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Biological potential and economic feasibility of rice (*Oryza sativa* L.): Wheat (*Triticum aestivum* L.) Cropping system under northern Gangetic alluvial plains

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Abstract
The field experiment was conducted during the two consecutive *kharif* and *rabi* seasons of 2012-13 and 2013-14 on sandy-clay-loam soil at Varanasi to study the assessment of nutrient management options under different methods of rice (*Oryza sativa* L.) cultivation and their carry-over effect on succeeding wheat (*Triticum aestivum* L.). System of rice intensification (SRI) exhibited their superiority in terms of higher rice yield (6530 kg/ha), system yield (9942 kg/ha), system productivity (37.2 kg/ha/day) and profitability (₹348 ha/day) than normal transplanted rice which were left over higher residual effect and led to produced higher yield attributes and yield of wheat. Rice hybrid Arize-6444 was found more productive in terms of biologically and economically with producing higher yield, R-W system yield (9802 kg/ha), system productivity (36.7 kg/ha/day) and profitability (₹ 332 ha/day) over PHB-71. Incorporation of 50% RDN + 50% N through FYM + *Azospirillum* recorded significantly higher rice yield (6942 kg/ha), R-W system yield (10734 kg/ha), system productivity (40.2 kg/ha/day) and profitability (₹ 374 ha/day). Residual effect of preceding experimental variables particularly normal transplanting, hybrid 'PHB-71' and application of 50% RDN + 50% N through FYM + *Azospirillum* produced higher yield (2979 kg/ha) of wheat.

Keywords: Crop establishment methods, rice equivalent yield, rice-wheat system yield, system productivity and wheat

1. Introduction
Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system (RWS) is one of the pre-dominant agricultural production systems in the world, occupying 13.5 million hectares of cultivated land in the Indo-Gangetic Plains (IGP) in South Asia. This provides food, income and employment to ensure livelihood security for millions of population. An opportunity for area expansion is limited due to finite and often over-exploited natural resources (Timsina and Connor, 2001) [12]. Rice is predominantly grown by transplanting seedlings into puddled soil and is continuously flooded for much of the growing season. However, this requires large amounts of labour, water and energy, which are gradually becoming scarce and more expensive, thus reducing the productivity, profitability and system sustainability. Therefore, agronomic management has to be improved for greater efficiency of applied inputs to sustain yields of RWS. Among all crops, rice consumed about 90% of total irrigation water (Bhuiyan, 1992) [2]. Accordingly suitable water management to grow more rice is urgently needed to search for alternate methods to reduce water requirement of rice without adversely affecting the yield. The conjunctive application of organics with inorganic sources of nutrient reduces partially dependence on chemical inputs but also provides micronutrient. Utilization of indigenous organic sources, *viz*. farmyard manure may serve as alternatives or supplements to chemical fertilizers, and help in increasing the productivity of the rice-based cropping system in all zones of the country. The optimization of nutrient supply to the crop depends on manures applied to the individual preceding crop and their carry-over effect on the succeeding crop, which is generally ignored while recommending dose of manures or fertilizers to be applied to the next crop. Complementary use of organic and biological source of plant nutrient along with chemical fertilizer is of great importance for the maintenance of soil health and productivity.

Considering the potential value of organic manure along with fertilizer in rice - wheat cropping systems, an attempt was made to study the biological and economic feasibility of rice - wheat cropping system under Northern-Gangetic alluvial plains with due emphasis on rice-wheat system yield, system productivity and profitability with their carry-over effect on succeeding wheat.

2. Materials and Methods

The field experiment was carried out during *kharif* and *rabi* season of 2012-13 and 2013-14 at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, situated in the South Eastern part of Varanasi city at 25°18' N latitude, 83°03' E longitude and at an altitude of 75.7 meters above the mean sea level in the Northern-Gangetic alluvial plains having characteristics of sub-tropical climate. The soil of experimental field was sandy-clay loam textural class with (0.34 and 0.35%) organic carbon, (205.20 and 213.21 kg/ha) available nitrogen, (25.30 and 25.86 kg/ha) phosphorus and (215.60 and 219.80 kg/ha) available potassium before the transplanting of rice during 2012 and 2013, respectively. The treatments consisted of two crop establishment methods (Normal transplanting and System of rice intensification) with two hybrids (PHB-71 and Arize-6444) as assigned to main plots. Each main plot were further divided into six sub-plot to accommodate six integrated nitrogen management treatments *viz.*, 100% RDF, 125% RDN, 50% RDN + 50% N through FYM, 50% RDN + 50% N through FYM + *Azospirillum*, 100% N through FYM and Control/No fertilizer were tested in split plot design with replicated thrice. For normal transplanting 23 days old seedling, nursery bed was raised fourteen days before the 10 days old seedlings used for SRI to synchronize the transplanting of rice with spacing 20 cm x 15 cm and 25 cm x 25 cm in puddled soil at a time on 5th July, 2012 and 4th July, 2013. FYM was manually incorporated plot wise as per the treatments. Recommended dose of fertilizer i.e. 150, 75 and 60 kg/ha N, P_2O_5 and K_2O for rice were applied as per treatments. Half of the total (150 kg N/ha) quantity of nitrogen along with the full dose of phosphorus and potassium were applied just before transplanting on puddled surface and incorporated into the top 15 cm soil manually with the help of spade and zinc sulphate (25 kg/ha) was also applied in the first year of experiment to all the plots. The urea fertilizer was top dressed into two equal instalments @ 37.5 kg N/ha at active tillering and remained 5-7 days before panicle initiation. The remaining crop management practices were followed as per the standard package. After harvesting of rice, residual crop wheat (HUW-234) was sown in same layout of rice and growing without fertilizers for assessing residual effect of preceding experimental variables. Rice equivalent yield of wheat was determined by converting the economic yield of wheat on the basis of their prevalent market rate during the cropping period and expressed in kg/ha. Rice-wheat system yield was computed by addition of rice yield in rice equivalent yield of wheat. System net returns were calculated by net return of rice plus net return of wheat. System productivity and profitability were also calculated by rice-wheat system yield and system net return divided by duration of both the crops from transplanting of rice to harvesting of wheat. All the data obtained from rice and wheat for two consecutive years was pooled and subjected to analysis of variance (Gomez and Gomez, 1984) [3].

3. Results and Discussion

3.1 Rice yield and rice equivalent yield of wheat (REY)

SRI planting produced significantly higher grain yield (6530 kg/ha) over normal transplanted rice and their relative increment was 14.66% higher over normal transplanted rice due to its phyllochronic potential embedded in younger aged seedling. The yield increment under SRI due to various individual practices proved conducive *i.e.* single seedling/hill, younger seedling, mechanical cono-weeding and alternate wetting and drying soil conditions with greater availability of prolonged period for better root development and tillering. These findings are close confirmed by Thakur *et al*. (2013) [11]. Rice hybrids Arize 6444 showed greater potential to exploit hybrid vigour to produce higher 8.63% higher grain yield and showed significant superiority over PHB 71. These results are in conformity with the earlier finding of Singh *et al*. (2013) [5] and Singh *et al*. (2014) [10]. However, Wheat grown after normal transplanted rice produced significantly higher REY (3654 kg/ha) over SRI planted plot and it was tended to increase by the margin of 7.09% over SRI planted plot. Furthermore, significantly higher REY of wheat (3629 kg/ha) recorded under PBH-71 plot as compared to 'Arize-6444'. This might be due more mining of nutrients by SRI and Arize-6444 which ultimately left lesser residual nutrient in soil over normal transplanted rice and PHB-71 resulted produced more yield of succeeding wheat. This results in agreement with the finding of Sharma *et al*. (2005). Application of 50% RDN + 50% N through FYM + *Azospirillum* recorded significantly higher grain yield (6942 kg/ha) of rice and REY (3792 kg/ha) of wheat as compared to rest of the treatments. The magnitude of rice yield and REY of wheat were increase by the margin of 60.17% and 23.72% over control. This is might be due to combined application of inorganic fertilizers and organic manure with biofertilizer might have supplied adequate amount of nutrients during reproductive phase bringing about better yield attributing traits and finally higher grain yield of rice. In addition, more carry over effects in these treatments might be due to reduced loss of nitrogen during wet season that improved the availability of nitrogen to the succeeding wheat crop. The similar results were also reported by Banayo *et al*. (2012) [1] and Ruiz-Sanchez *et al*. (2011) [6].

3.2 Rice-wheat system feasibility

The productivity of rice-wheat system as a whole was influenced by the management practices. SRI planted rice followed by wheat recorded about 6.34% higher R-W system yield along with system productivity (37.2 kg/ha/day) and profitability (348₹/ha/day) as compared to the normal transplanted rice (Table 1). The similar trends were also observed in system net returns. Among rice hybrids, growing of Arize-6444 followed by wheat recorded comparatively 3.29% higher system yield and ₹4205/ha higher system net returns over PHB-71, respectively. Rice hybrid 'Arize-6444' followed by wheat was also led to more biological as well as economic returns per day as compared to PHB-71. Incorporation of 50% RDN + 50% N through FYM + *Azospirillum* recorded significantly higher system yield nearly 45.09% more over control. The system net return (₹ 99938/ha), system productivity (40.2 kg/ha/day) and system profitability (₹374/ha/day) were also recorded higher with in the same treatment. This might be due to organic manures supplemented nutrients and increased nutrient availability in the soil increased wheat yield in plots treated with farm yard manure conjunction with inorganic fertilizer to rice which resulted produced more system yield. This was in close conformity with the findings of Sekhon *et al*. (2011) [7] and Hidayatullah *et al*. (2013).

3.3 Residual effect on wheat

Carry-over effect of preceding experimental variables *viz.*, rice establishment methods, hybrids and integrated nitrogen management proved marked variation on all yield attributes and yield of succeeding wheat (Table 2). Significantly higher number of effective tillers/m^2, number of grains/earhead, 1000-grain weight, grain yield and straw yield of succeeding wheat were found higher with wheat grown after normal transplanting of rice hybrid PHB-71 compared to Arize-6444 planted under SRI. Relatively lower amount of nutrient uptake under 'PHB-71' sown with normal transplanting and proved significant residual effect on increasing yield attributes and yield of succeeding wheat as compared to Arize-6444 grown under SRI. Incorporation of 50% RDN + 50% N through FYM + *Azospirillum* to preceding rice showed higher residual effect and recorded higher value of yield attributes and yield of succeeding wheat. However, harvest index of wheat could not influence significantly due to residual effect of previous experimental variables. These results indicated that organic manures supplemented nutrients increased their availability in the soil brought about marked increase in wheat yield in plots treated with farmyard manure during rice. This was in close conformity with the findings of Hidayatullah *et al*. (2013) [4].

3.4 Residual soil nutrient status

Among the crop establishment methods and rice hybrids did not exhibited significant variation on NPK status after harvest of succeeding wheat (Table 2). While, available potassium (196.4 kg/ha) in soil under 'PHB 71' followed by wheat recorded mark improvement in residual soil fertility over 'Arize-6444'. Higher value of NPK content in soil was obtained with organically treated source (FYM) than inorganic fertilizer treated. Application of 50% RND + 50% N as FYM + *Azospirillum* left out higher amount of residual nutrients than to other treatments. Increase in available NPK with FYM and biofertilizer may be owing to the direct addition of nitrogen through FYM and biofertilizer to the available nitrogen pool of soil. The favourable effect of organic sources in conjunction with chemical fertilizer and biofertilizers in enhancing the availability of nitrogen in soil is well documented. These results were confirmed with the findings of Paul *et al*. (2013) [5].

4. Conclusions

Thus, it could be concluded that rice hybrid 'Arize-6444' growing under system of rice intensification and fertilized by 50% RDN + 50% N through farm yard manure + *Azospirillum* performed better than sole inorganic fertilizer to obtain higher productivity and profitability in rice-wheat cropping system under Eastern Uttar Pradesh condition.

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Table 1: Effect of rice establishment methods, hybrids and nitrogen management on productivity of rice –wheat cropping system (Pooled data of 2 years)

Treatments	Rice grain yield (kg/ha)	REY of wheat (kg/ha)	R-W System yield (kg /ha)	System net returns (₹/ha)	System productivity (kg/ha/day)	System profitability (₹/ha/day)
Crop establishment methods						
Normal transplanting	5695	3654	9349	79992	35.0	300
SRI	6530	3412	9942	92983	37.2	348
SEm±	58.4	44.1	90.2	1259.8	0.3	4.7
CD (*P*=0.05)	180.1	135.8	277.8	3881.7	1.0	14.5
Hybrids						
PHB-71	5859	3629	9489	84517	35.5	316
Arize-6444	6365	3437	9802	88590	36.7	332
SEm±	58.4	44.1	90.2	1259.8	0.3	4.7
CD (*P*=0.05)	180.1	135.8	277.8	3881.7	1.0	14.5
Integrated nitrogen management						
100% RDN	6485	3459	9944	93407	37.3	350
125% RDN	6597	3604	10201	96548	38.2	362
50% RDN + 50% N through FYM	6407	3696	10103	90510	37.8	339
50% RDN + 50% N through FYM + *Azospirillum*	6942	3792	10734	99938	40.2	374
100% RDN through FYM	5909	3583	9492	75076	35.6	281
Control (No fertilizer)	4334	3065	7398	63447	27.7	238
SEm±	62.0	51.5	86.2	1102.8	0.3	4.1
CD (*P*=0.05)	174.5	144.9	242.7	3103.6	0.9	11.6

Table 2: Residual effects of rice establishment methods, hybrids and integrated nitrogen management on yield attributes and yield of succeeding wheat and soil fertility status after harvest of wheat (Pooled data of 2 years)

Treatments	No. of effective tillers/m²	No. of grains/earhead	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Crop establishment methods									
Normal transplanting	232.10	26.54	34.04	2871	4085	41.37	208.0	24.70	196.0
SRI	213.10	24.18	32.24	2681	3778	41.58	207.6	24.37	195.0
SEm±	3.128	0.220	0.260	34.6	54.1	0.211	0.8	0.1	0.5
CD (*P*=0.05)	9.638	0.679	0.801	106.7	166.6	NS	NS	NS	NS
Hybrids									
PHB-71	231.38	26.28	33.52	2852	4115	40.94	208.0	24.5	196.4
Arize-6444	213.82	24.44	32.75	2701	3748	42.00	207.6	24.6	194.6
SEm±	3.128	0.220	0.260	34.6	54.1	0.211	0.8	0.1	0.5
CD (*P*=0.05)	9.638	0.679	0.801	106.7	166.6	0.651	NS	NS	1.7
Integrated nitrogen management									
100% RDN	219.52	24.75	32.88	2718	3789	42.06	207.2	24.1	194.0
125% RDN	223.62	25.46	33.23	2832	4007	41.57	211.0	25.3	196.4
50% RDN + 50% N through FYM	234.24	26.88	33.81	2904	4085	41.57	214.5	25.6	197.0
50% RDN + 50% N through FYM +*Azospirillum*	240.38	28.64	34.81	2979	4205	41.51	215.4	25.6	197.2
100% RDN through FYM	219.02	25.23	33.14	2815	3924	41.82	213.3	24.4	197.2
Control (No fertilizer)	198.81	21.20	30.95	2408	3579	40.31	185.3	22.1	191.2
SEm±	2.348	0.259	0.295	40.5	41.5	0.418	1.4	0.2	0.8
CD (*P*=0.05)	6.609	0.729	0.831	113.9	116.9	NS	3.9	0.6	2.3

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