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Productivity, profitability, energetics and nutrient uptake of post *kharif* rice-cowpea preceded by rice varieties grown under different establishment methods

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Abstract

A field experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha during of 2014-15 and 2015-16 to evaluate the productivity, profitability, energetics and nutrient uptake of post *kharif* rice-cowpea preceded by rice varieties grown in *kharif* under different establishment methods. The treatments comprising three establishment methods (Direct Seeded Rice, Non Puddled Transplanted Rice and Puddled Transplanted rice) and three variety/hybrids of rice ('Arize 6129', 'Arize 6444' and 'Swarna') were tried in split plot design with three replications. The Puddled Transplanted Rice (PTR) recorded the maximum rice equivalent yield (8.43 t ha⁻¹) for post *kharif* rice-cowpea which was at par with NPTR (8.34 t ha⁻¹) and the minimum of 6.85 t ha⁻¹ was recorded under Direct Seeded Rice (DSR). The total cowpea biomass yield was the maximum under NPTR and the minimum under DSR. The maximum gross return of ₹ 1,20,380/-, total energy output of 2,25,045 MJ ha⁻¹ and energy use efficiency of 8.59 was recorded under PTR, NPTR and DSR, respectively. Uptake of nitrogen was higher under NPTR while phosphorus and potassium uptake values were higher under PTR. The rice cultivar/hybrids grown in *kharif* had no significant effect on yield, economics, energetics and uptake of nutrient, but hybrid 'Arize 6129' recorded higher mean values than hybrid 'Arize 6444' and cv. 'Swarna'.

Keywords: DSR, NPTR, PTR, REY, economics, energetics, nutrient uptake, cowpea residue

Introduction

Cropping intensity of the Eastern India is as low as 140% in an irrigated ecosystem, which can be enhanced to 300% by adopting developed diversified cropping systems (Singh *et al.*, 2012) [8]. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation and the judicious use of land and water resources, sustainable agriculture development and environmental improvement (Singh, 2010) [9]. Inclusion of legumes and other crops using intensification and interruptive approaches, as per resource availability, led to considerable improvement in productivity and profitability of the system and fertility of soil (Gangwar and Ram, 2005) [2]. Pulses provide an important option for diversification of conventional cereal-based rotations due to various inherent qualities like biological N-fixation, short duration, deep root, easy to accommodate under diverse agro-ecosystems and more importantly complementarity with cereals. The scope for exploiting direct and residual fertility due to legumes becomes increasingly apparent in India that has very low level of average plant nutrients consumption from chemical fertilizers on national basis (Ghosh *et al.* 2006) [3]. Sharma *et al.* (2005) [7] reported that the cropping system with pulse crop significantly increases the grain yield in direct seeded rice as compared to transplanting method carried out for the rice crop. The implications of including pulses in cereal-based system were explored by various researchers in particular concerning soil quality, system productivity and sustainability. Introducing pulses in cereal based system may alter the input-output balance over cereal-cereal system.

Materials and methods

The experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha during of 2014-15 and 2015-16. The experimental site is located at Bhubaneswar, Odisha, India with latitude of 20° 15'N, longitude of 85° 52'E and altitude of 25.9 m above mean sea level. The station falls under the East and South Eastern Coastal Plains Agro-climatic Zone of Odisha as per NARP classification (AZ 63) and Agro Ecological Sub Region (AESR) 18.4 of NBSS & LUP classification. The total rainfall received during 2014-15 and 2015-16 was 1534 and 994 mm, respectively. The mean monthly minimum and the mean monthly maximum temperature recorded during 2014-15 was 13.9°C & 38.9°C, respectively while during 2015-16 the mean monthly minimum and the mean monthly maximum temperature was 15.7°C and 40.8°C, respectively. The relative humidity ranged from 85 to 95% in morning and 39 to 82% in evening during 2014-15 and 82 to 93% in morning and 36 to 77% in evening hours during 2015-16. The soil at the experimental site was sandy loam.

The experiment was laid out in split plot design with three crop establishment methods viz. direct seeded rice (DSR), non-puddled transplanted rice (NPTR) and puddled transplanted rice (PTR) allocated to main plots and three cultivar duration groups viz. short duration ('Arize 6129'), medium duration ('Arize 6444') and long duration ('Swarna') allotted to sub plots in *kharif* season and treatments replicated thrice. After *kharif* rice, short duration rice cv. 'Arize 6129' and cowpea cv. 'Utkal Manik' were grown uniformly during *rabi* and summer, respectively, for productive utilisation of fallow period. The recommended fertilizer dose of 120-60-60-5 kg N-P₂O₅-K₂O-Zn/ha was applied to both *kharif* and *rabi* rice. No fertilizers were applied to the cowpea except 2% foliar spraying of DAP at flowering stage. The fertilizer amounting to 24 kg N and full dose of phosphorus, potash and zinc was applied as basal in the form of DAP, MOP and zinc sulphate before sowing in DSR and final cultivation in NPTR and PTR to rice. Then four top dressings of N were done at fortnight interval with 24 kg N per split applied in the form of urea starting at tillering stage and the last top dressing coinciding with the panicle initiation stage. The experimental field was initially dry ploughed with tractor drawn disc harrow followed by cultivator and rotavator operations to get fine tilth. Laser leveling was done to get perfect leveling. For preparing the field under Puddled Transplanted Rice (PTR), the ploughed field was given flooded irrigation. Then the field was puddled well with cage wheel and leveled with wooden leveling board. Under Non- Puddled Transplanted Rice (NPTR) field was initially dry ploughed with tractor drawn cultivator followed by rotavator to get fine tilth. Thereafter, the ploughed field was given a surface wetting with 50 mm of water which was just sufficient to soak the soil for smoother transplanting of seedling. In dry seeded rice (DSR), plots were initially dry ploughed with tractor drawn cultivator followed by rotavator to get fine tilth.

After *rabi* rice, cowpea was established as a zero till crop with spacing of 30 cm x 15 cm. Cowpea residue was incorporated after one picking under DSR plot and three number of pickings of fresh pod of cowpea under NPTR and PTR. Economic yields (pod yield) of cowpea was converted to rice-equivalent yield (REY), taking into account the prevailing market price (₹/kg) of rice (13.60 in 2014-15 and 14.10 in 2015-16) and cowpea (20.00/kg fresh pod). Gross returns of each crop establishment methods, cultivars and post *kharif*

crops were calculated from sale price of grain (according to minimum support price declared by Government of India) and straw during their respective crop growing seasons. Net returns were calculated by subtracting cost of production from gross returns, whereas benefit-cost ratio (B:C) was calculated by dividing gross returns with cost of production.

Energy fluxes were estimated using crop management (machinery operations and amount of inputs used) and grain and by-products production records. Inputs and outputs were converted from physical to energy unit measures through published conversion coefficients (Table 1). Energy equivalents for all inputs were summed to provide an estimate of total energy inputs. Energy output from the economic yield (grain) and by-products was calculated by multiplying the amount of production by its corresponding energy equivalent. Net energy returns and energy use efficiency were calculated by using the following formulae as suggested by Mittal and Dhawan (1988) [4].

1. Net energy return (MJ.ha⁻¹) = Total Output Energy (MJ.ha⁻¹) - Total Input Energy (MJ.ha⁻¹)
2. Energy use efficiency = Total Output Energy (MJ.ha⁻¹) / Total Input Energy (MJ.ha⁻¹)
3. The nutrient uptake was calculated by multiplying nutrient content in grain/pod and straw/stover with corresponding yield and expressed in kg ha⁻¹.

Table 1: Energy coefficient of inputs and outputs

Component	Energy coefficient (MJunit ⁻¹)
Labor (hr)	1.96
Diesel (lt)	56.31
Electricity (kWh)	11.93
Seed (kg)	14.7
N (kg)	60.6
P ₂ O ₅ (kg)	11.1
K ₂ O (kg)	6.7
ZnSO ₄ (kg)	20.9
Herbicide (kg)	288
Insecticide (kg)	237
Fungicide (kg)	196
Irrigation (m ³)	1.02
Machinery (hr)	62.7
Rice grain (kg)	14.7
Rice straw (kg)	12.5
Cowpea pod (kg)	3.91
Cowpea stover (kg)	12.5

Results and discussion

Rice equivalent yield of rice-cowpea and residue yield of cowpea

Establishment methods didn't influence grain yield of rice in *rabi* season significantly (Table 2). But PTR recorded the maximum (6.30 t ha⁻¹) followed by NPTR (6.18 t ha⁻¹) and DSR (6.01 t ha⁻¹). This result was consistent with findings of Alam *et al.*, (2017) [1]. Rice crop establishment methods influenced cowpea pod yield significantly. The NPTR recorded the maximum pod yield 1.50 t ha⁻¹ and PTR (1.47 t ha⁻¹) was at par. The minimum pod yield was recorded under DSR (0.58 t ha⁻¹) due to lesser time period occupied in field, which is attributed by sowing of cowpea in the same date under all the establishment methods due to excess soil moisture and only one picking under DSR to prepare the main field for direct seeding unlike seedling raising under NPTR and PTR. Thus the rice equivalent yield of cowpea followed the order of NPTR > PTR > DSR. Rice equivalent yield for post *kharif* rice-cowpea was computed by adding yield of *rabi* rice and rice equivalent yield of cowpea, which was

significantly affected by different establishment methods. The PTR recorded the maximum rice equivalent yield of 8.43 t ha⁻¹ which was at par with NPTR (8.34 t ha⁻¹). The minimum rice equivalent yield was recorded under DSR (6.85 t ha⁻¹) which may be attributed to low pod yield of cowpea.

The amount of residues incorporated from cowpea following the cultivation of rice under different establishment methods differed significantly. The NPTR (3.64 t ha⁻¹) registered the

maximum residues for incorporation, while DSR recorded the minimum (3.31 t ha⁻¹). Cultivar duration failed to cause significant variation in yield of component crops, rice equivalent yields and cowpea residue for incorporation. However, 'Azize 6129' recorded higher values over 'Arize 6444' and 'Swarna'. Similar result was reported by Mukundam *et al.* (2012) [5].

Table 2: Economic yield of *rabi* and summer crops, rice-equivalent yield (REY) and cowpea biomass yield as affected by establishment methods and cultivar duration of *kharif* rice

Particulars	Grain yield of <i>rabi</i> rice (t ha ⁻¹)		Pod yield of cowpea (t ha ⁻¹)		REY of cowpea (t ha ⁻¹)		REY of post <i>kharif</i> crops (t ha ⁻¹)		Cowpea biomass yield (t ha ⁻¹)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Establishment method										
DSR	6.04	5.97	0.58	0.58	0.85	0.82	6.89	6.80	3.30	3.31
NPTR	6.17	6.19	1.47	1.53	2.16	2.16	8.33	8.35	3.63	3.64
PTR	6.21	6.39	1.44	1.50	2.12	2.13	8.33	8.52	3.51	3.53
SEm±	0.12	0.11	0.03	0.05	0.04	0.07	0.13	0.14	0.03	0.04
CD (P=0.05)	NS	NS	0.10	0.18	0.15	0.26	0.50	0.56	0.11	0.16
Cultivar duration										
Arize 6129	6.11	6.26	1.19	1.24	1.75	1.76	7.86	8.01	3.51	3.53
Arize 6444	6.16	6.11	1.16	1.20	1.70	1.71	7.86	7.82	3.48	3.50
Swarna	6.16	6.18	1.14	1.17	1.68	1.66	7.83	7.84	3.45	3.46
SEm±	0.10	0.09	0.06	0.06	0.08	0.08	0.12	0.11	0.05	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Economics

Establishment methods influenced gross return of post *kharif* crops significantly (Table 3). The PTR recorded the maximum gross return of ₹1,20,380/- being at par with NPTR (₹1,19,405/-) and the DSR recorded the minimum of ₹98,900/-. Net return was not significantly influenced by establishment methods in the 1st year. In the 2nd year. The

PTR and the DSR gave the maximum (₹51,910/-) and minimum (₹40,900/-) net return, respectively, which contradicts the findings of Sarangi *et al.*, (2020) [6]. Establishment methods failed to cause significant variation on benefit cost ratio. Higher B:C was observed in the 2nd year than the 1st year. Cultivars did not exert significant influence on production economics of post *kharif* crops.

Table 3: Effect of crop establishment methods and cultivar duration of *kharif* rice on economics of post *kharif* rice – cowpea

Particulars	Gross return (x 10 ³ ₹ ha ⁻¹)		Net return (x 10 ³ ₹ ha ⁻¹)		B C ratio	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Establishment method						
DSR	97.87	99.93	40.08	40.90	1.69	1.69
NPTR	116.97	121.84	47.49	51.13	1.68	1.72
PTR	116.64	124.12	45.66	51.91	1.64	1.72
SEm±	1.71	2.08	1.71	2.08	0.025	0.031
CD (P=0.05)	6.72	8.17	NS	8.17	NS	NS
Cultivar duration						
Arize 6129	110.37	117.02	44.29	49.70	1.67	1.74
Arize 6444	110.91	114.30	44.83	46.99	1.68	1.69
Swarna	110.20	114.57	44.11	47.25	1.67	1.70
SEm±	1.74	1.60	1.74	1.60	0.026	0.025
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Energetics

Puddled transplanted rice (33,070 MJ ha⁻¹) recorded significantly higher total energy input requirement by post *kharif* crops (Table 4) followed by NPTR (29,430 MJ ha⁻¹) and DSR (25,500 MJ ha⁻¹). The minimum requirement of energy input under DSR was mainly due to reduced number of tillage for the main field preparation and less irrigation water given to the crop. Establishment methods significantly influenced the total energy output of post *kharif* crops in the 1st year. The NPTR recorded the maximum energy output (2,25,200 MJ ha⁻¹) which was at par with PTR (2,23,640 MJ ha⁻¹) and the minimum was recorded under DSR (2,17,965 MJ ha⁻¹). Establishment methods exhibited the similar trend in the 2nd year, but the differences were not statistically significant. During both the years, net energy return was not

significantly influenced. But, the years exhibited differential trend for this parameter. In the 1st year, the trend was NPTR (1,95,650 MJ ha⁻¹) >DSR(1,93,860 MJ ha⁻¹) >PTR (1,90,580 MJ ha⁻¹), while in the 2nd year, the trend was NPTR (1,97,640 MJ ha⁻¹) >PTR (1,93,390 MJ ha⁻¹) >DSR(1,91,080 MJ ha⁻¹). Establishment methods influenced energy use efficiency significantly. The DSR recorded the maximum value of 8.59 followed by NPTR (7.72) and DSR (6.85). This confirmed that the DSR was more energy efficient than the other establishment methods. Cultivars failed to cause significant variation in total energy input requirement, total energy output, net energy return and energy use efficiency. However, 'Arize 6129' rice hybrid grown in *kharif* season recorded higher values of energetics indices of post *kharif* rice-cowpea than other rice cultivars grown in *kharif*.

Table 4: Effect of crop establishment methods and cultivar duration of *kharif* rice on energetics of post *kharif* rice – cowpea

Particulars	Energy input (x 10 ³ MJ ha ⁻¹)		Energy output (x 10 ³ MJ ha ⁻¹)		Net energy return (x 10 ³ MJ ha ⁻¹)		Energy use efficiency	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Establishment method								
DSR	25.50	25.50	219.35	216.58	193.86	191.08	8.63	8.54
NPTR	29.24	29.62	225.20	227.26	195.96	197.64	7.73	7.71
PTR	33.07	33.06	223.64	226.45	190.58	193.39	6.78	6.91
SEm±	0.32	0.31	1.05	3.53	1.29	3.68	0.13	0.15
CD (P=0.05)	1.27	1.22	4.13	NS	NS	NS	0.50	0.58
Cultivar duration								
Arize 6129	29.16	29.45	223.84	224.49	194.68	195.03	7.79	7.74
Arize 6444	29.20	29.19	222.86	222.89	193.66	193.70	7.73	7.74
Swarna	29.45	29.53	221.50	222.92	192.06	193.38	7.63	7.67
SEm±	0.68	1.02	2.18	1.67	2.65	2.30	0.23	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Nutrient uptake

Establishment methods significantly influenced nitrogen uptake by post *kharif* crops (Table 5). The NPTR recorded significantly higher nitrogen uptake of 207.6 kg ha⁻¹ in the 1st year followed by PTR (196.9 kg ha⁻¹) and DSR (178.1 kg ha⁻¹). However, both NPTR (205.0 kg ha⁻¹) and PTR (200.9 kg ha⁻¹) remained at par in the 2nd year and proved significantly superior to DSR (178.3 kg ha⁻¹). Different establishment methods also influenced phosphorus and potassium uptake significantly. The maximum phosphorus uptake of 38.8 kg ha⁻¹

¹ and potassium uptake of 203.8 kg ha⁻¹ were recorded under PTR followed by NPTR (37.6 kg P ha⁻¹ and 198.1 kg K ha⁻¹) and DSR (31.0 kg P ha⁻¹ and 173.6 kg K ha⁻¹). The minimum uptake of nitrogen, phosphorus and potassium by post *kharif* rice-cowpea under DSR was due to low total rice equivalent yield. The uptake of nitrogen, phosphorus and potassium was not significantly influenced by the different duration of cultivars grown in *kharif*. However, 'Arize 6129' recorded higher mean value of nitrogen, phosphorus and potassium uptake by rice-cowpea due to higher yields.

Table 5: Effect of crop establishment methods and cultivar duration of *kharif* rice on nutrient uptake of post *kharif* rice – cowpea

Particulars	Nitrogen uptake (kg grain ha ⁻¹)		Phosphorus uptake (kg grain ha ⁻¹)		Potassium uptake (kg grain ha ⁻¹)	
	1 st Year	2 nd Year	1 st Year	2 nd Year	1 st Year	2 nd Year
Establishment method						
DSR	178.1	178.3	30.8	31.1	172.0	175.1
NPTR	207.6	205.0	37.2	37.9	198.1	198.1
PTR	196.9	200.9	37.9	39.6	202.1	205.5
SEm±	2.4	3.1	0.8	0.6	2.6	3.4
CD (P=0.05)	9.3	12.3	3.2	2.3	10.2	13.2
Cultivar duration						
Arize 6129	199.3	198.3	34.4	37.0	192.1	194.1
Arize 6444	195.1	196.4	35.7	36.3	192.1	193.5
Swarna	188.1	189.5	35.8	35.4	188.0	191.0
SEm±	3.1	3.3	0.6	0.8	2.0	3.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Conclusions

1. Puddled Transplanted Rice recorded the maximum rice equivalent yield (REY) of post *kharif* crops of 8.43 t ha⁻¹ which was at par with NPTR (8.34 t ha⁻¹) and the minimum REY was recorded under DSR (6.85 t ha⁻¹).
2. The PTR recorded the maximum gross return of ₹ 1,20,380/- while net return was the maximum (₹ 49,310/-) under NPTR. But, benefit cost ratio was not significantly affected by establishment methods.
3. The maximum energy input (33,070 MJ ha⁻¹) and output (2,25,045 MJ ha⁻¹) was recorded under the PTR and the NPTR, respectively. But, the DSR (8.59) registered higher energy use efficiency than NPTR and PTR.
4. The NPTR recorded the maximum nitrogen uptake of 206.3 kg ha⁻¹, while phosphorus (38.8 kg ha⁻¹) and potassium (203.8 kg ha⁻¹) uptake were the maximum under PTR.
5. The rice cultivar groups grown in *kharif* failed to cause significant difference in yield, economics, energetics and uptake of nutrient, while 'Arize 6129' recorded higher mean value than cv. Arize 6444 and cv. Swarna.

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