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ENERGETICS OF RICE-RATOON-GREEN GRAM PRODUCTION SYSTEM IN COASTAL ODISHA

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Abstract- Field experiments were carried out to study the influence of sowing time of rice and green gram, system of cultivation of rice genotypes on yield and energetics in coastal Odisha during 2009-10 and 2010-11 in split split-plot design. In the main plots, plant rice was sown by 20 June, 5 July and 20 July followed by green gram sown by 2 January, 17 January and 1 February after stubble crop of rice. Three systems of cultivation of rice *viz.* Best Management Practice (BMP), System of Rice Intensification (SRI) and Modified SRI (MSRI) were assigned in the sub-plots and; hybrid Ajay and *cv.* Tapaswini in the sub sub-plots, giving rise to 18 treatment combinations that were replicated thrice. Plant rice sown by 20 June so also its ratoon yielded the highest grain and straw with the highest energy output which however declined with subsequent fortnightly delay in sowing. MSRI recorded significantly the highest yields as well as energy output followed by SRI and BMP in sequence. The hybrid Ajay performed better with higher grain and straw yield with significantly more energy output. The rice equivalent yield followed the similar trend so also the energy output in rice-ratoon-green gram system of production in coastal Odisha.

Keywords- Sowing time, System of cultivation, Yield, Energetics.

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Introduction

Judicious use of energy in crop production, basically in the areas with rice as the major staple food crop in the cropping system, has been a great challenge in this world of depleting resources, diminishing agricultural work force and with ever increasing cost. A set of resource conservation approaches in rice management practices popularly known as System of Rice Intensification (SRI) has been introduced from Madagascar and being practiced in many countries including India. Its changes in management practices by transplanting of very young seedlings singly in a square pattern, maintaining non-flooded soil rhizosphere up to panicle initiation though alternate wetting and drying, mechanical weeding and much stress to organic nutrient and plant protection measures [1]. Although, the benefits of SRI in and around Odisha compared to the continuous flooded traditional farmers' practices are well established [2 and 3], but studies on its relative performance in comparison to the "Best Management Practices" (BMP) and "Modified SRI" (MSRI) in flood, drought and cyclone affected farming situations of coastal Odisha under assured irrigation system during *kharif* season need careful evaluation particularly when higher costs are involved in hiring farm machineries, implements and engaging work force, both of animal and human. In view of the seasonal non-availability of agricultural labourers due to shifting of work culture from agricultural field to the industrial corridor leading to the burgeoning wage-rate so also the reduced animal power has compelled the innocent farmers to explore alternate management practices of rice. It has also been high time to evaluate the energetics in such alternate crop management practices in coastal Odisha where rice is the only available option for livelihood and food security in view of the water surplus and flood prone agro-ecological compulsions. Moreover, efforts have also been made to analyse the energetics in rice-ratoon-green gram cropping system under varying sowing time.

Materials and Methods

Experimental site

The field experiments were conducted during *kharif* 2009 and 2010 at Nimakana village of Jagatsinghpur district in east and south east coastal plain zone of Odisha, India at 25.6 km air distance from the Bay of Bengal at east. The experiment site in particular was located at 86^0 22' E longitude, 20^0 17' N latitude and 14.0 m above the mean sea level. The experimental soil indicated clay loam texture, moderately acidic soil reaction (5.6 to 5.5), high organic carbon (0.79 to 0.87) and electrical conductivity (0.96 to 0.98 ds m^{-1}). That apart, the available primary plant nutrients analysed were to have medium in N, P_2O_5 (Brays') and K_2O.

Climate and weather parameters

The climate of the experimental location is characterized as "warm and moist" with a hot and humid summer and normal cold winter which broadly falls in the 'moist hot' group [4]. The range of maximum and minimum temperatures during the experimental cropping years was more or less similar as the long term average. The mean annual rainfall is 1,333.9 mm and nearly 62.0% of rainfall was being received between June and October (827.0 mm). The monsoon usually sets in around mid June and recedes by first week of October. July and August are wettest months, while December is the driest one.

Experimental design and treatments

The treatments consisted of three dates of sowing i.e. 20 June, 5 and 20 July; three systems of cultivation of rice i.e. BMP, SRI and Modified SRI; and two medium duration rice genotypes released from Central Rice Research Institute, Cuttack i.e. high yielding variety (HYV) 'Tapaswini' (IET 12168) and hybrid 'Ajay'(CRHR-7, IET 18166). The experiment was carried out in a split-split plot

design with 18 treatment combinations replicated thrice. The first treatment involving three dates of sowing were assigned to the main plots. The second treatment of three systems of cultivation was allotted to three sub plots and the two rice genotypes were grown in sub sub-plots.

Table-1 *Agronomic practices of plant rice*

Practices	Best management practice (BMP)	System of Rice Intensification (SRI)	Modified System of Rice Intensification (MSRI)
Seedling age at transplanting	25 days old seedlings from raised dry bed nursery	10 days old seedlings from raised dry bed nursery	10 days old seedlings from raised dry bed nursery
Plant spacing and density	Two seedlings per hill at 25.0 cm X 12.5 cm spacing quickly after uprooting	One seedling per hill at 25.0 cm X 25.0 cm spacing quickly after uprooting	Two seedlings per hill at 25.0 cm X 12.5 cm spacing quickly after uprooting
Nutrient management	FYM @ 5.0 t ha^{-1} along with total P and 1/3rd of the total recommended dose (100:50:50 kg ha^{-1} of $N:P_2O_5:K_2O$) of the nitrogenous (N) and potassic (K) fertilizers were applied before final puddling. Rest of the N and K fertilizers were applied in two equal halves i.e.1/3rd at maximum tillering (40 DAS) and 1/3rd at panicle initiation (PI) stage (70 DAS).	FYM @ 15.0 t ha^{-1} along with total P and 1/4th of the total (50:50:50 kg ha^{-1} of $N:P_2O_5:K_2O$) nitrogenous and potassic fertilizers were applied before final puddling. Rest of the N and K fertilizers were applied in three equal splits i.e. 1/4th each at 25, 40 and 70 DAS. The share of the N fertilizer from chemical source has been reduced to half of the recommended dose keeping in view its availability from the 10.0 t extra FYM applied to the field at the time of final land preparation.	
Weed management	Three hand weedings at 40, 55 and 70 DAS incorporating the weeds *in situ*.	Four weedings at 20, 30, 40 and 50 DAS by cono-weeder in criss-cross manner.	Four weedings at 20, 30, 40 and 50 DAS by conoweeder in east west direction only.
Water management	Water was allowed to stand in the plots since planting of the seedlings by irrigating at alternate days so as to maintain a layer of 5 to 8 cm depth of water during the entire crop period till 15 days before harvest.	Water was not allowed to stand in the plots and special care was taken to avoid submergence of 10 days' old seedlings just after planting in the field. The soil was kept moist above the field capacity by irrigating the sub sub-plots as per requirement till PI. These plots were first irrigated 5 days after transplanting to moisten the field without ponding. A second irrigation was given on the evening of 9th day after planting at a ponding depth of 2.0 to 5.0 cm and the next morning first weeding was performed by using cono-weeder. Thereafter alternate wetting and drying irrigation method was practiced and subsequent irrigations were applied three days after disappearance of the ponded water or immediately after the development of hair cracks on the soil surface. However, after PI stage, the plots were allowed to hold standing water of 5.0 cm height up to two weeks before harvest.	
Plant protection	Prophylactic sprays of neem oil @ 5.0 ml $liter^{-1}$ of water at 15 days intervals were carried out to avoid any possible damage by insects and diseases. In addition, Trichocards with 1,00,000 viable eggs of *Trichogramma japonicum* ha^{-1} were released at 15 days intervals i.e. at 40, 55 and 70 DAS for preventing the infestation by stem borers in all three systems of planting. Sex pheromone traps @ 20 traps ha^{-1} were installed and lures were regularly changed at 15 days intervals. However, necessary and adequate plant protection measures were adopted depending upon the possibility and incidence of the disease and pest infestation reached at economic threshold limit (ETL).		

Agronomic practices of ratoon rice

Immediate after harvesting of plant rice, the nitrogenous fertilizer @ 60.0 kg ha^{-1} was applied to the sub sub-plots. Subsequently, the field was irrigated for suppressing the fallen seeds from sprouting and acting as weeds. After retillering, sufficient water was maintained in the field to control weeds. As the maturity in ratoon rice was irregular, the field was drained out at 80% maturity stage and crop was then harvested leaving the residue at 5.0 cm above the ground level.

Agronomic practices of green gram crop

After harvesting of the ratoon rice crop, the field was ploughed thoroughly and deeply and cross ploughed according to dates of sowing of green gram at 15 days intervals i.e. 2 January, 17 January and 1 February each year. Green gram seeds of *cv.* Samrat (PDM 139) after seed treatment with Vitavax power @ 1.5 g kg^{-1} were sown at 5.0 cm deep furrows and in paired rows with 15 cm intra paired row spacing and 35 cm inter paired row spacing. The crop was grown with residual soil fertility to study the effect of each treatment combination on the growth and yield attributes of the third crop of green gram after preceding plant and ratoon rice crops. However, the seeds were inoculated with strains of *Rhizobium sps* and P solubilising bacteria (PSB) each @ 20 g kg^{-1} of seeds just before sowing. The plots were irrigated with 5.0 cm depth of water just after sowing for early and uniform germination of the seeds. The weeds thus emerged were effectively managed with pre-emergence application of herbicide like Pendimethalin @ 0.5 kg a.i. ha^{-1}. Subsequently, two irrigations were applied at 20 and 40 DAS for mitigating the water requirement of green gram crop. The plants were thinned in the rows leaving 10 vigorous plants per running meter or 40 plants m^{-2} at about two weeks stage. Earthing up was carried out at 20 DAS and weeds remaining after herbicide application were thus incorporated. The crops were well protected from the attack of insect-pests like white fly by using yellow sticky traps @ 50 traps ha^{-1}. That apart, neem oil @ 5.0 ml $liter^{-1}$ of water was sprayed as prophylactic measures. Harvesting dates ranged from the month of March to April for the crop under different sowing dates of the green gram. The matured pods were plucked manually from the plants in net plot area for recording the economic yield plot-wise. The pods were sun-dried for 3-4 days and threshed manually. The seed and haulm yield were recorded plot-wise after reduction of moisture content to 8%.

Energetic calculation

Energy input was calculated from sowing to harvesting pertaining to each treatment. It was estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by [5]. The standard energy coefficients for seed and straw were multiplied with their respective yields and summed up to obtain the energy output. Based on the energy equivalents of inputs and outputs, the energy indices such as energy ratio (energy output per energy input) and energy productivity (grain yield per energy input) were calculated [6].

Statistical analysis

The data collected were arranged in appropriate tables and analysed statistically by applying analysis of variance technique (ANOVA). Standard error of means i.e. S.Em (±) were used in all cases. The significance of variance was tested by 'Error mean square' method of Fisher Snedecor's F-test at the probability level of 0.05 for appropriate degrees of freedom. The relationships between yield and yield attributing characters were studied by simple correlation coefficient formula as stated below.

$$r = \frac{Cov\,(xy)}{\sqrt{V(x).V(y)}}$$

Where,
Cov (xy) = Covariance xy
V(y) = Variance y
V(x) = Variance x

Results and Discussion

Yield

Effect of date of sowing of rice and green gram

Early sowing by 20 June had the advantage of recording the highest grain yield in

plant (5.811 t ha^{-1}) as well as in its ratoon rice (0.569 t ha^{-1}) and subsequent fortnight delay in sowing beyond this time reduced grain yield significantly [Table 2]. Late sown rice lagged behind in this regard compared to other earlier sowing dates both in plant (4.815 t ha^{-1}) as well as ratoon rice (0.505 t ha^{-1}). Such decline in grain yield could be due to diminishing trend in yield components under delayed sowing. Early sowing of green gram by 2 January had the advantage of recording the highest seed yield (0.703 t ha^{-1}) and rice equivalent ratio (REY) (2.933 t ha^{-1}). 17 January and 1 February sowing followed behind 2 January sowing of rice in this aspect.

Effect of systems of cultivation of rice

MSRI had the advantage of recording significantly the highest grain yield (6.108 t ha^{-1}) in both plant (5.487 t ha^{-1}) and ratoon rice (0.603 t ha^{-1}) followed by SRI and BMP [Table-2]. Superiority of ratoon rice in MSRI rice might be due to the synergistic effect of all yield attributes. Contrastingly, BMP lagged behind possibly due to poor production of these yield components in main and stubble rice. Seed yield (0.711 t ha^{-1}) and REY (2.844 t ha^{-1}) of green gram were significantly higher in crop sown after SRI-ratoon than the crops grown after MSRI-ratoon and BMP-ratoon. Such type of yield performance in green gram might be owing to the commensurating residual effect of the systems.

Table-2 *Effect of treatments on days to harvest and yield of plant rice, ratoon and green gram during kharif (Pooled over 2009-10 and 2010-11)*

Treatments	Days to harvest			Yield (t ha^{-1})							
	Plant rice	Ratoon rice	Green gram	Plant rice		Ratoon rice		Green gram			System REY
				Straw	Grain	Straw	Grain	Haulm	Seed	REY	
Dates of sowing of rice and green gram											
20 June (Pr)/2 January (Gg)	135.14a	58.51a	71.97a	6.508a[1]	5.811a	1.304a	0.569a	2.08a	0.703a	2.933a	9.314a
5 July (Pr)/17 January (Gg)	127.12b	53.35b	69.77b	6.347a	5.478b	1.210b[1]	0.524b[1]	1.91b	0.643b	2.571b	8.573b
20 July (Pr)/1 February (Gg)	119.30c	50.02c	63.44c	5.701b	4.815c	1.183b	0.505b	1.63c	0.552c	2.207c	7.527c
S.Em (±)	0.22	0.10	0.20	0.077	0.082	0.024	0.006	0.03	0.011	0.070	0.089
C.D. (0.05)	0.71	0.31	0.67	0.252	0.267	0.077	0.020	0.11	0.036	0.228	0.291
Systems of cultivation of rice											
Pr (BMP)-Rr-Gg	130.76a	52.75b	67.82b	5.693b[1]	4.509c	1.122c	0.463c	1.53c	0.516c	2.065b	7.036c
Pr (SRI)-Rr-Gg	124.85c	54.77a[1]	68.88a[1]	5.917b	5.487b	1.200b	0.533b	2.11a	0.711a	2.844a[1]	8.864b
Pr (MSRI)-Rr-Gg	125.95b	54.37a	68.49a	6.946a	6.108a	1.376a	0.603a	1.99b	0.670b	2.803a	9.514a
S.Em (±)	0.25	0.28	0.14	0.079	0.080	0.024	0.007	0.03	0.011	0.088	0.109
C.D. (0.05)	0.74	0.82	0.40	0.229	0.232	0.069	0.021	0.09	0.031	0.257	0.319
Genotypes of rice											
Tapaswini	130.07a	54.06	68.69a	5.858b	5.135b	1.204b	0.524b	1.90a	0.641	2.645	8.304b
Ajay	124.30b	53.86	68.10b	6.513a	5.601a	1.261a	0.542a	1.85b	0.624	2.496	8.639a
S.Em (±)	0.18	0.08	0.10	0.054	0.049	0.011	0.005	0.01	0.005	0.057	0.080
C.D. (0.05)	0.50	NS	0.29	0.154	0.141	0.033	0.015	0.04	NS	NS	0.230

Pr- Plant rice, Rr-Ratoon rice and Gg-Green gram

[1] Means followed by common letters did not differ significantly up to 5% level

Effects of genotypes of rice

Hybrid rice Ajay had the advantage of recording significantly higher grain yield in both plant (5.601 t ha^{-1}) and ratoon rice (0.542 t ha^{-1}) which could be due to the synergistic effect of good number of yield attributes. Rice variety Tapaswini had significant and positive effect on the yield of subsequent green gram crop compared to hybrid Ajay in rice-ratoon-green gram system. It could possibly be due to positive combining effect of yield attributes resulting due to the effect of positive residual soil nutrients in former combination.

Table-3 *Effect of treatments on energy output (MJ 10^3 ha^{-1}) of rice-ratoon-green gram system (Pooled over 2009-10 and 2010-11)*

Treatments	Plant rice			Ratoon rice			Green gram			System
	Straw	Grain	Total	Straw	Grain	Total	Haulm	Seed[2]	Total	Grand total
Dates of sowing of rice and green gram										
20 June (Pr)/2 January (Gg)	81.353a[1]	85.427a	166.780a[1]	16.304a	8.371a	24.675a	26.029a	17.564a	43.593a	235.047a
5 July (Pr)/17 January (Gg)	79.333a	80.529b	159.863a	15.123b[1]	7.702b[1]	22.824b[1]	23.930b	16.066b	39.996b	222.683b
20 July (Pr)/1 February (Gg)	71.268b	70.776c	142.044b	14.785b	7.420b	22.205b	20.343c	13.794c	34.137c	198.386c
S.Em (±)	0.967	1.203	2.142	0.296	0.088	0.325	0.404	0.276	0.680	1.637
C.D. (0.05)	3.155	3.924	6.984	0.966	0.287	1.061	1.317	0.900	2.217	5.340
Systems of cultivation of rice										
Pr (BMP)-Rr-Gg	71.167b[1]	66.279c	137.446c	14.019c	6.800c	20.819c	19.132c	12.904c	32.036c	190.301c
Pr (SRI)-Rr-Gg	73.962b	80.662b	154.623b	14.998b	7.832b	22.830b	26.348a	17.773a	44.120a	221.574b
Pr (MSRI)-Rr-Gg	86.826a	89.791a	176.617a	17.195a	8.860a	26.055a	24.823b	16.747b	41.570b	244.242a
S.Em (±)	0.982	1.171	1.963	0.296	0.103	0.388	0.396	0.265	0.661	2.291
C.D. (0.05)	2.868	3.417	5.730	0.865	0.301	1.133	1.156	0.775	1.930	6.689
Genotypes of rice										
Tapaswini	73.219b	75.485b	148.704b	15.045b	7.702b	22.746b	23.743a	16.016a	39.759a	211.209b
Ajay	81.417a	82.336a	163.753a	15.763a	7.960a	23.723a	23.126b	15.600b	38.726b	226.202a
S.Em (±)	0.672	0.723	1.348	0.143	0.077	0.204	0.181	0.123	0.304	1.456
C.D. (0.05)	1.928	2.075	3.870	0.411	0.220	0.586	0.521	0.352	0.872	4.180

Pr- Plant rice, Rr-Ratoon rice and Gg-Green gram

[1] Means followed by common letters did not differ significantly up to 5% level

[2] Calculated by taking the real seed yield of green gram

Energetics

Effect of date of sowing of rice and green gram

The total energy output [Table-3] of plant rice sown by 20 June (166.353 MJ 10^3 ha^{-1}) and 5 July (159.529 MJ 10^3 ha^{-1}) although were significantly superior to the 20 July (142.044 MJ 10^3 ha^{-1}) sowing but were at par with each other due to similar grain yield pattern and grains are having larger influence on the energy

output than straw. Energy productivity and energy ratio in plant rice were in the similar line as above. In the contrary, the total energy input [Table-4] in rice sown on 20 July was the highest (17.802 MJ 10^3 ha^{-1}) and that was mostly due to the relatively higher energy requirement for irrigating this crop than in crop of earlier two dates. The studies on energy output revealed the superiority of the stubble crop (ratoon) of 20 June sown rice (24.67MJ 10^3 ha^{-1}) over subsequent sowing dates with statistical differences. However, there was no such difference between the latter two dates of sowings of rice in this aspect. The total energy output in ratoon rice followed its grain and straw yield pattern [Table-2]. However, the total energy input in production of ratoon was in the reverse way with highest value in 20 July (6.934 MJ 10^3 ha^{-1}). There was no statistical difference with regard to energy productivity and energy ratio of ratoon at varying dates of sowing of rice. But, these parameters were in diminishing trend in rice and green gram at subsequent forwarding of sowing dates beyond 20 June in rice and 2 January in green gram.

Table-4 *Effect of treatments on energetics of rice-ratoon-green gram system (Pooled over 2009-10 and 2010-11)*

Treatments	Total energy input (MJ 10^3 ha^{-1})				Energy productivity (kg $MJ^{-1}10^{-3}$)				Energy ratio			
	Plant rice	Ratoon rice	Green gram	System	Plant rice	Ratoon rice	Green gram[2]	System[3]	Plant rice	Ratoon rice	Green gram	System
Dates of sowing of rice and green gram												
20 June (Pr)/2 January (Gg)	16.871b[1]	6.934a	4.223a	28.029b[1]	333.8a[1]	80.8	773.9a[1]	336.6a[1]	9.58a[1]	3.51	11.11a[1]	8.29a[1]
5 July (Pr)/17 January (Gg)	17.119b	6.577c	4.151b[1]	27.846b	328.6a	77.8	666.7ab	318.7a	9.45a	3.39	10.31a	8.13a
20 July (Pr)/1 February(Gg)	17.802a	6.638b	4.153b	28.593a	265.0b	79.7	577.4b[1]	266.1b	7.74b	3.50	8.83b	6.89b
S.Em (±)	0.102	0.008	0.019	0.115	7.3	1.5	34.2	6.7	0.18	0.07	0.25	0.08
C.D. (0.05)	0.402	0.030	0.076	0.453	28.5	NS	134.4	26.3	0.72	NS	0.98	0.33
Systems of cultivation of rice												
Pr (BMP)-Rr-Gg	19.441a	6.648b	4.560a	30.650a	241.1c	71.7c	461.3b	236.6c	7.21c	3.23b[1]	7.14b	6.32c
Pr (SRI)-Rr-Gg	15.837b[1]	6.758a[1]	3.987b[1]	26.582b[1]	329.9b	77.3b	767.9a[1]	331.4b	9.31b	3.31b	11.89a[1]	8.17b
Pr (MSRI)-Rr-Gg	16.513b	6.743a	3.979b	27.236b	356.4a	89.2a	788.9a	353.5a	10.26a	3.86a	11.22a	8.81a
S.Em (±)	0.233	0.017	0.023	0.252	6.6	1.5	44.2	7.0	0.17	0.08	0.25	0.11
C.D. (0.05)	0.719	0.052	0.071	0.778	20.4	4.6	136.1	21.7	0.52	0.25	0.78	0.35
Genotypes of rice												
Tapaswini	17.226	6.725a	4.165	28.116	298.1b	80.0a	703.4a	304.9	8.54b	3.47	10.23	7.56b
Ajay	17.301	6.707b	4.187	28.196	320.1a	78.9b	641.9b	309.5	9.30a	3.46	9.94	7.98a
S.Em (±)	0.083	0.005	0.016	0.094	4.6	1.2	28.8	5.5	0.13	0.05	0.12	0.08
C.D. (0.05)	NS	0.015	NS	NS	13.8	3.6	85.6	NS	0.39	NS	NS	0.25

Pr- Plant rice, Rr-Ratoon rice and Gg-Green gram

[1] Means followed by common letters did not differ significantly up to 5% level

[2] Calculated by taking the real seed yield of green gram

[3] Calculated by taking the Rice Equivalent (REY) of green gram seed yield

Effect of systems of cultivation of rice

Due to the combined effect of the corresponding energy outputs in grain and straw, plant (176.61 MJ 10^3 ha^{-1}) and ratoon rice (26.055 MJ 10^3 ha^{-1}) under MSRI had the highest energy output that were followed in sequence by rice and ratoon under SRI and BMP [Table-3]. The energy efficiency and energy ratio were in this line. The data on these energetic parameters of the systems (energy outputs, energy efficiency and energy ratio) also showed the similar trend. However, the effect of SRI on green gram in sequence led to its highest total energy output (44.12 MJ 10^3 ha^{-1}) due to the similar and combined positive effects of haulm and seed yield on it. Although the total energy input in green gram grown in BMP-ratoon field was the highest (4.56 MJ 10^3 ha^{-1}) but the total energy output (32.036 MJ 10^3 ha^{-1}), energy productivity (461.3 kg MJ 10^{-3}) and energy ratio (3.23) were of the lowest.

Effects of genotypes of rice

The values for total energy output in plant (163.753 MJ 10^3 ha^{-1}) and ratoon rice (23.723 MJ 10^3 ha^{-1}) with hybrid Ajay were 10.12 and 4.3% higher than that of the high yielding Tapaswini but it was in the opposite direction in green gram in sequence. The above pattern of energy configuration was the direct reflection of the biological outputs of respective crops. Only in ratoon rice, the energy input followed a reverse trend to that of the energy output, whereas in plant rice as well as green gram, the former one did not differ due to varietal intervention. The values for energy input and energy productivity in the rice-ratoon-green gram system did not vary with the variation of varieties of plant rice. However, the total energy output and energy ratio of this system was significantly superior with hybrid Ajay by 7.1 and 5.56% than in *cv.* Tapaswini.

Conclusion

It can be concluded that hybrid rice Ajay sown early by 20 June in MSRI followed subsequently by its ratooning and green gram *cv*-Samrat sown by 2 January in sequence revealed to be the best combination in terms of production and energy efficiency under rice-ratoon-green gram system of cultivation in East and South East Coastal Plain zone of Odisha, India.

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