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System productivity, profitability and resource use efficiency of jute (*Corchorus olitorius*) based cropping systems in the eastern Indo-gangetic plain

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ABSTRACT

The study was conducted to investigate productivity, profitability and energy use of different jute (*Corchorus olitorius* L.) based cropping systems in the eastern India on farmers' fields during 2009-12. Nine cropping systems, viz. jute-rice-wheat; jute-rice-potato; jute-rice-garden pea; jute-rice-lentil; jute-rice-mustard; jute-rice-French bean; jute-rice-rice; rice-rice-mustard and fallow-rice-rice were tested in randomised block design. Jute-rice-potato system recorded significantly higher system productivity in terms of jute equivalent yield(JEY) than all other cropping systems. The JEY of jute-rice-garden pea and jute-rice-French bean cropping systems were comparable, but recorded significantly higher JEY than that of rice-rice-mustard and rice-rice cropping systems. The highest energy input (61.2 GJ)/ha) was required for jute-rice-potato and lowest (34.3 GJ/ha) for jute-rice-lentil cropping systems. The highest energy productivity was recorded in jute-rice-potato but the highest energy use efficiency was recorded in jute-rice-garden pea and jute-rice-lentil cropping systems. The jute-rice-potato cropping system recorded the highest net return (₹134 868/ha),benefit-cost ratio (2.0) and economic efficiency (₹369.5/ha/day). Thus among the nine cropping systems of Indo-gangetic plain jute-rice-potato system had the highest system productivity, energy productivity and profitability whereas jute-rice-garden pea cropping system recorded the highest energy use efficiency.

Key words : Cropping system, Energy use efficiency Jute, Profitability, System productivity

The jute (*Corchorus olitorius* L.) known as 'golden fibre'is grown mostly by small and marginal farmers. Cultivated on 0.80 m ha of area in the eastern India, provides livelihood support to 4 million farm families, 0.25 million industrial workers and 0.5 million traders. It is grown as a pre-*kharif* (summer) season crop in succession with *kharif* (rainy) season crops mainly rice and *rabi* (winter) season crops, viz. mustard and pulses on residual moisture after harvest of rice (Mahapatra *et al.* 2012). But many large farmers having irrigation facilities generally prefer to grow rice-rice-potato and rice-rice-mustard cropping sequences. These multiple/intensive cropping systems are common in this region to get higher production per unit area per unit time resulted in higher water requirement and nutrients removal from the soil. The rice, mustard and wheat crops are exhaustive users of plant nutrients and continuous adoption of these cropping systems results in the removal of nutrients in substantial amounts that often exceed replenishments through fertilizers and manures, leading to deterioration in soil fertility and reduction in the productivity of the system (Biswas *et al.* 2009).Further, the practices of intensive cropping systems increase the use of energy input, which is invested in various forms such as mechanical (farm machines, human labour, and animal draft), chemicals, fertilizers, pesticides, diesel, electrical (Devsenapathy *et al.* 2009). In Indian agriculture, it has been reported that consumption of energy has been increasing at a steady rate for improving the productivity, but the energy use efficiency is declining consistently (Chaudhary *et al.* 2009). In the changing climatic scenario, sustainability of any cropping system lie on energy use pattern/consumption in the system. Thus, examination of the energy input–output relationship or energy use efficiency is becoming more and more important for any cropping system. Thus,there is a need to think for more productive, efficient and remunerative cropping systems, which practice sustained use of natural resources. Besides, farmers' acceptance and perception regarding adoption and/or diversify

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cropping system should also be taken care. Realizing this, present study was undertaken on farmers' field to investigate the productivity and profitability and energy use of jute based cropping systems.

MATERIALS AND METHODS

The present study was conducted at farmers' fields located in North-24 Pargana district of West Bengal, India during 2009-12. The site was located at 23°14′N latitude and 88°30′ E longitude at an elevation of 12 m above mean sea level. The three cropping seasons includes a rainy or *kharif* season from June to October, a winter or *rabi* season from November to February, and a summer or dry season from March to May. Nine cropping systems, viz. jute-rice-wheat (J-R-W), jute-rice -potato (J-R-P), jute-rice-garden pea (J-R-Gp), jute-rice-lentil (J-R-L), jute-rice-mustard (J-R-M),jute–rice- French bean (J-R-Fb), jute-rice-rice (J-R-R), rice-rice-mustard (R-R-M) and fallow-rice-rice(R-R) were tested in farmers' fields. These cropping systems represent traditional and recent cropping systems in the eastern Indo-gangetic plain. A total of twenty seven farmers were selected and each cropping sequence was grown at three farmers' fields in different and/or same villages of North-24-Pargana district of West Bengal. The average annual rainfall received during 2009 and 2010 were 1030 mm and 1036 mm, respectively, which was lower than annual mean average rainfall of 36 year (1558 mm) while, rainfall in 2011 was 2282 mm, which was 45% higher than 36 year annual average rainfall. The soil of experimental sites was clay loam with medium in organic carbon content (0.65-0.67%), available N (296-325 kg/ha), and P (32-38 kg/ha) and high in K content (282-290 kg/ha) across the farmers' fields.

All variables were analyzed following a RBD model by adopting cropping systems as treatments and number of farmers assigned the particular cropping system as replication. The least significant difference (LSD) test was carried out for analyzed mean square errors for jute equivalent yield. The procedure provides for a single LSD value at 5% level of significance (Gomez and Gomez 1984). All the crops in cropping sequence were grown in same field of the gross area of 1230 m^2 for three years with recommended package and practices. Details of duration of crops and inputs used in these cropping practices are given in Table 1. Field preparation was done with a tractor drawn cultivator followed by laddering to level the land. For rice, puddling was done prior to transplanting and 30 and 45 days old rice seedlings were transplanted for *kharif* (rainy) season and *boro* (dry) season rice, respectively. Seeds of jute, wheat, mustard and lentil were sown manually by *Pora* method while garden pea, French bean was sown by dibbling method. Recommended doses of fertilizers to each crop in various cropping systems were applied. Need based irrigation was given to each crop. All crops were harvested manually at maturity from net plot area of 750 m^2 out of 1230 m^2 gross plot area. After harvesting data of biomass and economic yield of each crop were converted into per hectare. Economic produce of all the crops were obtained manually by their specified processing techniques. Retting, the process of obtaining fibre from stem was done by dipping the jute plants in bundle in pond for 20 days and the fibre extraction was done manually. To compare the performance of different cropping sequences, economic yield of all the crops were converted into jute equivalent yield (JEY) based on prevailed market price using the formula:

JEY (of a crop) = Yx (Px)/Pj

where, Y_x is the yield of crop x (t/ha of economic harvest), Px is the price of crop x, and Pj is the price of jute.

To assess the resource use efficiency of the system, land use efficiency (LUE) was calculated from total duration of crop in cropping system divided by 365 and production efficiency in terms of kg/ha/day and was calculated by dividing total economic yield (JEY) by total duration of crop in cropping system.

The energy value of each cropping system was determined based on energy inputs and energy production for the individual crops in the system. Inputs and outputs

Table 1 Agronomic practices of individual crop followed during experimentation

Crop	Variety	Seed rate (kg/ha)	Spacing (cm × cm)	Crop season (seed to seed)#	No. of irrigation	Fertilizers N:P:K kg/ha	No. of intercultural operation
Jute	JRO 204	5	25 × 5	April(1) -Aug(1)	2	80:17:33	2
Rice	Satabdi	45	20 × 10	July(1)- Nov(1)	5	80:17:33	2
Boro rice	Khitish	75	20 × 10	Dec (3)- April (2)	8	120:26:33	2
Wheat	PBW 343	100	22.5	Nov(2)- March (4)	5	120:26:33	2
Potato	Jyoti	2500	45 × 15	Nov (1)-Feb(4)	6	180:34:100	3
Mustard	B-9	7	30 × 10	Nov.(1)-Feb(3)	2	80:17:33	1
Garden pea	Azad P-3	80	45	Nov.(3)- Feb(4)	5	40:26:33	2
Lentil	B-256	30	30	Nov (2)-March (1)	2	20:26:33	1
French bean	Contender	75	45 × 15	Nov.(3)-Feb(4)	2	40:26:33	2

#Figure in parentheses is week of respective month were converted from physical to energy unit measures through published conversion coefficients (Mittal *et al.* 1985, Devsenapathy *et al.* 2009).The biomass of the crop is separated into economic yield and by-product (straw/stalk/vine). Energy output from the economic product (grain/pod/fibre) and by-product (straw/stalk/vine) was calculated by multiplying the amount of production and its corresponding energy equivalent. The energy input-output relationship was determined by calculating energy use efficiency, dividing output energy by input energy. The relationship between yield and energy was determined by calculating energy productivity by dividing the economic yield of system, i.e. JEY by energy input. The cost of cultivation was calculated each year by taking account of prevailing market price of inputs. Minimum support price was used for grain of rice, wheat, mustard, lentil and jute fibre and local market price was used for vegetable pea, French bean, potato and by-products (straw/stalk/stick) of crops for calculating the gross return. Economic efficiency was calculated in terms of (₹/ha/day) from net return of the cropping system divided by total duration of crop in a cropping system.

RESULTS AND DISCUSSION

Jute and system productivity

The productivity of jute fibre varied with cropping systems and it was the highest (3.25 tonnes/ha) in J-R-P system and the lowest in J-R-R (2.8 tonnes/ha) cropping system (Table 2). The highest fibre yield of jute in J-R-P system was mainly due to residual effects of high doses of fertilizer applied to potato crop and also soil aeration during potato harvesting were beneficial for jute growth and development as it has also been reported in other studies with jute-potato systems (Mandal *et al.* 1981).In contrary, rice after rice cropping sequence known to be an exhaustive system (Gangwar *et al.* 2006) and jute in this system obtained the lowest fibre yield (Biswas *et al* 2006). System productivity in terms of jute equivalent yield (JEY) was significantly higher (14.3 tonnes/ha) in J-R-P system compared to remaining other cropping systems. Higher productivity of jute and potato in J-R-P system and stable market price during experimentation period contributed to higher JEY in this system. The JEY of J-R-Gp and J-R-Fb systems were intermediary (8.1 tonnes/ha) but significantly higher than R-R-M and R-R cropping systems. Rice, wheat and mustard are known to be more nutrient exhaustive crops than leguminous crops like garden pea, lentil and French bean. Leguminous crops have deep root system which recycle the nutrients, improve the soil structure, add nutrient and other nutrients by biological nitrogen fixation and/or by leaf fall, and they show better overall nutrient use efficiency, hence, improves system productivity (Ladha and Kundu 1997, Dwivedi *et al.* 2003).The R-R-M triple cropping and R-R double cropping system recorded the lowest system productivity. Nevertheless, these cropping systems are prevalent in this area and grown by most of the farmers, because farmers are unaware of adverse effects of monoculture and they are growing rice-rice system from generation to generation.

Resource use efficiency

Resource use efficiency in terms of land use efficiency and production efficiency have been calculated and presented in Table 2. The J-R-W system occupied the land for maximum duration thus recorded the highest land use efficiency (93.2%); however, production efficiency of this system was

Table 2 Economic yield of individual crop, jute equivalent yield (JEY), production efficiency and land use efficiency of different jute based cropping systems (pooled data of three years)

Cropping system	Economic yield (tonnes/ha)			JEY (t/ha)	Total duration (days)	Production efficiency (kg/ha/day)	Land use efficiency (%)
	Summer	Rainy	Winter				
J-R-W	3.13	3.77	3.82	7.63	$110^{\#}+95^{\$}+135^{¥}=340^{‡}$	22.43	93.15
J-R-P	3.25	3.86	26.12	14.3	110+95+110=315	45.79	86.30
J-R-Gp	3.15	3.86	7.53	8.10	110+95+90=295	27.36	80.82
J-R-L	3.13	3.86	1.08	6.71	110+95+105=310	21.77	84.93
J-R-M	3.05	3.74	1.66	7.01	110+95+100=305	23.06	83.56
J-R-Fb	3.20	3.84	4.15	8.10	110+95+120=325	24.12	89.04
J-R-R	2.80	3.64	5.29	7.81	110+95+115=320	25.67	87.67
R-R-M	5.2	3.55	1.42	6.50	115+100+95=310	22.14	84.93
R-R	0	3.94	5.40	5.24	$0+115+135^{\$}=250$	21.61	68.49
LSD		1.10					

J: Jute; R: Rice; W: Wheat; P: Potato; Gp: Garden pea; L: Lentil; M: Mustard; Fb: French bean; [#]total time required from sowing to harvest of jute; [$] total time required from transplanting to harvest of rice; [¥]time required from sowing to harvest of winter season crop in sequence; [‡] total duration of cropping sequence in same piece of land

Table 3 Energy analysis of different jute based cropping systems

Cropping system	Input energy (GJ/ha)				Output energy (GJ/ha)				Energy use efficiency	Energy productivity (t/GJ)
	Summer	Rainy	Winter	System	Summer	Rainy	Winter	System		
J-R-W	10.5	17.2	15.5	43.2	178.2	123.7	116.8	418.7	9.7	0.18
J-R-P	10.5	17.2	33.5	61.2	183.2	123.5	138.5	445.2	7.3	0.23
J-R-Gp	10.5	17.2	9.6	37.3	168.5	122.7	91.8	383.1	10.3	0.22
J-R-L	10.5	17.2	6.6	34.3	174.8	125.0	51.4	351.2	10.3	0.20
J-R-M	10.5	17.2	7.9	35.6	170.0	119.9	68.4	358.4	10.1	0.20
J-R-Fb	10.5	17.2	10.4	38.1	161.0	126.4	30.4	317.8	8.3	0.21
J-R-R	10.5	17.2	18.0	45.7	159.9	123.5	162.8	446.2	9.8	0.17
R-R-M	18.0	17.2	7.9	43.1	155.1	118.4	61.7	335.3	7.8	0.20
R-R	0	17.2	18.0	35.2	0	130.4	169.4	299.8	7.8	0.15

J; Jute; R: Rice; W: Wheat; P: Potato; Gp: Garden pea; L: Lentil; M: Mustard;Fb: French bean

comparatively less than J-R-P, J-R-Gp, J-R-Fb and J-R-M cropping systems. The land use efficiency of J-R-P cropping system was 86.3%; less than J-R-W, J-R-Fb, R-R-M triple cropping system, but recorded the highest production efficiency (45.79 kg/ha/day). The J-R-Gp recorded the second highest production efficiency (27.36 kg/ha/day) with land use efficiency of 80.8%; the lowest one among triple cropping. The lowest production efficiency and land use efficiency were recorded in R-R sequences because of comparatively less productivity and this double cropping system utilised land for shorter duration.

Energy analysis

Energy input and output relationships for growing crops in the studied cropping systems had been analysed and presented in Table 3. The highest input energy (33.5 GJ/ha) was required for growing potato crop in sequences and the lowest energy (6.6 GJ/ha) was required for growing lentil in sequence. It was mainly due to variable amount of inputs required for growing the crops. Hence, the highest input energy was required for J-R-P system and the lowest was for the J-R-L cropping system. The potato required high amount of inputs, i.e. seed, manures and fertilizers and these inputs contributed to most of the input energy requirement. The input energy of *boro* rice cropping (J-R-R and R-R-M) systems was higher than the remaining cropping system except J-R-P. Cultivation of *boro* rice required very high amount of energy (18 GJ/ha) due to its comparatively high requirement of inputs, i.e. irrigation and fertilizers. Among the individual crop in cropping system, output energy of *boro* rice was the highest (varied 160.4 to 166.4 GJ/ha) due to high biomass (grain +straw) and energy equivalent. Whereas system output energy (445.2 GJ/ha) was recorded the highest in J-R-P cropping followed by J-R-R system (444.2 GJ/ha). Although, higher output energy was recorded in *boro* rice (160.8 GJ/ha) which was higher than potato (138.5 GJ/ha),system output energy was recorded the highest in J-R-P, because jute in sequence of potato produced higher biomass (fibre + jute stick) compared to in sequence with *boro* rice. The highest energy use efficiency was recorded for J-R-Gp and J-R-L and the lowest for J-R-P cropping systems. Nevertheless, these systems recorded lower output energy than J-R-R, J-R-P and J-R-W systems. This was mainly due to leguminous crop in sequences required very less input energy and gives optimum output energy. The highest energy productivity was recorded in J-R-P system (0.23 t/GJ) followed by J-R-Gp (0.22 t/GJ) system. The highest productivity of jute and potato in J-R-P system resulted in their higher system productivity and output energy and hence, the highest energy productivity. Double rice cropping sequence, i.e. J-R-R and R-R recorded the lowest energy productivity.

Economic analysis

Economic analysis of different cropping sequences (Table 4) revealed that the highest cost of cultivation was required for J-R-P sequence and the maximum amount of cost was incurred in potato seeds and fertilizers. The lowest cost of cultivation was for R-R due to double cropping system, but among the triple cropping sequences the lowest cost of

Table 4 Economic analysis of jute based cropping systems

Cropping sequence	Cost of cultivation (₹)	Gross return (₹)	Net income (₹)	Return per invested	Economic efficiency (₹/ha/day)
J-R-W	102 749	150 483	47734	1.5	130.8
J-R-P	135 184	270 052	134868	2.0	369.5
J-R-Gp	101 427	157 227	55800	1.6	152.8
J-R-L	91 221	132 104	40882	1.4	112.0
J-R-M	91 689	137 309	45620	1.5	125.0
J-R-Fb	99 849	156 676	56827	1.6	155.7
J-R-R	106 447	157 164	50717	1.5	139.0
R-R	70 327	108 268	37941	1.5	104.0

J; Jute; R: Rice; W: Wheat; P: Potato; Gp: Garden pea; L: Lentil; M: Mustard; Fb: French bean cultivation was recorded in J-R-L. Gross and net return and return per ₹ invested were the highest for J-R-P system due to increasing in MSP and stable market for potato in the year of study. Among all these cropping systems, J-R-Gp and J-R Fb incurred intermediary net income and B:C ratio. The highest economic efficiency was obtained in J-R-P (₹ 369.5/ha/day) followed by J-R-Fb ((₹ 155.7 /ha/day) and J-R-Gp (₹ 152.8) cropping systems.

Thus, it may be concluded that jute-rice-potato (J-R-P) system recorded the highest system productivity, energy productivity, net return and economic efficiency whereas, jute-rice-garden pea and jute-rice-lentil cropping systems recorded highest energy use efficiency. Although farmers' selection of different jute-based cropping sequences depends on the availability of resources and market demand prevailing for various crops, leguminous crops like garden pea or lentil should be included in jute cropping system as these are energy efficient crops in the system.

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