Indian Journal of Agricultural Sciences **89** (11): 1846–9, November 2019/Article
https://doi.org/10.56093/ijas.v89i11.95312

Production potential, economics and energetics of rice (*Oryza sativa*) genotypes as influenced by varying levels of nitrogen

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Received: 10 December 2018; Accepted: 23 July 2019

ABSTRACT

Performance of eight rice (*Oryza sativa* L.) genotypes (IR 83383–B–B–129–4, IR 83387–B–B–27–4, IR88867–9–1–1–4, IR88964–24–2–1–4, IR88964–11–2–2–4, IR88966–39–1–4–4, Rajendra Sweta and Rajendra Bhagwati) were evaluated in different levels of nitrogen (N) application, i.e. control, 50% RDN (60 kg N/ha), 100% RDN (120 kg N/ha) and 150% RDN (180 kg N/ha) during the rainy season of 2016–17 in lowland transplanted condition of Patna, Bihar. Significantly higher grain yields (5.19 t/ha) and net returns (₹ 52260/ha) were recorded with application of 180 kg N/ha. Grain yields and net returns were noted higher with IR 83383–B–B–129–4 (4.27 t/ha and ₹ 38181/ha). Carbohydrate equivalent yield (4.06 t/ha) and carbon output (6.42 t CE/ha) were also higher with 150% RDN. IR83383–B–B–129–4 had significantly higher carbohydrate equivalent yield (3.34 t/ha) and carbon output (5.23 t CE/ha). Gross energy output, net energy return, energy use efficiency, energy profitability, energy productivity, energy intensity in economic terms and energy output efficiency were markedly higher with 180 kg N/ha. These attributes were higher with IR83383–B–B–129–4 but being on a par with IR83387–B–B–27–4. Therefore, growing of IR 83383–B–B–129–4 along with application of 180 kg N/ha is an ideal approach to achieve the higher productivity, profitability and energetics in lowland transplanted condition of Bihar.

Key words: Carbon output, Energetics, Economics, Nitrogen levels, Rice genotypes, Yield

Rice (*Oryza sativa* L.) is one of the principal food crops of the world and accounts for ~60% of global energy consumption (Kumar *et al.* 2018). It is grown in diverse ecologies ranging from irrigated to rainfed upland, lowland and deep water ecosystem in India (Kumar *et al.* 2016a,b). In India, ~23.3% of gross cropped area is occupied by rice, which contributes to ~43% of total food grain production and ~46% of total cereal production. Demand for rice growing is increasing every year, it is estimated that by 2025, its requirement would be ~140 mt (Singh *et al.* 2019). To sustain the present food-sufficiency and to meet the future requirement, India has to increase rice productivity by ~3% per annum (Kumar *et al.* 2017a). Crop nutrition is an important aspect to achieve the higher production of rice. Continuous practice of exhaustive rice-wheat sequences with imbalanced nutrient use led to deterioration of soil fertility especially mining of major, secondary and micronutrient (Prasad *et al.* 2019). To overcome these problems and to get higher crop yield, it is necessary to provide a balanced nutrition to the crop, which may sustain the soil fertility. Nitrogen (N) requirement of transplanted rice is varied due to continuous flooding in these cropping systems. Practicing of intensive cropping with improved varieties resulted in a marked depletion of nutrient reserve in the soil (Kumar and Bohra 2014). Imbalanced nutrition resulted into yield stagnation, low nutrient use efficiency and more environmental risk. Limited studies had been conducted on optimization on N-requirement for lowland transplanted condition is still realized as major researchable issues. Therefore, evaluation and identification of superior N responsive rice genotypes may be an attractive, cost-effective, safe approach for sustaining the rice productivity (Kumar *et al.* 2018). Hence, the present study was undertaken to evaluate the performance of rice genotypes in varying levels of N in lowland transplanted agro-ecosystem of Bihar.

MATERIALS AND METHODS

Field experiment was conducted during rainy season of 2016 and 2017 at the ICAR- Research Complex for Eastern Region, Patna ($25^0$30`N latitude, $85^0$15`E longitude and 52 m amsl). Soil of the experimental site was clay loam in texture (42.4% sand, 34.3% silt and 23.3% clay), low in organic carbon (0.44%), N (219 kg/ha), K (224 kg K_2O/ha) and medium in available P (22.5 kg P_2O_5/ha). Total rainfall received during cropping period was 977 and 840 mm in

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2016 and 2017, respectively. Experiment was consisted of four levels of nitrogen application, viz. control, 50% RDN (60 kg N/ha), 100% RDN (120 kg N/ha) and 150% RDN (180 kg N/ha) in main–plot and eight rice genotypes including two released varieties, viz. IR83383–B–B–129–4, IR83387–B–B–27–4, IR88867–9–1–1–4, IR88964–24–2–1–4, IR88964–11–2–2–4, IR88966–39–1–44, Rajendra Sweta and Rajendra Bhagwati (check) as sub-plot and replicated thrice in split-plot design. Gross plot size was 5 m × 5 m and treatments were superimposed in same plot every year to study the cumulative effect of the treatments. About 21 days old seedlings @3 seedlings/hill were transplanted with spacing of 20 cm × 15 cm. Recommended dose of nitrogen (RDN) represents 120 kg/ha applied through urea (46% N). Uniform dose of P and K were applied @60 kg P_2O_5 and 40 K_2O as basal through di-ammonium phospahate (46% P_2O_5 and 18% N) and muriate of potash (66% K), respectively. Nitrogen was applied in 3-split each at basal (50%), maximum tillering (25%) and panicle initiation (25%). Butachlor @1.25 kg/ha (post–em.) was applied to manage the initial weed flush in next day after transplanting (DAT) using 500 l/ha spray volume followed by hand weeding at 50 DAT. Continuous flooded water level 5±2 cm was maintained in experimental plot during the cropping. Grain yield were taken from an area of 4 m × 4 m of each plot and expressed in t/ha. Net income was calculated as difference between gross returns and cost of cultivation. Production and economic efficiency was calculated as suggested by Kumar *et al.* (2015a). The dry-matter efficiency was computed by the method given by Kumar *et al.* (2017d). Rice grain yield were converted into equivalent value of carbohydrate as suggested by Gopalan *et al.* (2004). Carbon output was calculated in terms of carbon equivalent (CE) based on plant biomass contains on an average ~44% carbon (Lal 2004). Energetics was calculated on energy equivalent of various input and output (Devasenapathy *et al.* 2009). Data pertaining to each characters of experimental crop were analyzed statistically using the standard procedures.

RESULTS AND DISCUSSION

Productivity: Application of 180 kg N/ha had significantly higher grain yield (5.19 t/ha), straw yield (9.41 t/ha) and biological yield (14.6 t/ha), respectively (Table 1). Application of 150% RDN were produced 98.9, 51.8 and 13.8% higher grain yield, respectively over control, 50 and 100% RDN, mainly because of higher growth attributes with increased levels of N fertilization (Kumar *et al.* 2018). Significantly higher crop productivity was noted with (40.6 kg/ha/day). Increase in each subsequent levels of N correspondingly improved the dry matter efficiency up to the highest levels of applied N (150% RDN). This might be due to higher yields. Significantly higher carbohydrate equivalent yield (4.06 t/ha) and carbon output (6.42 t CE/ha) were noted with 180 kg N/ha (Fig 1). This might be due to higher yield and total biomass production (Kumar *et al.* 2017 a,b,c). Markedly higher gain yield was recorded with IR 83383–B–B–129–4 (4.27 t/ha). This genotype had increased grain yields by 7.8 and 20.6% higher over Rajendra Sweta and Rajendra Bhagwati, respectively. Crop productivity was notably higher with IR 88964–11–2–2–4 (33.9 kg/ha/day) but being on a par with IR83387–B–B–27–4 (33.1 kg/ha/day), IR88867–9–1–1–4 (32.9 kg/ha/day) and IR 88964–24–2–1–4 (33.2 kg/ha/day). Carbohydrate equivalent yield (3.34 t/ha) and carbon output (5.23 t CE/ha) had higher with IR 83383–B–B–129–4 but being at par with IR 83387–B–B–27–4 and IR 88964–11–2–2–4 (Fig 1). This might be due to higher grain yields as well as total biomass production.

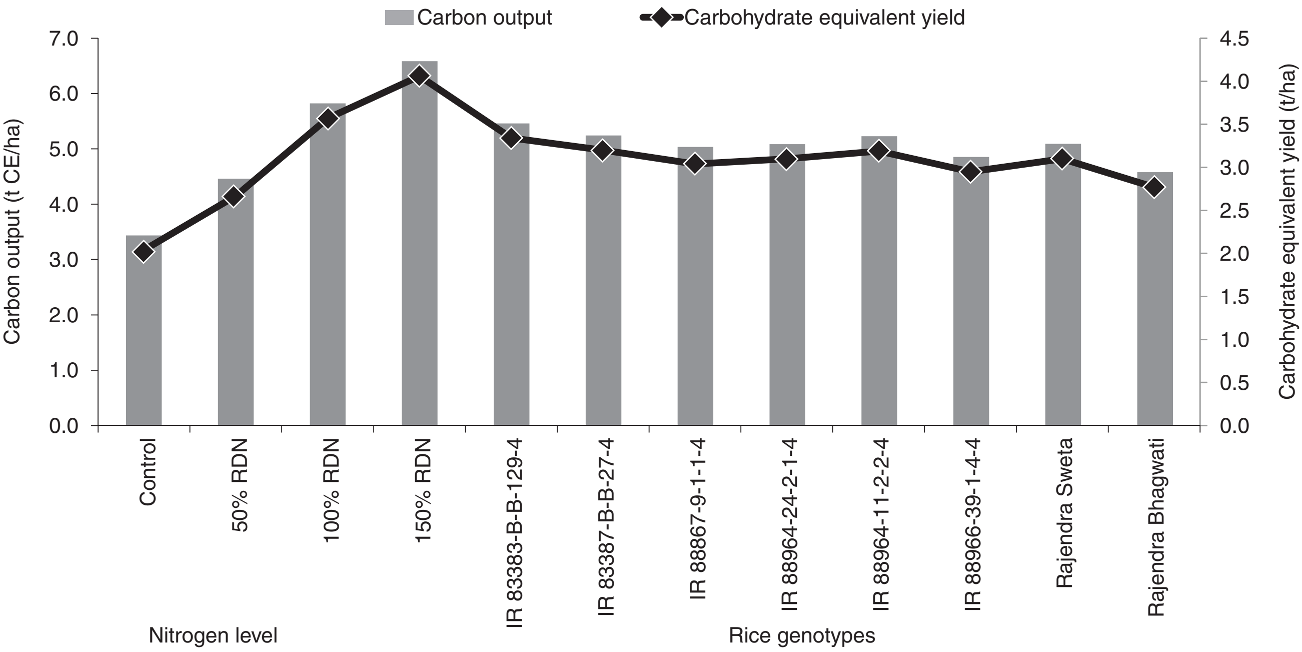

Fig 1 Carbon output and carbohydrate equivalent of rice genotypes as influenced by varying levels of nitrogen under lowland transplanted condition (Pooled data of 2 years).

Table 1 Effect of nitrogen levels on yields and economics of rice genotypes under lowland transplanted condition (Pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Crop productivity (kg/ha/day)	Dry matter efficiency (kg/ha/day)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Economic efficiency (₹/ha/day)
Nitrogen level									
Control	2.61	5.19	7.80	21.9	65.4	48202	12886	1.36	108
50% RDN	3.42	6.34	9.76	27.9	79.7	62504	22725	1.57	185
100% RDN	4.56	8.10	12.66	36.2	100.7	82892	42482	2.05	336
150% RDN	5.19	9.41	14.60	40.6	114.3	94563	52260	2.24	409
LSD (P=0.05)	0.11	0.22	0.30	0.9	2.7	1915	1915	0.05	16
Rice genotypes									
IR 83383–B–B–129–4	4.27	7.61	11.88	31.6	88.0	77633	38181	1.94	281
IR 83387–B–B–27–4	4.09	7.50	11.59	33.1	94.0	74629	35177	1.87	283
IR 88867–9–1–1–4	3.89	7.20	11.09	32.9	93.8	71040	31588	1.79	266
IR 88964–24–2–1–4	3.97	7.40	11.36	33.2	95.2	72572	33120	1.81	275
IR 88964–11–2–2–4	4.07	7.45	11.53	33.9	95.9	74322	34870	1.86	288
IR 88966–39–1–4–4	3.77	6.99	10.75	30.1	86.0	68892	29440	1.73	234
Rajendra Sweta	3.96	7.24	11.20	28.7	81.2	72308	32856	1.82	238
Rajendra Bhagwati	3.54	6.69	10.23	29.7	85.9	64925	25473	1.63	213
LSD (P=0.05)	0.15	0.31	0.43	1.3	3.8	2708	2708	0.07	22

100% RDN, 120 kg N/ha

Table 2 Effect of nitrogen levels on energetics of rice genotypes under lowland transplanted condition (Pooled data of 2 years)

Treatment	Energy input (MJ/ha)	Gross energy output (MJ/ha)	Net energy returns (MJ/ha)	Energy use efficiency	Energy profitability	Energy productivity (kg /MJ/ha)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (MJ/₹)	Energy output efficiency (MJ/ha/day)
Nitrogen level									
Control	27415	103257	75842	4.94	2.77	0.285	3.53	2.92	866
50% RDN	31985	129482	97497	4.73	3.05	0.305	3.29	3.26	1057
100% RDN	35621	168346	132725	4.05	3.73	0.356	2.86	4.17	1338
150% RDN	39257	193874	154617	3.77	3.94	0.372	2.71	4.58	1518
LSD (P=0.05)	-	3973	3973	0.12	0.12	0.009	0.09	0.10	35
Rice genotypes									
IR 83383–B–B–129–4	33569	157888	124319	4.60	3.60	0.346	3.02	3.95	1170
IR 83387–B–B–27–4	33569	153876	120306	4.51	3.51	0.340	3.00	3.86	1248
IR 88867–9–1–1–4	33569	147139	113569	4.34	3.34	0.327	3.09	3.70	1245
IR 88964–24–2–1–4	33569	150768	117199	4.40	3.40	0.332	3.11	3.78	1263
IR 88964–11–2–2–4	33569	153046	119477	4.50	3.50	0.339	2.99	3.84	1274
IR 88966–39–1–4–4	33569	142716	109147	4.20	3.20	0.316	3.21	3.58	1141
Rajendra Sweta	33569	148766	115197	4.39	3.39	0.331	3.05	3.74	1078
Rajendra Bhagwati	33569	135717	102148	4.02	3.02	0.303	3.32	3.42	1139
LSD (P=0.05)	0	5618	5618	0.17	0.17	0.013	0.12	0.14	50

100% RDN, 120 kg N/ha

Profitability: Application of 150% RDN had significantly higher gross and net returns, B: C ratio and economic efficiency (Table 1). Application of 150% RDN had 129 and 23% higher net returns than 50 and 100% RDN, respectively. This might be due to higher yield and monetary returns. Significantly higher gross and net returns and B: C ratio was noted with IR 83383–B–B–129–4. This genotype had increased net returns by 16 and 50%, respectively over Rajendra Sweta and Rajendra Bhagwati. Similar trends were followed in economic efficiency due to variation in grain yield and monetary returns (Kumar *et al.* 2018).

Energetics: Consumption of energy input followed trends of 150% RDN>100% RDN> 50% RDN>control (Table 2). This might be due to consumption of more inputs especially N fertilization (Kumar *et al.* 2018). Significantly maximum gross energy output (193874 MJ/ha), net energy returns (154617 MJ/ha), energy use efficiency (4.94), energy profitability (3.94), energy productivity (0.372 kg/MJ/ha), energy intensity in economic terms (4.58 MJ/₹) and energy output efficiency (1518 MJ/ha/day) were noted with 150% RDN. Each subsequent increasing levels of N had significant decline in energy intensity in physical terms (3.53 MJ/₹). This might be due to higher consumption of energy inputs (Kumar *et al.* 2015c).

IR 83383–B–B–129–4 had significantly higher gross energy input (157888 MJ/ha), net energy returns (124319 MJ/ha, energy use efficiency (4.6), energy profitability (3.6), energy productivity (0.346 kg/MJ/ha) and energy intensity in economic terms (3.95 MJ/₹) but statistically similar with IR 83387–B–B–27–4. Significantly higher energy output efficiency was noted with IR 83387–B–B–27–4. Higher energy use efficiency of rice genotypes was mainly attributed to higher yields with use of lesser energy utilization.

From the above study, it may be concluded that growing of IR 83383–B–B–129–4 along with150% RDN is an ideal approach to achieve the higher productivity, profitability and energetics under lowland transplanted condition of Bihar.

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