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Research Paper

Productivity and profitability of rice (*Oryza sativa*) genotypes as influenced by crop management practices under middle Indo-Gangetic Plains

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ABSTRACT

A field experiment was carried out during the wet seasons of 2012 and 2013 at Patna, Bihar, to evaluate the performance of 7 promising rice (*Oryza sativa* L.) genotypes under 2 crop establishment methods, viz. best management practices (BMPs) and system of rice intensification (SRI). Results revealed that BMPs recorded significantly higher grain yield, biological and production efficiency than to SRI. Among the rice genotypes, 'IR83387 B-B 40-1' recorded significantly higher grain yield (4.86 t/ha) followed by 'Abhishek' (4.52 t/ha) and 'Shusk Samrat' (4.40 t/ha). Rice genotype 'IR83387 B-B 40-1' found significantly superior in terms of gross and net returns (₹66.3×10^3/ha and ₹34.5×10^3/ha) to rest of the genotypes. Moreover, BMP gave the highest carbohydrate equivalent and carbon output (3.34 t/ha and 4.71 t CO_2/ha) as compared to SRI (3.17 t/ha and 4.22 t CO_2/ha).

Key words: Best management practices, Carbohydrate equivalent, Carbon output, Rice genotypes, SRI

Rice is the most important staple food crop for more than half of the world's population, providing ~21% of the total calorie intake (Singh *et al*., 2017). In India, it occupies an area of ~43.8 million ha and a production of ~105 million tonnes (mt), with average productivity of ~2.21 t/ha (Kumar *et al*., 2016a). Demand for rice growing is increasing every year, and it is estimated that by 2025 AD, its requirement would be ~140 mt (Kumar *et al*., 2016b). To sustain the present food self-sufficiency and to meet the future food requirement, India has to increase rice productivity by~3% per annum (Kumar *et al*., 2016c).The conventional method of crop establishment in rice is manual transplanting of seedling into puddled soil. It requires a large amount of water, energy, labour, which are becoming increasingly scarce and expensive (Bohra and Kumar, 2015). Moreover, continuous puddling of rice fields over decades has led to the deterioration of soil physical properties through structural breakdown of soil aggregates, capillary pores and clay dispersion, thereby restricting germination and rooting of succeeding crops (Mandal *et al*., 2011; Roy *et al*., 2011).

However, appropriate seedling age at transplanting is essential for optimum yield (Das *et al*., 2014). The system of rice intensification (SRI) concept maintains that early transplanting of younger seedling preserves potential of plant for much greater tillering, more root growth and better yield than older ones. Number of seedlings that are transplanted in a hill also influences crop yield (Kumar *et al*., 2015a). The SRI advocates use of transplanting of younger seedling at single seedling/hill, use of wider spacing, intermittent irrigation, seedling uprooting by scooping and careful transplanting, and weed control by conoweeder and use of organic manures (Kumar *et al*., 2015b). Although SRI is gaining wider acceptance in many countries, there are some limitations in high productive areas of the eastern India, wherein production of rice is not promising as it should have been. To overcome these decorative limits of SRI, at the outset one can go for the best management practices (BMPs), in which 21 days old seedlings are transplanted with spacing of 20 cm × 15 cm at 1 seedling/hill, and organic manures as well as fertilizers are used in integration. Hence integration of BMPs along with identification of responsive rice genotypes is a cost-effective and safe approach to sustain rice productivity, particularly

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by the resource-poor farmers of this region (Kumar *et al*., 2016d). It is therefore, imperative to identify the best crop management practices and efficient rice genotypes, which maximize the productivity as well as profitability in middle Indo-Gangetic Plains. Hence, keeping these things in view the present investigations was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at the ICAR Research Complex for Eastern Region, Patna (25.30^{O}N, longitude 85.15^{O}E), during 2 wet seasons of 2012 and 2013 under the rainfed condition of Bihar. Soil of the experimental plot was clay loam (42% sand, 35% silt and 23% clay), low in organic carbon (0.46%) and N (212 kg/ha), and medium in available phosphorus (26 kg P_2O_5/ha) and potassium (215 kg K_2O/ha). Total rainfall received during cropping period (June–November) was 542.4 and 715.7 mm in 2012 and 2013 respectively (Fig. 1). Experimental treatments comprising 2 crop establishment methods, viz. best management practices (BMPs) and system of rice cultivation (SRI), in main plots and 7 rice genotypes including released 4 drought-tolerant released varieties, viz. 'Sahbhagi Dhan', 'Shusk Samrat', 'CR Dhan 40', 'Abhishek', along with 3 advanced breeding lines, viz. 'IR83387 B-B-40-1', 'IR 82870-11', and 'IR 84899 B 183 CRA 19-1', in subplots, were replicated thrice. The gross and net plot size was 5 m × 5 m and 4.5 m × 4.5 m, respectively, and treatments were superimposed in same plots during both years to study the cumulative treatment effect. Nurseries for both the crop establishment methods were sown on the same day, but transplanting dates varied as per treatment requirement. For SRI, 13-day-old seedlings at 1 seedling/hill were used with 25 cm × 25 cm spacing, while for BMPs, 21-day-old seedlings at 1 seedling/hill with a spacing of 20 cm × 15 cm were planted. Nurseries for SRI as well as BMPs were prepared using a modified mat-nursery method (MMN method) as suggested by Das *et al.* (2014). Seedlings were raised in 4 cm layer of soil arranged on a firm surface covered with plastic sheet. A wooden frame of 1 m width, 0.04 m height and suitable length, divided into the equal segment of 0.75 m each, was placed over this firm surface covered with plastic sheet. The frame was filled with soil mixture uniformly, and pre-germinated seeds were sown on soil surface with a seed rate of 50 g/m^2 and covered with same soil mixture. Soil mixture (4 m^3 for 100 m^2 of mat nursery) was prepared by mixing 80% soil and 20% well-decomposed farmyard manure (FYM). Seed-bed was sprinkled with water using rose-can, as and when needed. The young seedlings attaining one and half leaf stage in ~13 days, by scooping single seedlings for SRI, and 2–3 leaves 21-day-old seedlings for BMPs were transplanted. The farmyard manure was applied @ 10 t/ha, 20 days ahead of transplanting to the main field. Recommended dose of fertilizers, i.e. 100, 50 and 40 kg N, P and K/ha was applied for both the establishment methods through urea, diammonium phosphate (DAP) and muriate of potash (MoP). Half dose of N and full dose of P and K were applied basal and the remaining N was applied in 2 equal splits– at maximum tillering and panicle-initiation stages. The field was subjected to conditions of alternate wetting and drying, and only a thin film of water was maintained by closing and opening of bund around plots as necessary for SRI and BMP rice culture. For easy irrigation and drainage of water, channel of 30 cm width and 20 cm depth was provided around each plot. The growth and yield attributes, i.e. plant height, tillers/hill, dry-matter production, number of grains/panicle and 1,000-grain weight, were recorded at harvesting from 5 random hills in each plot. Crop was threshed manually; grains were cleaned and weighed for expressing yield in t/ha. Economics was calculated on the basis of prevailing market prices of inputs and produce. Net returns were calculated by deducting cost of cultivation from gross returns. The production efficiency and economic efficiency were computed as suggested by Kumawat *et al*. (2012). Economic yield of rice was converted into equivalent value of carbohydrate (t/ha) as suggested by Gopalan *et al*. (2004). Carbon output was calculated based on plant biomass (Lal, 2004) and Singh and Ahlawat (2015). The field data obtained for 2 years were pooled and statistically analysed using F-test (Gomez and Gomez, 1984). Test of significance of the treatment differences were done on the basis of t-test. The significant difference between treatment means were compared with critical differences at 5% levels of probability.

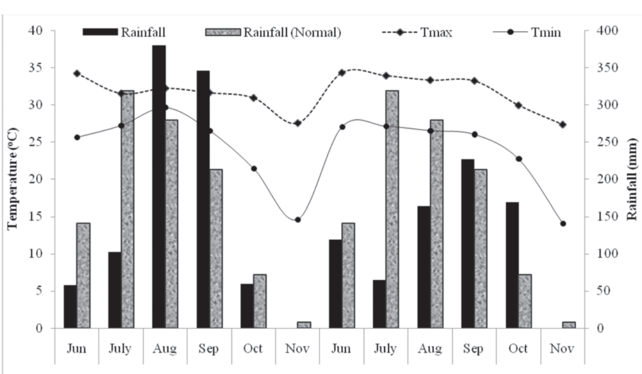

Fig. 1. Weather conditions during the experimentation (2012 and 2013)

RESULTS AND DISCUSSION

Growth parameters

The growth parameters, viz. plant height, tillers and

Table 1. Growth, yield attributes and yield of rice genotypes under different management practices (average data of 2 years)

Treatment	Plant height (cm)	Tillers/m^2	Dry matter (g/hill)	Days to 50% flowering	Grains/ panicle	1,000-grain weight (g)	Spikelet fertility (%)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index	Production efficiency (kg/ha/day)	Biological efficiency (kg/ha/day)
Management practices												
BMP	100.6	280	23.3	87	175	21.6	86.7	4.27	10.1	0.40	29	33.6
SRI	93.8	311	27.2	86	171	21.9	85.0	4.15	9.6	0.42	27	28.7
SEm±	1.2	2.89	0.9	0.77	2.3	0.3	0.93	0.02	0.05	0.01	1.03	0.7
CD (P=0.05)	3.7	11.8	3.4	NS	NS	NS	NS	NS	NS	NS	NS	2.3
Genotypes												
'IR 83387 B-B 40-1'	93.2	334	26.2	91	184	24.8	88.6	4.86	11.3	0.44	41	36.0
'Shusk Samrat'	94.9	290	25.7	88	168	20.9	82.5	4.40	10.2	0.43	39	35.5
'Abhishek'	87.1	322	27.6	92	178	21.6	91.3	4.52	10.8	0.42	37	33.5
'IR 82870 11'	88.1	304	25.0	90	161	20.7	82.8	4.01	10.3	0.39	32	27.7
'Sahbhagi Dhan'	95.0	271	24.4	85	172	22.6	88.4	4.02	10.1	0.40	37	34.4
'CR Dhan 40'	115.0	272	22.9	79	180	20.4	80.7	3.55	8.8	0.40	26	23.7
'IR84899 B 183 CRA 19-1'	107.0	278	25.2	80	169	21.1	84.5	3.78	9.45	0.43	32	28.4
SEm±	1.8	9.3	1.05	1.27	4.6	0.42	1.42	0.03	0.07	0.01	1.4	1.24
CD (P=0.05)	5.3	28.9	4.1	5.0	14.8	1.13	4.7	0.11	0.28	0.03	4.3	3.6

BMP, Best management practices; SRI, system of rice intensification

dry-matter production, of rice were influenced markedly by the crop establishment methods (Table 1). Significantly higher plant height was recorded with the BMPs (100.6 cm) than that under SRI (93.8 cm). This might be due to better management practices influencing these attributes positively, which helped in better crop growth and development (Das *et al*., 2014; Wahlang *et al.* 2016). The tillers and dry-matter production were significantly higher with SRI (311 and 27.2 g) than BMPs (280 and 23.3 g). This might be owing to better establishment methods and young seedlings along with the wider spacing might be responsible for production of more tillers and dry matter (Kumar *et al.*, 2017). The per cent increase in number of tillers and dry-matter production of SRI over BMPs was 11.1 and 16.7%, respectively. This might be ascribed to advantage of early transplanting of younger seedling under SRI that produced more tillers and more root growth, leading to better crop growth and development (Kumar *et al.*, 2016d). There was marked variation amongst the rice genotypes in terms of growth attributes, i.e. plant height, tillers and dry-matter production/hill (Table 1). Significantly taller plants were recorded with 'CR Dhan 40' (115 cm), followed by 'IR84899 B183-CRA 19-1' (107 cm) than the other genotypes. However, maximum tillers per unit area were recorded with 'IR83387 B-B 40-1' (334/m^2), which being on a par with 'Abhishek' (322/m^2), was significantly superior to rest of the genotypes. 'Abhishek' rice had significantly higher dry-matter production/hill (27.6 g), being on a par with 'IR83387 B-B 40-1' (26.2 g) and 'Shusk Samrat' (25.7 g). Similarly, rice variety 'Sahbhagi Dhan' took significantly lesser number of days to 50% flowering (79 days) than 'Abhishek' (92 days) and 'IR83387 B-B 40-1' (91 days).

Yield attributes and yield

The yield attributes of rice, viz. grains/panicle, spikelet fertility, grain and biological yield, production and biological efficiency and carbohydrate-equivalent yield were higher under BMPs than SRI, but it could not reach the level of significance (Table 1). However, 1,000-grain weight and harvest index were higher under SRI than BMPs. This might be attributed to the effective crop management leading to improvement in these attributes under the BMPs. It was probably owing to better growth and higher values of yield-attributing characters caused by better nutrient absorption from the soil, increased rate of metabolic process and photosynthesis under the BMPs (Kumar *et al*., 2015b; Singh and Ahlawat, 2015).

The yield attributes of rice genotypes varied significantly among themselves (Table 1). Genotype 'IR83387 B-B 40-1' (184), being at par with 'CR Dhan 40' (180) and 'Abhishek' (178), produced significantly higher grains/panicle than the remaining genotypes. Significantly higher 1,000-grain weight was noted with 'IR83387 B-B 40-1' (24.8 g) followed by 'Sahbhagi Dhan' (22.6 g) and Abhishek (21.6 g). Spikelet fertility, one of major yield attributes, might be higher owing to conversion of source to sink effectively in respective genotypes. The spikelet fertility was significantly higher with 'Abhishek' (91.3%) followed by 'IR83387 B-B 40-1' (88.6%) and 'Sahbhagi Dhan' (88.4%). Rice genotype 'IR83387 B-B 40-1' performed significantly better in terms of grain yield (4.86 t/ha) and biological yield (11.3 t/ha) than the remaining promising genotypes (Table 2) and similar trend was followed in case of harvest index also, might be owing to better growth, i.e. plant height and dry-matter production, resulting in more value of yield attributes and ultimately higher grain yield. Production efficiency and biological efficiency were higher with 'IR83387 B-B 40-1' (36 and 83.7 kg/ha/day) and the lowest with 'CR Dhan 40' (23.7 and 58.7 kg/ha/day) (Table 1). Significantly higher values of carbohydrate equivalent was recorded with 'IR83387 B-B 40-1' (3.89 t/ha). The differential values of attributes among the genotypes might be due to genetic traits (Kumar *et al*., 2016d; Singh and Ahlawat, 2015).

Economics

Higher gross returns (₹58.3×10^3/ha), net returns (₹27.9×10^3/ha) and benefit: cost ratio (1.92) were recorded with BMPs as compared to SRI (Table 2). The BMPs revealed 5.43 and 25.7% higher gross and net returns over SRI owing to higher yield accounted with the respective treatments. Similar finding was reported by Kumar *et al*. (2015a). Among the rice genotypes, 'IR83387 B-B 40-1' had significantly highest gross returns (₹66.3×10^3/ha), net returns (₹34.5×10^3/ha) and benefit: cost ratio (2.09). However, the lowest values of these attributes were associated with 'CR Dhan 40' because of its lower yield. Economic efficiency was higher with 'IR83387 B-B 40-1' (₹256 ha/day) compared to rest of the genotypes. This might be owing to the higher grain yield with the respective genotypes (Kumar *et al*., 2015b; Kumar *et al*., 2016d).

Interaction effects

Significant interaction was observed between the crop establishment methods and the rice genotypes for grain yield (Table 3). On the pooled basis, rice genotypes 'Abhishek', 'Sahbhagi Dhan' and 'IR84899 B 183 CRA 19-1' gave significantly higher grain yield when planted

Table 3. Interaction effect on grain yield of rice genotypes under different management practices (average data of 2 years)

Rice genotype	Grain yield (t/ha)	
	BMP	SRI
'IR 83387 B-B 40-1'	5.03	4.69
'Shusk Samrat'	4.30	4.50
'Abhishek '	4.94	4.10
'IR 82870 11'	3.65	4.37
'Sahbhagi Dhan'	4.30	3.74
'CR Dhan 40'	3.49	3.61
'IR84899 B 183 CRA 19-1'	4.18	3.37
SEm±		0.04
CD (P=0.05)		0.14

Table 2. Economics of rice genotypes as influenced by different crop management practices (average data of 2 years)

Treatment	Cost of cultivation (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)	Carbohydrate-equivalent yield (t/ha)	Carbon output (CO_2 eq./ha)
Management practices							
BMP	30.4	58.3	27.9	1.92	220	3.34	4.71
SRI	33.1	55.3	22.2	1.67	157	3.17	4.22
SEm±	–	0.02	0.02	0.09	6.7	0.02	0.3
CD (P=0.05)	–	NS	NS	NS	NS	NS	NS
Genotypes							
'IR 83387 B-B 40-1'	31.8	66.3	34.5	2.09	256	3.89	4.97
'Shusk Samrat'	31.8	60.1	28.3	1.89	228	3.51	4.49
'Abhishek'	31.8	61.7	29.9	1.94	221	3.73	4.77
'IR 82870 11'	31.8	54.7	22.9	1.72	158	3.56	4.55
'Sahbhagi Dhan'	31.8	54.9	23.1	1.73	197	3.49	4.46
'CR Dhan 40'	31.8	48.5	16.7	1.52	111	3.03	3.87
'IR84899 B 183 CRA 19-1'	31.8	51.6	19.8	1.62	149	3.25	4.16
SEm±	–	0.32	0.32	0.11	9.8	0.04	0.5
CD (P=0.05)	–	1.1	1.1	0.29	29	NS	NS

BMP, Best management practices; SRI, system of rice intensification with BMPs as compared to SRI. However, 'Shusk Samrat' and 'IR 82870-11' gave significantly higher grain yield, when planted with SRI as compared to BMPs. These varieties were more responsive to SRI management practices owing to adopting younger seedlings and better establishment methods (Kumar *et al*., 2017)

It was concluded that growing of rice genotypes 'IR83387 B-B 40-1' and 'Abhishek' with the best management practices gives higher productivity and profitability under the Middle Indo-Gangetic Plains of India.

REFERENCES

Bohra, J.S. and Kumar, R. 2015. Effect of crop establishment methods on productivity, economics and energetics in rice *(Oryza sativa*)–wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Sciences* **85**(2): 217–223.

Das A., Patel, D.P., Munda, G.C., Ramkrushna, G.I., Kumar, M. and Ngachan, S.V. 2014. Improving productivity, water and energy-use efficiency in lowland rice (*Oryza sativa*) through appropriate establishment methods and nutrient management practices in the mid altitudes of north east India. *Experimental Agriculture* **50**(3): 353–75.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research*, edn. 2, pp. 241–71. John Wiley & Sons, New York.

Gopalan, C., Sastri R. and Balasubramaniam. 2004. *Nutritive Value of Indian Foods,* revised edition, pp. 47–57. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India.

Kumar, A., Sen, A. and Kumar, R. 2016a. Micronutrient fortification in crop to enhance growth, yield and quality of aromatic rice. *Journal of Environmental Biology* **37**(5): 973–977.

Kumar, M., Kumar, R., Meena, K.L., Rajkhowa, D.J. and Kumar, A. 2016b. Productivity enhancement of rice through crop establishment techniques for livelihood improvement in Eastern Himalayas. *Oryza* **53**(3): 300–308.

Kumar, R., Hangsing, N., Zeliang, P.K. and Deka, B.C. 2016c. Exploration, collection and conservation of local rice germplasm of Nagaland. *Environment and Ecology* **34**(4D): 2,514–2,517.

Kumar, R., Kumar, M. and Deka, B.C. 2015a. Production potential, profitability and energetics of transplanted rice as influenced by establishment methods and nutrient management practices in Eastern Himalaya. *Research on Crop* **16**(4): 625–633: *doi*: 10.5958/2348–7542.2015.00088.1.

Kumar, R., Kumar, M., Kumar, A. and Pandey, A. 2015b. Productivity, profitability, nutrient uptake and soil health as influenced by establishment methods and nutrient management practices in transplanted rice (*Oryza sativa*) under hill ecosystem of North East India. *Indian Journal of Agricultural Sciences* **85**(5): 634–639.

Kumar, S., Kumar, R., Mishra, J.S., Dwivedi, S.K., Prakash, V., Bhkata, N., Singh, A.K., Singh, S.K., Haris, A.A., Rao, K.K., Mondal, S., Bhatt, B.P., Singh, S. and Yadav, A. 2017. Evaluation of rice (*Oryza sativa*) cultivars under different crop establishment methods to enhance productivity, profitability and energetics of rice in middle Indo-Gangetic Plains of Eastern India. *Indian Journal of Agronomy* **62**(3): 307–314.

Kumar, S., Mishra, J.S., Singh, A.K., Dwivedi, S.K., Singh, S.K., Singh, S.S., Haris, A.A., Mondal, S, Bhatt, B.P., Singh, S. and Yadav, A. 2016d. Response of rice (*Oryza sativa*) genotypes to weed management in rainfed ecosystems of eastern India. *Indian Journal of Agronomy* **61**(1): 37–44.

Kumawat, N., Singh, R.P., Kumar, R., Kumari, A. and Kumar, P. 2012. Response of intercropping and integrated nutrition on production potential and profitability of rainfed pigeonpea. *Journal of Agricultural Science* **4**(7): 154–162. *doi*:10.5539/jas.v4n7p154.

Lal, R. 2004. Carbon emission from farm operations. *Environmental International* **30**: 981–990.*doi*: 10.1016/j. envint. 2004.03.005.

Mandal, D., Singh, D., Kumar, R., Kumari, A. and Kumar, V. 2011. Effects on production potential and economics of direct seeded rice sowing dates and weed management techniques. *Indian Journal of Weed Science* **43**(3 & 4): 139–144.

Roy, D.K., Kumar, R. and Kumar, A. 2011. Production potentiality and sustainability of rice-based cropping sequences in flood prone lowlands of North Bihar. *Oryza* **48**(1): 47–51.

Singh, R.J. and Ahlawat, I.P.S. 2015. Energy budgeting and carbon footprint of transgenic cotton-wheat production system through peanut intercropping and FYM addition. *Environmental Monitoring and Assessment* **187**(5): 1–16. *doi*:10.1007/s10661-015-4516-4.

Singh, S.K., Abraham, T., Kumar, R. and Kumar, R. 2017. Response of crop establishment methods and split application of nitrogen on productivity of rice under irrigated ecosystem. *Environment & Ecology* **35**(2A): 859–862.

Wahlang B., Das, A., Layek, J., Munda, G.C., Ramkrushna, G.I. and Panwar, A.S. 2016. Effect of establishment methods and nutrient management on physiological attributes and water-use efficiency of rice (*Oryza sativa*) in a sub-tropical climate. *Indian Journal of Agronomy* **60**(4): 157–163.