets panicle^{-1} (23.56) and sterility (11.54%) as compared to normal transplanted rice (Table 3). Harvest index was remained equally effective due to both the establishment methods. This might be due to SRI seedling utilized phyllochronic potential to produce significantly higher grain and straw yield over normal transplanting. The irrigation water application depends on the total rainfall and its pattern of distribution. The highest water productivity (5.59 kg/ha-mm) was recorded in SRI followed by normal transplanting (4.80 kg/ha-mm) which was 14.13% higher over normal transplanting. Due to marked improvement in growth and yield attributes, likewise dry matter accumulation, panicles m^{-2} and grains panicle^{-1} proved instrumental in increasing grain and straw yield under SRI. Improvement in yield attributes, yield and water productivity associated with SRI management proved conducive for increasing rice yields under irrigated production systems due to single seedling hill^{-1}, young seedlings and moderate wetting and drying soil conditions. With SRI, the transplanting of young seedlings results in a prolonged period for more root development and tillering. Moreover, with young seedlings the transplanting shock will be minimal, while greatly reduced plant density over normal transplanting favour the development of a distinctly different plant phenotype. These findings are confirmed by (Thakur et al., 2013). Meanwhile, rice hybrid Arize-6444 out yielded over PHB 71 with recording significantly higher filled grains panicles^{-1} (183) and harvest index (42.95%) along with minimum unfilled spikelet panicle^{-1} and sterility percent. Hybrids 'Arize-6444' showed great potential to exploit hybrids vigour to produce higher grain yield and showed marked superiority over 'PHB-71'. Data on grain yield revealed that 'Arize-6444' recorded significantly higher grain yield (6365 kg ha^{-1}) and straw yield (5859 kg ha^{-1}) over 'PHB-71'. This hybrid also registered significantly higher

Table 3: Effect of crop establishment methods, hybrids and nitrogen management on yield characters and yield of rice (Pooled data of 2 years)

Treatments	No. of filled grains panicle^{-1}	No. of unfilled spikelet panicle^{-1}	Sterility (%)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Water productivity (kg/ha-mm)
A. Crop establishment methods							
Normal transplanting	169.71	25.40	13.15	5695	7700	42.43	4.80
SRI	184.27	23.56	11.54	6530	8711	42.73	5.59
SEm±	2.342	0.263	0.063	58.4	62.4	0.197	0.050
CD (*p*=0.05)	7.215	0.809	0.193	180.1	192.3	NS	0.154
B. Hybrids							
PHB-71	170.46	25.35	13.06	5859	7993	42.21	4.98
Arize-6444	183.51	23.61	11.63	6365	8419	42.95	5.41
SEm±	2.342	0.263	0.063	58.4	62.4	0.197	0.050
CD (*p*=0.05)	7.215	0.809	0.193	180.1	192.3	0.608	0.154
C. Integrated nitrogen management							
100% RDN	183.65	23.82	11.55	6485	8664	42.77	5.51
125 % RDN	188.59	23.21	11.02	6597	8773	42.84	5.61
50% RDN+50% N through FYM	181.51	24.86	12.13	6407	8498	42.96	5.45
50% RDN+50% N through FYM+ *Azospirillum*	193.35	22.07	10.32	6942	9158	43.13	5.90
100% RDN through FYM	171.15	25.60	13.05	5909	7916	42.73	5.02
Control (No fertilizer)	143.66	27.30	16.01	4334	6225	41.03	3.68
SEm±	1.847	0.237	0.072	62.0	68.2	0.261	0.053
CD (*p*=0.05)	5.199	0.666	0.203	174.5	192.1	0.734	0.149

*DAT= Day after transplanting

water productivity as compared to PHB-7, respectively. These results are in close conformity with the earlier findings of (Choudhary et al., 2013; Gupta et al., 2011; Jat et al., 2015; Jat et al., 2016; Vishwakarma et al., 2016). Production potential, vigourness (genetic traits) and physiological efficiency of hybrid are responsible to differentiate it from other hybrids in their growth habits, rooting pattern, input utilization and resistance development against insect pest and diseases that ascribed to harvest optimum yield under a definite set of agro-climatic condition (Shukla et al., 2015; Jagtap et al., 2018). The application of 50% RND+50% N through FYM+*Azospirillum* brought about marked improvement in filled grains panicle^{-1} and grain yield of rice and also recorded significantly lowest unfilled spikelet panicle^{-1} and sterility percent over remaining treatments. Combined application of 50% RND+50% N through FYM+*Azospirillum* had a total water productivity of 5.90 kg/ha-mm, whereas control treatment had a lowest water productivity of 3.68 kg/ha-mm as two years pooled data basis. It is might be due to cumulative effect of organic sources combined with inorganic and bio fertilizer resulted more contribution in photosynthesis. Plants remained green for longer time with increase in nitrogen release for longer period contributed in production of carbohydrates from current photosynthates for increased number of filled grains panicle^{-1}, coinciding with more sunshine hours for increased photosynthetic products to fill better sink resulting in higher filled grain panicle^{-1} (Pandey et al., 2007). Significant positive linear relationships between filled grains panicle^{-1} and number of panicles m^{-2} with grain yield were observed with the respective values of r^2=0.884 (Figure 1) and r^2=0.800 (Figure 2). The number of panicles m^{-2} and filled grains panicle^{-1} increased as rice yield increased, while an inverse trend was observed with unfilled spikelets panicle^{-1} and sterility percent with grain yield with the value of r^2=0.531 (Figure 1) and r^2=0.801 (Figure 2). Yield is a function of complex inter-relationships of its components, which are determined from the growth rhythms in vegetative phase and its subsequent reflection in reproductive phase of the plant. These results are in agreement with the findings of (Alim, 2012; Islam et al., 2012; Jat et al., 2016).

3.3. *Protein content and protein yield*

Protein content (7.74%) and protein yield (507 kg ha^{-1}) was recorded significantly higher (Table 4) under SRI planting over

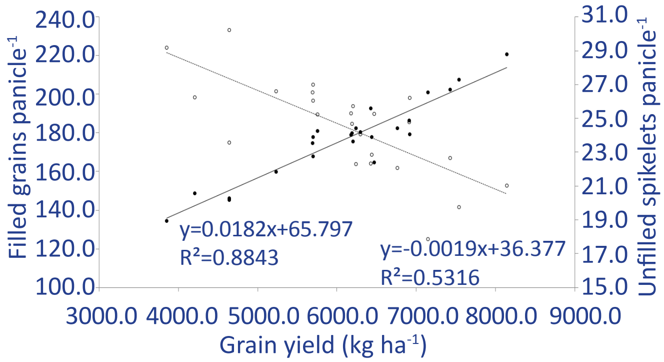

Figure 1: Relationship between filled grain panicle^{-1}, unfilled grain panicle^{-1} and grain yield of rice. Positive correlations are represented by closed symbol and negative correlations are represented by open symbols (Mean data of two years)

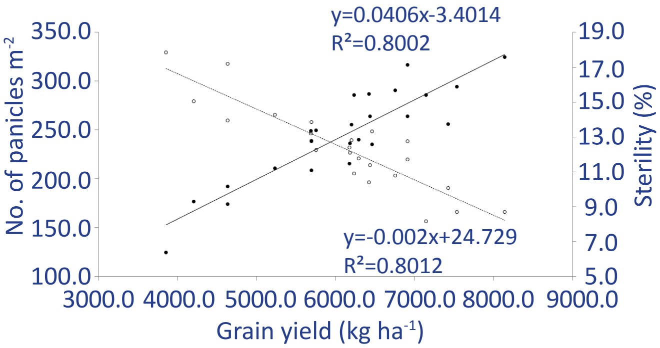

Figure 2: Relationship between number of panicles m^{-2}, sterility (%) and grain yield of rice. Positive correlations are represented by closed symbol and negative correlations are represented by open symbols (Mean data of two years)

Table 4: Effect of crop establishment methods, hybrids and nitrogen management on nutrient content in rice (Pooled data of 2 years)

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
			Grain	Straw	Grain	Straw	Grain	Straw
A. Crop establishment methods								
Normal transplanting	7.40	422	1.185	0.612	0.202	0.094	0.239	1.452
SRI	7.74	507	1.238	0.617	0.213	0.097	0.248	1.559
SEm±	0.03	3.54	0.005	0.0008	0.0011	0.0005	0.002	0.0082
CD (*p*=0.05)	0.10	10.90	0.0153	0.0023	0.0034	0.0016	0.005	0.0252
B. Hybrids								
PHB-71	7.61	447	1.217	0.616	0.209	0.097	0.246	1.512
Arize-6444	7.67	482	1.206	0.614	0.206	0.095	0.240	1.498
SEm±	0.03	3.54	0.005	0.0008	0.0011	0.0005	0.002	0.0082
CD (*p*=0.05)	NS	10.90	NS	NS	NS	0.0016	0.005	NS
C. Integrated nitrogen management								
100% RDN	7.61	495	1.218	0.619	0.211	0.096	0.241	1.503
125 % RDN	7.67	507	1.228	0.629	0.221	0.096	0.251	1.526
50% RDN+50% N through FYM	7.52	482	1.203	0.611	0.206	0.095	0.255	1.512
50% RDN+50% N through FYM+ *Azospirillum*	7.80	542	1.247	0.633	0.229	0.098	0.262	1.546
100% RDN through FYM	7.45	441	1.192	0.605	0.193	0.096	0.228	1.479
Control (No fertilizer)	7.37	320	1.197	0.593	0.184	0.092	0.224	1.465
SEm±	0.04	5.24	0.0058	0.0006	0.0009	0.0006	0.002	0.0098
CD (*p*=0.05)	0.10	14.75	0.0162	0.0017	0.0025	0.0017	0.005	0.0277

*DAT= Day after transplanting

normal transplanting (7.40% and 422 kg ha^{-1}). This might be due to higher affectivity for nitrate reduction activities in source and catalyses enzyme '*protease*' that are associates with synthesis of amino acid, a precursor for building block of protein in grains. These results were supported by (Krishna et al., 2008). Protein content in rice grain did not influenced significantly due to different hybrids (Table 4). However, rice hybrid 'Arize-6444' recorded significantly higher protein yield (482 kg ha^{-1}) over 'PHB-71', respectively. Quality parameters are genetically governed and different cultivars haves different constituents which cannot be change, but can slightly be bio-fortified with agronomic practices. These results were supported by (Singh et al., 2013). Incorporation of 50% RND+50% N through FYM+*Azospirillum* recorded significantly higher protein content and protein yield over rest of the treatments. However, both the inorganic treatments *i.e*. 100% and 125% RDN proved statistically at par with each other in regards to protein content and their yield. This may be due to the increased concentration of N in the grains, which might have modified the proportion of grain constitutions. These results are in close conformity with the findings of (Hossain et al., 2009; Davari and Sharma, 2010).

3.4. NPK content, uptake and nutrient harvest index

Transplanting of rice under SRI induced significant in bringing marked improvement in NPK content (Table 4) and their uptake in grain and straw with the total uptake margin was 20.14, 3.64 and 26.3 kg ha^{-1} more over normal transplanting, respectively. Similar trends were also observed with regards to NPK harvest index (Table 5). Vigorously growing plants are able to absorb larger quantity of mineral nutrients through well-developed root system. Larger root systems enable plants to access a greater volume of soil and to acquire more nutrients from various soil depths. Under aerobic soil conditions of SRI, root systems experience less deterioration and senescence. Aerobic soil conditions are generally more favourable for root functioning compared to anaerobic circumstances (Drew, 1997; Kirk and Solivas, 1997). A relatively higher increase of accumulated NPK in SRI planted crops as compared to their increase in conventionally planted rice. This can be further explained by regression analysis of rice grain yield with total NPK uptake for plants grown under both the environment was done assuming a polynomial relationship (Figure 3). This analysis indicated that with regard to NPK uptake, conventionally grown plants have a much faster decrease of internal efficiency. This decrease in grain production in response to marginal increases in nutrient uptake is expressed by the second degree of the parabolic equation having value of r^2=0.956, 0.929 and 0.852 for normal transplanting and r^2=0.947, 0.927 and 0.842 for SRI methods with N, P and K uptake in response to grain yield (Figure 3). This means that increments to grain yield declined more rapidly in conventionally grown plants as these increased their uptake of nutrients compared with SRI plants. The difference in the respective abilities of these two categories of rice plant to convert the NPK taken up into grain yield reflects phenotypical divergence in terms of plant structure and physiology. Similar

Table 5: Effect of crop establishment methods, hybrids and integrated nitrogen management on nutrient uptake and nutrient harvest index of rice (Pooled data of 2 years)

Treatments	Total nutrient uptake (kg ha^{-1})			Nutrient harvest index (%)		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
A. Crop establishment methods						
Normal transplanting	114.85	18.86	125.82	58.71	61.11	10.85
SRI	134.99	22.50	152.12	59.89	61.95	10.62
SEm±	0.770	0.213	1.186	0.216	0.260	0.129
CD (*p*=0.05)	2.371	0.655	3.655	0.665	0.800	NS
B. Hybrids						
PHB-71	120.98	20.13	135.92	59.01	61.10	10.68
Arize-6444	128.85	21.22	142.02	59.60	61.96	10.80
SEm±	0.770	0.213	1.186	0.216	0.260	0.129
CD (*p*=0.05)	2.371	0.655	3.655	NS	0.800	NS
C. Integrated nitrogen management						
100% RDN	132.87	22.11	145.87	59.47	62.08	10.72
125 % RDN	136.30	23.06	150.69	59.36	63.25	10.98
50% RDN+50% N through FYM	129.00	21.29	145.18	59.68	62.02	11.32
50% RDN+50% N through FYM+*Azospirillum*	144.78	24.85	160.17	59.86	63.92	11.39
100% RDN through FYM	118.50	19.01	130.77	59.44	59.84	10.36
Control (No fertilizer)	88.05	13.75	101.14	58.01	58.05	9.66
SEm±	1.059	0.198	1.380	0.299	0.333	0.137
CD (*p*=0.05)	2.982	0.558	3.883	0.842	0.938	0.387

*DAT= Day after transplanting

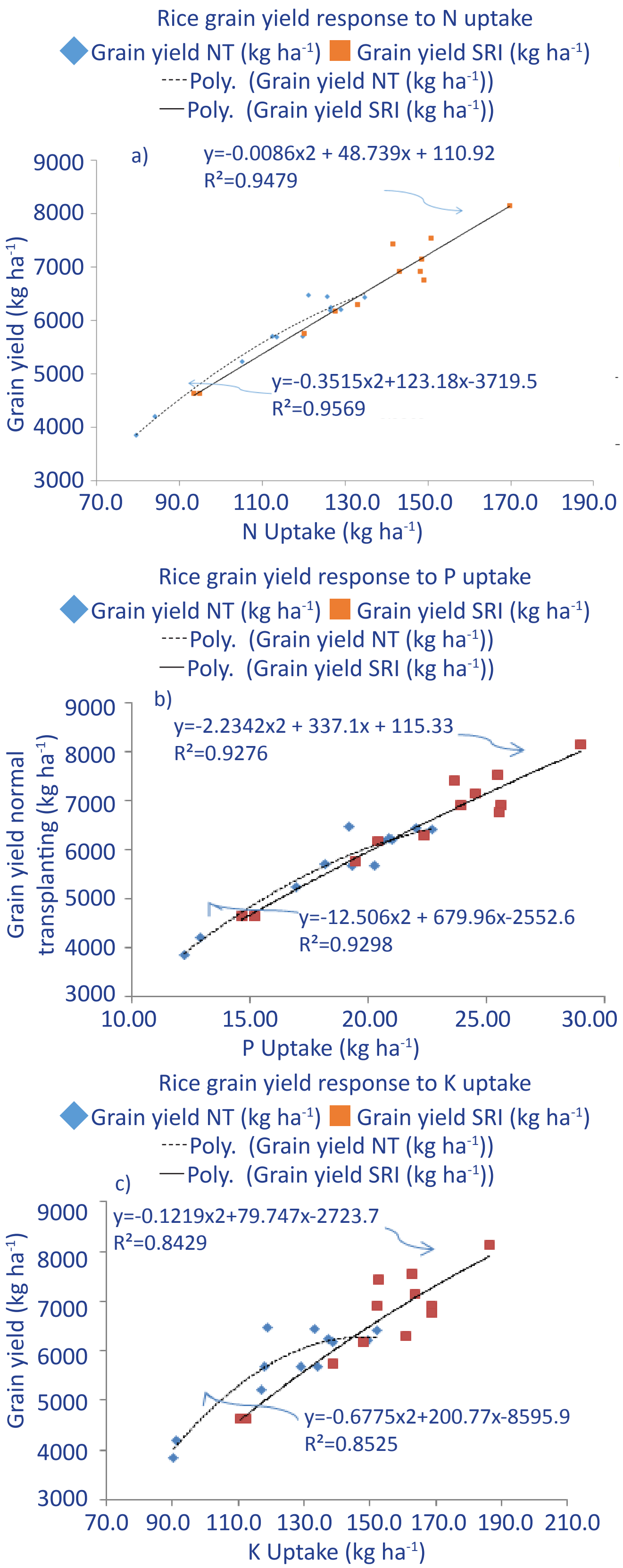

Figure 3 (a,b,c): Relationship between NPK uptake and grain yield of rice grown under normal transplanting (NT) versus SRI (Poly: polynomial regression line)

findings were also reported by (Barison and Uphoff, 2011). NPK contents in grain and straw were not influenced significantly by hybrids except phosphorus content in straw and potassium content in grain, which were significantly higher under PHB-71 over Arize-6444. Hybrids produced significant variation on NPK uptake in grain as well as straw. Higher NPK uptake in Arize-6444 showed its dominancy over PHB-71. Arize-6444 assimilated 7.87, 1.09 and 6.10 kg NPK ha^{-1} higher total uptake as compared to PHB-71. NK harvest index comparable at par to both the hybrids but Arize-6444 showed mark improvement in P harvest index over PHB-71.Similar findings were reported by (Singh et al., 2013; Gupta et al., 2011; Vishwakarma et al., 2016). The combined application of 50% RDN+50% N through FYM+*Azospirillum* showed significantly higher NPK content and their uptake and harvest index over rest of the nitrogen management treatments but both the 50% N applied through FYM treated treatments remained statistically at par to each other in respect to K harvest index (Table 5). Moreover, all the nitrogen management options showed significant superiority over control. Furthermore, the application of 50% RDN+50% N through FYM+*Azospirillum* recorded 56.73, 11.10 and 59.03 kg ha^{-1} induced more total NPK uptake over control, respectively (Table 5). 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 in to better growth, higher biological yield as well as more nutrient concentration. Beneficial effect of farmyard manure and biofertilizer due to their mineralization and releasing profuse amount of nitrogen to the soil and checking downward movement of N making it available to the growing crop was also reported by (Pathak et al., 2005).

4. Conclusion

System of rice intensification (SRI) should be adopted with rice hybrid 'Arize-6444' for achieving its maximum yield, incorporation of 50% recommended dose of nitrogen through inorganic fertilizer and remaining 50% N through FYM along with *Azospirillum* (bio-fertilizer) may be adopted under eastern Uttar Pradesh region.

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