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Productivity and Energetics of Raising Rice-Arhar Concerning Sowing Windows Under Different Nutrient Management and Crop Geometry

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Abstract

As a staple food, rice plays a central role in the food security and economic growth of India. Rice cultivation was mostly adopted in India because of the climatic condition suitable for the crop, which uses large quantities of locally available noncommercial energy, such as manure and animal energy, and commercial energy directly and indirectly in the form of seed, diesel, electricity, fertilizer, plant protection chemicals, irrigation water, machinery, etc. Under this investigation, the mean system yield (10466 kg ha-1), production efficiency (43.9 kg REY ha-1 day-1), energy use efficiency (12.08), energy efficiency ratio (5.13), energy productivity (0.35 kg REY MJ-1), energy profitability (11.08) was highest in early planting (10 July) than 15 days delay in planting. The STBFR+GM treated plot recorded mean energy use efficiency of 11.77, energy efficiency ratio of 5.05, energy productivity of 0.34 kg MJ-1, and energy profitability of 10.77 followed by STBFR+FYM and STBFR alone. STBFR+FYM resulted in higher system yield (9715 kg ha-1) and gross returns (₹ 183462 ha-1) while STBFR+GM during both the years of study resulted in gaining more net return (₹ 83490 ha-1) and B: C ratio (1.83) and production efficiency (41.4 kg REY ha-1 day-1) showing its superiority to other nutrient combinations.

Keywords: *Energy, system yield, production efficiency, economics, STBFR, FYM/GM*

Introduction

The sustainability of rice-based cropping systems is a prime concern for Asia to maintain food security and to support economic growth. But continuous cultivation of rice is lowering soil fertility and organic matter depleting groundwater resources in tube well-irrigated areas and exacerbating weed, diseases, and pest problems. It has been suggested that if these systems could be appropriately diversified, especially with legumes, the system's sustainability could be enhanced and the process of land degradation reversed. Balanced fertilizer use, complementary use of organic nutrient inputs with fertilizers, and inclusion of legumes are possible agro-techniques to sustain yield, increase fertilizer use efficiency, and restore soil fertility under intensive cropping [4]. Pigeonpea as a soil ameliorant is known to provide several benefits to the soil in which it is grown. Pigeonpea requires little input of fertilizers and due to their deep root system thrive well even under limited rainfall situations.

This gain in productivity not only depends on agricultural inputs but also depends on social and environmental factors. To address these emerging issues, new resource- and capital-efficient and profitable technologies have been introduced. Agriculture is an energy user and energy supplier in the form of bioenergy, the agricultural sector requires energy as an essential input to production [13], enhancing food security, adding value [10], and contributing to rural economic development. If the

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energy in the agricultural sector is used judiciously, it will not only reduce the environmental impacts in terms of greenhouse gas (GHG) emissions and other hazardous effects but will also lead to desirable sustainable agriculture [16].

Energy consumption per unit area in agriculture is directly related to the development of farming technology and production levels. Energy use is one of the key indicators for developing more sustainable agricultural practices. The amount of energy used in agricultural production, processing, and distribution is significantly higher. A sufficient supply of the right amount of energy and its effective and efficient use is necessary for improved agricultural production. The prevalence of high consumption of non-renewable energies is a challenge about agriculture. The available evidence suggests that the excessive consumption of certain agricultural inputs, not only has inhibited the increase in production but also reduced it in some cases [17]. The energy-agriculture relationship is becoming more and more important with the intensification of the cropping systems, which is considered to be the only means of raising agricultural output in land-scarce situations. Timely solving the problems and large-scale implementation the approaches to developing the agricultural energy system will contribute to the independence of the energy supply for overcoming the energy crisis and reviving national farming, which will be a considerable input in ensuring national food security.

Therefore the present study was undertaken to analyze the input, output, and net return energy of different dates of planting along with nutrient management techniques using different organic-inorganic combinations to identify energy-efficient nutrient management techniques and the effect of planting and spacing for satisfactory energy output in the whole cropping system.

Material Methods

The experiment was conducted during the *Kharif* and *rabi* season of the year 2018-19 and 2019-20 in the medium land of agronomy main research farm, OUAT, Bhubaneswar, Odisha. The research farm is situated at 20°15’ N latitude and 85°52’ E longitude, about 64 km away from the Bay of Bengal at an elevation of 25.9 meters above Mean Sea Level (MSL). The research farm comes under the east and southeastern coastal plain agro-climatic zone of Odisha. The soil at the experimental location was sandy loam in texture and somewhat acidic in reaction with a pH of 5.3. It also had low levels of organic carbon (0.51 percent) and available nitrogen (198 kg ha-1), medium levels of available phosphorus (18 kg ha-1), and high levels of available potassium (193 kg ha-1).

Rice was grown in split-plot designs, with six treatment combinations consisting of two planting dates (10 July and 25 July) in the main plot and three nutrient management techniques in sub-plots, namely soil test-based fertilizer recommendation (STBFR, fully inorganic), STBFR+ Sesbania green manure (GM), and STBFR+ Farmyard manure (FYM). To ensure the overall amount of nutrients applied, the nitrogen and phosphorus content of FYM and Sesbania spp were analyzed before application. After the harvest of Kharif rice, rabi arhar (var. PT-0012) was grown in a split-split plot design with 18 treatment combinations consisting of two sowing dates (29 October and 14 November) and the residual effects of three nutrient management strategies applied to rice in sub-plots and three-row spacing of S1:20 cm, S2:30 cm and S3:40 cm in sub-sub-plot. The treatments were replicated four times.

The climate was warm and moist having hot and humid summer and mild winter. The climate is classified into the group of moist hot type. The cropping season of 2018-19 experienced a maximum temperature of 38.3 0C in June 2018 whereas a minimum temperature (of 10.20C) was experienced in January 2019. Normally, the monsoon commences around 2nd week of June and recedes by the first fortnight of October. Rainfall received during crop growing season i.e June to November in 2018 and 2019 was 1829.2 mm (79 rainy days) and 1530 mm (81 rainy days), respectively, which was sufficient enough for rice cultivation under rainfed conditions.

The value of the produce per hectare of each crop was calculated as per the prevailing market price. It was divided by the value of rice per kg to get the rice equivalent yield in kg ha-1. The total REY of component crops of a system was the System yield or system productivity. Production efficiency (kg REY ha-1day-1) is expressed as

Production efficiency (kg REY ha-1 day-1) = Total system yield/cropping period duration

Where the system yield indicates the rice equivalent yield

System nutrient uptake (N, P, and K) in the cropping

system was calculated by summing the nutrient uptake of rice of individual treatment with nutrient uptake of arhar in the same treatment and expressed as kg ha-1. The profit obtained by the crops is considered on a hectare basis and refers to system profitability.
System profitability (Rs ha-1day-1) = Net return/ cropping period duration

The energy value of each cropping system was determined based on energy inputs and energy production for the individual crops in the system as given by Tuti et al. [20]. Inputs and outputs were converted from physical to energy unit measures through published conversion factors [15] as given in Appendix 39. Energy equivalents for all inputs were summed up to provide an estimate of total energy input. The energy output of grain and straw was estimated by multiplying the amount of grain and straw/stover with the corresponding equivalent.

On the basis of energy input and output; net energy returns, energy use efficiency, energy efficiency ratio, specific energy, energy productivity, and energy profitability were calculated by using the following formulae [13] and [5].

Various energy use indices were computed by using the following formula.

a. Net energy return (MJ ha-1) = Total Output Energy (MJ ha-1) - Total Input Energy (MJ ha-1)
b. Energy use efficiency = Total Output Energy (MJ ha-1)/Total Input Energy (MJ ha-1)
c. Energy efficiency ratio = Total Output Energy in main product (MJ ha-1)/Total Input Energy (MJ ha-1)
d. Specific energy (MJ kg-1) = Total Input Energy (MJ ha-1)/Total main product yield (kg ha-1)
e. Energy productivity (kg MJ-1) = Total main product yield (kg ha-1)/Total Input Energy (MJ ha-1)
f. Energy profitability = Net energy return (MJ ha-1))/Total Input Energy MJ ha-1

The experimental data for various growth, yield attributing characters, yield, quality parameters, and nutrient uptake was statistically analyzed by the methods of analysis of variance (ANOVA) as described by Panse and Sukhatme [18]. The significance of treatment effects was computed with the help of the 'F' (variance ratio) test and to judge the significance of differences between the means of two treatment, critical differences (CD) was worked out as described by Gomez and Gomez [6] as follows:

Where,

$$CD = \sqrt{(EMS \times 2) \div n} \times t - \text{value for error d.f at a 5\% level of significance}$$

CD = Critical difference
EMS= Error mean sum of square
n = Number of observations of that factor for which CD is to be calculated.
t = Value of Fisher's table for error degree of freedom at 5% level of significance
Data generated on different biometric observations and yield parameters of different component crops over the years were subjected to pooled analysis following the procedure mentioned in Gomez and Gomez [6].

Results

Rice equivalent yield (REY) of arhar

The data about rice equivalent yield of arhar was presented in Table 1. Perusal of the data revealed that maximum rice equivalent yield of 5458 kg ha-1 was obtained with a succeding arhar crop i.e sown on 29 October against 15 days delay in sowing (3782 kg ha-1). Similarly, the average REY was found to be more with nutrient residues of STBFR+FYM applied to preceding rice registering 4.95 percent and 15.84 percent more yield over STBFR+GM and STBFR residue respectively. Among the spacing, 30 cm spacing gives a maximum REY value of 5022 kg ha-1 followed by 40 cm (4590 kg ha-1) and 20 cm (4246 kg ha-1) spacing.

Total system yield (kg REY ha-1)

The value of system productivity in terms of system yield (kg REY ha-1) was calculated and presented in Table 1.

The data revealed that system yield in terms of rice equivalent yield (kg REY ha-1 day-1) and rice grain yield (kg REY ha-1) was maximum in early sowing condition i.e. 10 July planted cropping sequence followed by 25 July planted rice-arhar sequence. Maximum average values of 10466 kg REY ha-1 were observed with the early sown condition and found significantly superior over late planted condition

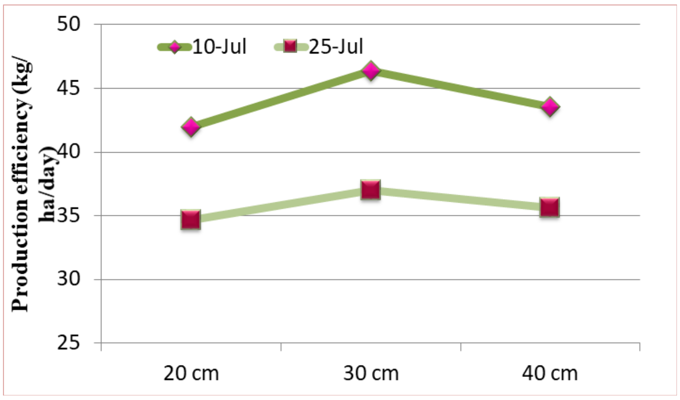

Figure 1. Interaction effect of date of planting and row spacing on production efficiency (kg ha-1 day-1)

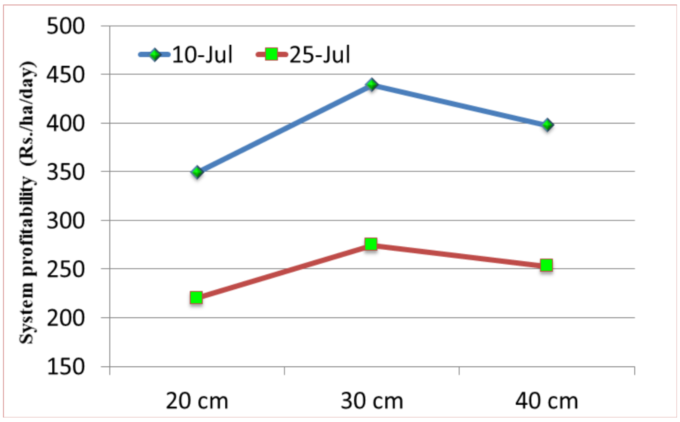

Figure 2. Interaction effect of date of planting and row spacing on system profitability (Rs./ha/day)

(8262 kg REY ha-1). Similarly, STBFR+GM/FYM-based treatment registered higher system yield over only inorganic treated plot. STBFR+FYM and STBFR+GM recorded significantly higher yields than STBFR by 12.01, 11.90 percent. 30 cm row spacing observed maximum system yield of 9767 kg REY ha-1. On the other hand, the lowest system yield was observed in 20 cm row spacing (8991 kg REY ha-1). It is also observed that early planted 30 cm spaced crops gives higher system productivity (Figure 2.) than othe treatment combinations.

Production efficiency

The data based on production efficiency mentioned in table 1 revealed that production efficiency was maximum in early sowing condition (10 July planted cropping sequence) followed by 25 July planted rice-arhar sequence. Maximum mean values of 43.9 were observed in the early planting system, significantly superior over the late planted condition (35.8). Similarly, STBFR+GM/FYM (41.4/41.3) based treatment registered higher production efficiency over only inorganic treated plot. 30 cm row spacing gives maximum production efficiency of 41.7 than wider and narrow row-spaced crop. However, the

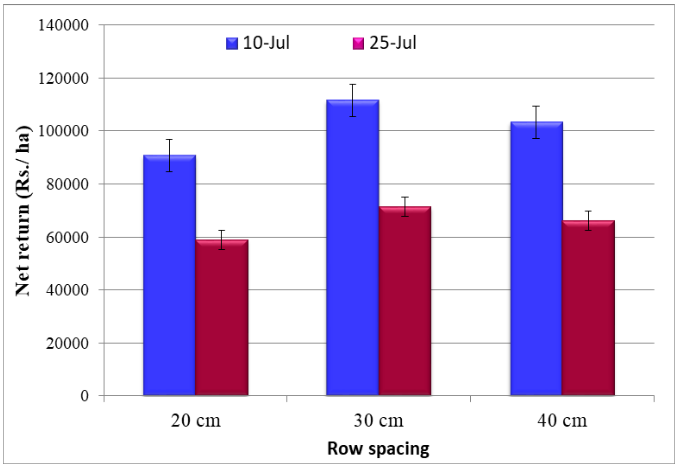

Figure 3. Interaction effect of date of planting and row spacing on net return (Rs./ha) of the cropping system

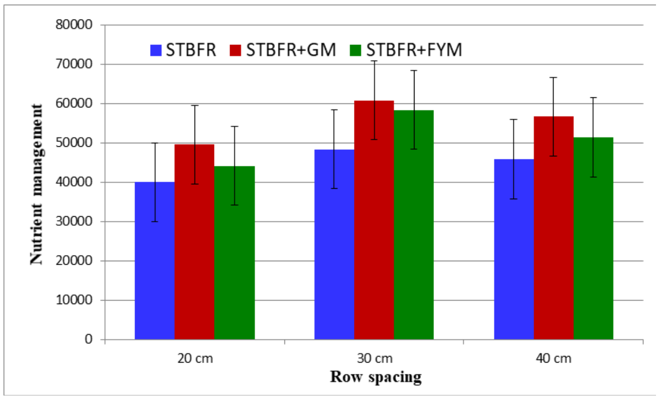

Figure 4. Interaction effect of date of planting and row spacing on net return (Rs./ha) of the cropping system

lowest production efficiency was observed in the 20 cm row spacing value of 38.3. Early planted cropping system alongwith 30 cm row spacing gives highest production efficiency (Figure 1.)

Energy Budgeting

Total energy input-output relationship

During the whole cropping system followed, the total energy input was maximum in 10 July planting (19227 MJ ha-1) followed by 25 July planting (18858 MJ ha-1). Similarly, the output energy is found to be maximum in early planting (233295 MJ ha-1).

The total energy input in rice ranged from 18434 MJ ha-1 to 19858 MJ ha-1. Maximum energy input (19830 MJ ha-1) was utilized under FYM treated plot followed by STBFR+GM (18835 MJ ha-1) treated rice-arhar cropping system. On the other hand, minimum energy input was recorded in the STBFR-treated rice system (18462 MJ ha-1). Similarly, total energy output was highest in STBFR+GM (221932

Table 1: Grain yield, REY of arhar, system yield of rice-rabi arhar cropping system as influenced by spacing of arhar, date of planting and nutrient management in rice (Pooled data of two years)

Treatment	Rice grain yield (kg ha-1)	REY of arhar (kg ha-1)	System yield (kg REY ha-1)	Production efficiency (kg REY ha-1 day-1)
Date of planting in rice				
10 July	5008	5458	10466	43.9
25 July	4481	3782	8262	35.8
SEm±	43.4	47.9	34.2	0.17
CD (0.05)	150.3	166	118	0.6
Nutrient management in rice				
STBFR	4424	4248	8673	36.9
STBFR+ GM	5015	4689	9705	41.4
STBFR+ FYM	4794	4921	9715	41.3
SEm±	54.5	69.7	95.0	0.41
CD (0.05)	158.9	203	277	1.2
Row spacing in arhar				
20 cm	4745	4246	8991	38.3
30 cm	4744	5022	9767	41.7
40 cm	4745	4590	9335	39.6
SEm±	0.51	48.6	48.7	0.21
CD (0.05)	N.S	137	137	0.6

MJ ha-1) followed by STBFR+FYM (220073 MJ ha-1), and lowest in STBFR treatment (199165 MJ ha-1). Both GM and FYM treatments give -par results and are significantly higher than STBFR-treated plots.

Spacing had a significant effect on energy utilization as well as energy production of the rice arhar cropping system indicating maximum energy utilized by 20 cm row spacing while maximum energy output produced by 30 cm row spacing.
Net energy

The date of planting influenced net energy return significantly in both years. Early planting gives a higher net energy return of 214067 MJ ha-1 and the lowest energy return observed in case of delay in planting by 15 days (175295 MJ ha-1) in both years.

The total net energy return of rice-arhar cropping system ranged from 175414 MJ ha-1 to 208719 MJ ha-1. Maximum net energy return (203097 MJ ha-1) was realized under STBFR +GM treated rice crop followed by STBFR+FYM (200243 MJ ha-1). On the other hand, minimum energy return was recorded under only inorganic (STBFR) treated rice (180703 MJ ha-1).

Table 2. Energy indices (MJ ha-1) of rice-arhar cropping system as influenced by spacing of arhar, date of planting and nutrient management in rice.

Treatment	Input energy of system			Output energy of system			Net energy of system		
	18-19	19-20	Pooled	18-19	19-20	Pooled	18-19	19-20	Pooled
Date of planting									
10 July	19213	19241	19227	229559	237031	233295	210346	217789	214067
25 July	18816	18899	18858	186387	201918	194152	167571	183018	175295
SEm±	-	-	-	920.1	1290.4	792.4	920.1	1290.4	792.4
CD at 5%	-	-	-	4140	5807	2742	4140	5807	2742
Nutrient management									
STBFR	18434	18489	18462	193848	204481	199165	175414	185992	180703
STBFR+ GM	18806	18864	18835	216281	227584	221932	197475	208719	203097
STBFR+ FYM	19803	19858	19830	213789	226357	220073	193986	206500	200243
SEm±	-	-	-	2364.6	2849.3	1851.3	2364.6	2849.3	1851.3
CD at 5%	-	-	-	7285	8778	5403	7285	8778	5403
Row spacing									
20 cm	19268	19324	19296	203834	215224	209529	184566	195900	190233
30 cm	18960	19016	18988	213138	224299	218718	194178	205283	199730
40 cm	18815	18871	18843	206947	218900	212923	188132	200029	194080
SEm±	-	-	-	759.7	1486.1	834.5	759.5	1485.9	834.5
CD at 5%	-	-	-	2179	4262	2352	2178	4261	2352

Table 3 Energy indices of rice-arhar cropping system as influenced by spacing of arhar, date of planting and nutrient management in rice (Pooled data of two years)

Treatment	Energy use efficiency	Energy efficiency ratio	Specific energy (MJ kg-1 REY)	Energy productivity (Kg REY MJ-1)	Energy profitability
Date of planting					
10 July	12.08	5.13	2.88	0.35	11.08
25 July	10.33	4.41	3.36	0.30	9.33
SEm±	0.045	0.026	0.018	0.002	0.045
CD (0.05)	0.15	0.09	0.06	0.01	0.15
Nutrient management in rice					
STBFR	10.75	4.57	3.26	0.31	9.75
STBFR+ GM	11.77	5.05	2.93	0.34	10.77
STBFR+ FYM	11.10	4.69	3.17	0.32	10.10
SEm±	0.096	0.047	0.031	0.003	0.096
CD (0.05)	0.28	0.14	0.09	0.01	0.28
Row spacing in arhar					
20 cm	10.79	4.62	3.22	0.31	9.79
30 cm	11.52	4.88	3.05	0.33	10.52
40 cm	11.31	4.81	3.09	0.33	10.31
SEm±	0.057	0.012	0.007	0.001	0.057
CD (0.05)	0.16	0.03	0.02	0.003	0.16

Spacing had a significant effect in improving the net energy return of the rice arhar cropping system. Maximum net energy obtained in 30 cm spacing (199730 MJ ha-1), followed by 40 cm spacing. The lowest energy return was observed in 20 cm spacing (190233 MJ ha-1).

Energy indices

Date of planting exerted a significant influence on the energy indices of the rice-arhar cropping system. The mean energy use efficiency (12.08), energy efficiency ratio (5.13), energy productivity (0.35 kg REY MJ-1), and energy profitability (11.08) were highest in early planting (10 July) than 15 days delay in planting except for specific energy (2.88 MJ kg-1 REY) which is higher in delayed planting condition.

The residual effect of nutrient management also affects energy indices. The maximum energy indices were observed in the STBFR+GM treatment. The STBFR+GM treated plot recorded mean energy use efficiency of 11.77, energy efficiency ratio of 5.05, energy productivity of 0.34 kg MJ-1, and energy profitability of 10.77 followed by STBFR+FYM and STBFR alone. On the other hand, the lowest specific energy was recorded in the STBFR+GM treatment (2.93 MJ kg-1). While specific energy is found to be higher in STBFR (3.26 MJ kg-1 REY) followed by STBFR+FYM (3.17 MJ kg-1 REY).

Among different spacing 30 cm row spacing gave higher energy indices i.e. energy use efficiency of 11.52, an energy efficiency ratio of 4.88, energy productivity of 0.33 kg MJ-1, and energy profitability of 10.52 followed by 40 cm and 20 cm row spacing. However, specific energy is found to be lower in 30 cm spacing (3.05 MJ kg-1).

System economics

The data presented about economics of the system in terms of cost, gross return, the net return, B: C ratio indicated that arhar as a preceding crop was beneficial. It was calculated for the entire rice-arhar sequence taking into consideration the inputs used and the economic yield for both years was presented in Table 4.

Perusal of the data indicated that there was an increase in gross return, the net return, and BCR with the 10 July planted cropping sequence. The increase in net gross return, the net return, and BCR due to early sowing were to the tune of 26.32, 63.58, and 20.89 percent more over 15 days delay in planting both the years of study.

Highest gross returns (₹197426 ha-1), net returns (₹ 94141 ha-1), and B: C ratio (1.91) were recorded with cropping sequence during both the year of study. STBFR+FYM resulted in higher gross returns (₹ 183462 ha-1) while STBFR+GM during both the years of study resulted in gaining more net return (₹ 83490 ha-1) and B: C ratio (1.83) showing its superiority to other nutrient combinations. Inorganic fertilizer application and its residual effect on the preceding crop had resulted in significantly lowest gross return (₹163860 ha-1), net return (₹ 67102 ha-1), B: C ratio (1.69) in this rice-rabi arhar sequence.

Row spacing had a significant effect on improving the return and B: C ratio of the cropping system. 30 cm row spacing gave a maximum gross return of ₹184287 ha-1, the net return of ₹ 83743 ha-1, B: C ratio of 1.83 against 40 cm and 20 cm row spacing succeeding. Interaction effect of date of planting with row spacing shows higher net return at early planted 30 cm spaced cropping system (figure 3.). Similarly

Table 4 Economics of the rice-arhar cropping system as influenced by spacing of arhar, date of planting and nutrient management in rice (Pooled data of two years)

Treatment	Cost of cultivation (₹ ha-1)	Gross return (₹ ha-1)	Net return (₹ ha-1)	B:C ratio	System profitability (₹ ha-1 day-1)
Date of planting in rice					
10 July	1,03,285	1,97,426	94,141	1.91	395.4
25 July	98,730	1,56,281	57,550	1.58	249.0
SEm±	-	624.8	642.9	0.006	2.83
CD (0.05)	-	2224	2225	0.02	9.8
Nutrient management in rice					
STBFR	97,580	1,63,860	66,280	1.68	281.4
STBFR+ GM	99,747	1,83,237	83,490	1.83	355.8
STBFR+ FYM	1,05,695	1,83,462	77,767	1.73	329.4
SEm±	-	1776.6	1776.4	0.017	7.54
CD (0.05)	-	5185	5184	0.05	21.9
Row spacing in arhar					
20 cm	1,03,144	1,69,993	66,848	1.64	284.5
30 cm	1,00,544	1,84,287	83,743	1.83	356.9
40 cm	99,335	1,76,280	76,945	1.77	325.2
SEm±	-	922.1	920.1	0.009	3.79
CD (0.05)	-	2599	2593	0.03	10.7

green manure treated crpopping system along with 30 cm row spacing gives higher net return (Figure 4.).

Discussion

Rice-arhar cropping system

Effect of date of planting on cropping system

Significantly higher REY (5458 kg ha-1) of succeeding arhar crop, system yield (10466 kg REY ha-1), and production efficiency (43.9 kg REY ha-1 day-1) obtained through earlier planting than 15 days delayed cropping system [21]. The decreased productivity might be associated with a lower number of productive yield attributes and low test weight as well as seed index. The higher yield on the 10 July planted crop might be due to more productive tillers branches-1, more grains panicle-1 and pods plant-1, and increased grain weight. These results are in line with the finding of Dahiya et al. [2] and Ahmed et al. [1].

Higher energy budgeting in terms of energy use efficiency (12.08), energy efficiency ratio (5.13), energy productivity (0.35 kg REY MJ-1), and profitability (11.08) was higher in early planting treatment than other treatments. This might be due consumption of similar input energy resulting in higher energy output through higher yield production [3].

The net returns (₹ 94141 ha-1) and B: C ratio (1.91) obtained with earlier sown crops in the cropping system were significantly higher over 15 days of delayed planted crops.

Effect of nutrient management on the cropping system

Nutrient management had a significant effect on the rice-arhar cropping system. Higher REY (4921 kg ha-1) of succeeding arhar crop, system yield (9715 kg REY ha-1) through STBFR+FYM, while production efficiency (41.4 kg REY ha-1 day-1) was higher in STBFR+GM treatment. Integrated use of organic and inorganic sources of the nutrient might have contributed to more synchronization of nutrient availability to rice crops, which was reflected in the highest rice grain yield and dry matter production. Comparable results were obtained by Gudadhe et al. [9] in the case of cotton. The higher yield of rice might be due to improvement in soil physical and chemical properties which increased the availability of nutrients with the addition of FYM along with other sources of organics [14].

Energy calculation such as energy use efficiency (11.77), energy efficiency ratio (5.05), and energy profitability (₹ 10.77 ha-1 day-1) was higher in STBFR+GM treatment. Higher energy consumption due to the application of mineral fertilizers, calls for the supplementation of plant nutrients through renewable sources. But higher output production in terms of yield improved the energy indices due to fertilizers representing higher energy indices [20] and [12]. Economics involving net return (₹ 83490 ha-1), B: C ratio (1.83), and system profitability (355.8 kg ha-1) was higher in STBFR+GM treatment. The higher economic returns in these treatments were mainly due to higher yields with a nearly similar cost of cultivation. Similar findings were reported by Laxmi et al. [11] in the Rice-green gram cropping system. These findings are in close confirmation with the study of Gudadhe et al. [7] and Gudadhe et al. [8]. Effect of spacing on system

Medium row spacing of 30 cm in rabi arhar performed better in all aspects resulting in higher REY of 5022 kg ha-1 of succeeding arhar crop, system yield of 9767 kg REY ha-1, the production efficiency of 41.7 kg REY ha-1 day-1 than other two-row spacing. This might be due to the higher yield obtained by both rice and arhar crop in the cropping sequence.
Energy budgeting in terms of energy use efficiency (11.52), energy efficiency ratio (4.88), energy productivity (0.33 kg REY MJ-1), and profitability (10.52) were found to be higher with 30 cm row spacing treatment than other spaced cropping systems.

Medium-spaced crop (30 cm) gave maximum gross return (₹ 184287 ha-1), net return (₹ 83743 ha-1), B: C ratio (1.83), and system profitability of 356.9 than other plant geometry. The results are under Reddy et al. [19].

Conclusion

Early planting (10 July) with integrated nutrient management consisting of sesbania green manuring supplemented with soil test-based fertilizer recommendation to kharif rice and medium row spacing (30 cm) of relayed rabi arhar produced the maximum system productivity (11247 kg REY ha-1), profitability (₹ 0.37 ha-1 day-1), energy use efficiency (12.88), with higher system net return (₹ 110350 ha-1) and B:C ratio of 2.09 in rice-arhar cropping system.

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