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Productivity and Resource Use Efficiency of different Jute based Cropping Systems under Nutrient and Crop Residue Management Practices

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ABSTRACT

A field experiment was conducted to study the effect of nutrient and crop residue incorporation on productivity jute based cropping system in split plot design during 2012-14. The main plot comprised of five cropping sequences *viz.*, rice-rice, jute-rice-wheat, jute-rice-baby corn-jute (for leafy vegetable), jute-rice-garden pea, jute-rice-mustard-mungbean andfour nutrient management practices*viz.* 75% recommended doses of fertilizers (RDF) with and without crop residue (rice, wheat, corn, garden pea and mungbean with their respective cropping sequence) and 100 % RDF with and without crop residue in sub plot. Jute-rice-baby corn- jute(leafy vegetable) cropping system recorded the highest system productivity (192.36q/ha) followed by jute-rice-garden pea (88.6 q/ha), water use efficiency (34.86 kg/m^3), production efficiency (65.9 kg/ha/day), and economic efficiency (Rs724/ha/day) followed by jute-rice-garden pea recorded those parameter were (89.4 q/ha), 27.01 kg/m^3, 30.31 kg/ha/day and Rs.346/ha/day, respectively.The land use efficacy (94.5%) was higher in jute-rice-mustard- mungbean followed by jute-rice-baby corn-veg. jute(93.2%). The higher system productivity of all crop sequences was recorded with 100 % RDF with crop residue. However it was at par with 75% RDF with crop residue and100% RDF.

Keywords: *Crop residue, cropping system, energy, jute, RDF*

INTRODUCTION

The growing demands of food, feed and natural fibres are increasing with increasing population and can only be met by intensive cultivation of crops per unit area per unit time per unit resources. To achieve these targets, we have to think for more productive, more efficient and remunerative intensive cropping systems, which practice sustained use of natural resources (Meena *et al*., 2013) .But intensive cropping systems increases the use of inputs like fertilizers, water and energy (Singh *et al*., 2013). Rise in fertilizers price because of high price of fossil fuel which is required for production of fertilizers (especially N and P) is increasing day by day (Chaudhary *et al*., 2009 and Singh and Kumar, 2009). For crop production input energy in fertilizers operation shared higher than all other operation. Hence, we should think about other source of nutrients which substitute fully or partially for the nutrient requirement of crop and reduce the burden on inorganic fertilizers. Crop residues which are one of the sources of nutrient found to be beneficial to soil health crop productivity and nutrient use efficiency can be a alternative source of nutrients (Singh and Kumar, 2009). Pathak *et al*. (2010) estimated that about 90 Mt of crop residues are burnt on-farm and this figure is close to 85 Mt when the coefficients developed by the Inter-Governmental Panel on Climate Change (IPCC) are used. Jute (*Corchorus olitoris*) is grown as a cash crop in, 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; Kumar *et al*., 2014). But many largefarmers having irrigation facilities generally prefer to grow rice-rice-potato and rice-rice-mustard cropping systems. 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 nutrientsremoval 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*., 2006; Singh *et al*., 2011). Therefore, research needed to focus on multi-dimensional involving integrated nutrient management, land and water management, crop management to take advantage of complementarities among them for improving overall productivity, resourceor input use efficiency and livelihoods of farmers (Singh *et al*., 2014). Moreover, 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 cropping system should also be taken care. Realizing this, present study was undertaken to investigate the productivity and profitability and resource use efficiency of jute based cropping systems under different nutrient management strategies.

MATERIALS AND METHODS

A field experiment was conducted to study the effect of

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nutrient and crop residue incorporation on productivity jute based cropping system in split plot design during 2012-14. The main plot comprised of five cropping systems *viz.*, rice-rice (R-R), jute-rice-wheat(J-R-W), jute-rice-baby corn-leafy vegetable jute (J-R-Bc-Jv), jute-rice-garden pea (J-R-Gp), jute-rice-mustard-mungbean (J-R-M-Mu) and four nutrient management practices *viz.* 75% recommended doses of fertilizers (RDF) for each crop in a system with and without crop residue and 100 % RDF with and without crop residue with their respective cropping system in sub plot. Residue of rice, wheat and corn @ 3t/ha were incorporated in R-R, J-R-W and J-R-Bc-Jv cropping systems, respectively, and residue of garden pea and mungbean @ 2t/ha incorporated in J-R-Gp and J-R-M-Mu cropping system, respectively. Crop residues were incorporated through power tiller before sowing of jute in every year. The soil of experimental sites was clay loam with medium in organic carbon content (0.65-0.67 %), available N (256-275 kg/ha), and P (32-38 kg/ha) and high in K content (212-219 kg/ha) across the treatments.

All the crop were grown with recommended packages and practice (Table 1), however, mustard and mungbean was sown on zero tillage after rice and mustard, respectively in J-R-M-Mu cropping systems. Fertilizers were applied as per treatment with N applied in two split and P and K as basal in all crops except garden pea and mungbean where all N,P and K were applied as basal. Plant protection measures were taken as and when needed. System productivity was calculated in terms of jute equivalent yield (JEY) on the basis of prevailing minimum support price (MSP). 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 systems. Economic efficiency was calculated in term of (Rs/ha/day) from net return of the cropping system divided by total duration of crop in a cropping system. Water productivity was calculated in terms of irrigation water use efficiency (IWUE) *i.e.* kg dry weight grain produced/ unit (m^3) of water applied. 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 were converted from physical to energy unit measures through published conversion coefficients (Devasenapathy *et al.*, 2009). Energy input of different crop residues were calculated by multiply the energy equivalent of N, P_2O_5 and K_2O with amount of these nutrient added by crop residues 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 and net energy calculated by subtraction the input energy from output energy. 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. 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).

Table 1: Packages and practice followed for each crop in cropping system

Particulars	Jute	Wet rice	Boro rice	Wheat	Baby corn	Garden pea	Mustard	Mung bean	Jute (vegetable)
Land preparation	One rotavator	Puddling	Puddling	One rotavator	One rotavator	One rotavator	No tillage	No tillage	No tillage Relay with corn
Sowing/ transplanting time	15th April	12th August	24 Jan	25thnov	15thnov	25thNov	th Nov	5th Feb	7th Feb
Variety	JRO-204	Khitish	Khitish	PBW 343	G-5414	Azad P-3	B-54	Pant mung-5	JRO-8432
Crop duration (days)	110	120	140	130	90	100	85	70	50
Spacing	25 ×7 cm	20× 15 cm	20×15 cm	20 cm	50 ×15 cm	40×10 cm	35 ×5cm	35 ×10 cm	25 cm
Intercultural	Thinning and one Hand weeding	Mechanical weeding /hoeing	Mechanical weeding /hoeing	Mechanical weeding /hoeing	Mechanical weeding /hoeing	Mechanical weeding /hoeing	Hand weeding	Hand weeding	Hand weeding
Recommended Fertilizers (N: P2O5:K2O kg/ha)	80:40:40	80:40:40	120:60:40	120:60:40	100:60:40	25:60:40	60:30:30	20:60:40	30 kg N only
Harvesting and processing	5th Aug.	12th Nov	13thjune	5th April	15th Feb.	5th March	th Feb	10th April	28th March

RESULTS AND DISCUSSION

System productivity

The results showed the remarkable variation in system productivity of all cropping systems under different nutrient and crop residue practices (Table 2). Significantly higher system productivity (192.36q/ha) was recorded with J-R-Bc-Vj cropping systems compared to all others systems. J-R-Gp was the second best treatment with system productivity of 88.6 q/ha. This is mainly due to higher market price of baby corn and garden pea as these crops were grown and harvested as vegetables. J-R-M-Mu cropping system had four crops in this sequence recorded significantly lower system productivity (83.11 q/ha) than J-R-Gp and J-R-Bc-Vj. This might be due to low yield of mustard variety (B-54) which has crop duration (75 days) yielded less (5- 6 q/ha) and mungbean (Pant Mung-5) yielded 6- 8 q/ha as only one picking was done in mungbean. Nutrient and crop residue management practices did not influenced significantly the system productivity of any cropping system; however, maximum system productivity of all cropping systems was recorded with 100% RDF with crop residue incorporation. It means that 25% nutrient substituted from different crop residue did not affect the soil nutrient supply system thereby the productivity of crops in different cropping system recorded comparatively low. This result corroborated with was reported of many researchers that in early phase of residue incorporation yield of crops reduced due to initial immobilization of nutrients in soil (Dhiman *et al.*, 2000; Singh *et al.*, 2004a), however, in long term effect of residue improve soil health by enhancing soil organic carbon, microbial biomass (Singh, 2005; Beare *et al.* 2002) nutrients like P (Gupta *et al.*, 2007) and K (Singh *et al.*, 2004b). Karchoo and Dixit (2005) reported that incorporation of crop residue not only improved crop yield but also increased the nutrient uptakes besides improving the physicochemical properties of soil providing a better soil environment for growth and development. Singh *et al.* (2010) reported incorporation of crop residue along with RDF improve the crop productivity in potato-onion-rice and potato-wheat-rice cropping systems and was at par with 125% RDF.

Table 2: System productivity (q/ha) of different cropping system under nutrient and residue incorporation on (mean of two year)

Cropping system	75% RDF + No crop residue	75% RDF + with crop residue	100 % RDF + No crop residue	100 % RDF + with crop residue	Mean
Rice-rice	45.64	45.26	47.10	49.00	46.75
Jute-rice-wheat	65.86	66.84	67.21	69.48	67.35
Jute-rice-baby corn-jute (leafy vegetable)§	187.90	188.61	192.71	200.20	192.36
Jute-rice-garden pea	86.82	86.69	89.55	91.34	88.60
Jute-rice-mustard¥-mung§	81.78	82.81	82.27	85.57	83.11
SEm (±)	3.32				
LSD (P=0.05)	9.60				

¥: Mustard was sown in zero tillage: §crop was sown in relay with previous crop in sequence. # crop residue of rice, wheat and corn @ 3 t/ha and pea and mung @ 2t/ha incorporated in their respective cropping sequences

Energy input:

Maximum input energy (46.13 GJ/ha) required for J-R-Bc-Vj followed by J-R-W cropping systems (Table 3). Although, J-R-M-Mu having four crops in sequence required comparatively lower input energy for their cultivation only because mustard (M) and mungbean (Mu) crop was sown in zero tillage after

Table 3: Input energyand net energy (GJ/ha) of different cropping system under nutrientsand residue incorporation (mean of two year)

Cropping system	75% RDF +No crop residue		75% RDF + with crop residue		100 % RDF + No crop residue		100 % RDF + with crop residue	
	Input energy	Net energy	Input energy	Net energy	Input energy	Net energy	Input energy	Net enegy
Rice-rice	36.94	229.01	38.21 (1.27)	223.49	40.42	202.55	41.69 (1.27)	194.52
Jute-rice-wheat	44.81	292.19	46.32 (1.51)	283.84	49.64	269.21	51.15 (1.51)	276.41
Jute-rice-baby corn-jute (leafy egetable)§	46.13	312.97	48.33 (2.20)	299.58	51.42	314.19	53.62 (2.20)	314.31
Jute-rice-garden pea	37.76	246.92	40.62 (2.87)	248.42	41.37	236.80	44.24 (2.87)	236.58
Jute-rice-mustard¥-mung§	41.58	308.61	43.42 (3.22)	294.65	46.09	294.56	47.93 (3.22)	290.50

¥: Mustard was sown in zero tillage: §crop was sown in relay with previous crop in sequence. # crop residue of rice, wheat and corn @ 3 t/ha and pea and mung @ 2t/ha incorporated in their respective cropping sequences. Figure in parentheses is energy of crop residue rice and mustard, respectively, and this tillage operation required very less input energy (Chaudhary *et al.,* 2009). Among all cropping system the lowest input energy (37.76 GJ/ha) was required for J-R-Gp cropping system. Among the nutrient and crop residue management practices 75% RDF without crop residue recorded the lowest input energy this is mainly due to lower doses of fertilizers were applied in all crops , as fertilizers had higher energy equivalent lower doses recorded comparatively lower input energy. Maximum net energy was also recorded with J-R-Bc-Vj followed by J-R-M-Mu cropping system. Almost all cropping systems recorded higher net energy under 100% RDF without crop residue incorporation except J-R-Bc-Vj cropping system where higher net energy was obtained under 100% RDF with crop residue incorporation. It means that crop residue did not enhance the output of crops in cropping system as it has been discussed earlier also that crop residue had positive effect on yield and soil heath after a longer period of time at least five years of residue incorporation practices.

Resource use efficiency:

Resource use efficiency in term of land use efficiency (LUE), water use efficiency (WUE), energy use efficiency (EUE), production efficiency (PE) and economic efficiency (EE) were varied in different cropping systems under nutrient and crop residue management practices (Table 4). Comparatively higher production efficiency (66 kg/ha/day), economic efficiency (Rs. 724/ha/day) and water use efficiency (34.86 kg/m^3) were recorded with J-R-Bc-Vj cropping systems. While, higher energy use efficiency (7.66) was recorded with J-R-M-Mu cropping system followed by J-R-Bc-Vj with energy use efficiency of 7.13. This was because of less input energy was required in J-R-M-Mu cropping system as mentioned in earlier section. Land use efficiency (94.5 %) was also higher in J-R-M-Mu cropping system followed by J-R-Bc-Vj (93.2 %) as almost all year round lands was cover with crops under these cropping systems. Among nutrient and residue management practice, higher production efficacy, water use efficiency and economic efficiency was recorded with 100% RDF with crop residue incorporation, while higher energy use efficiency recorded with 75% RDF without crop residue incorporation practices.

Table 4: Resource use efficiency of different cropping systemunder nutrient and residue incorporation (mean of two year)

Treatments	Production efficiency (kg/ha/day)	Energy use efficiency	Economic efficiency (Rs/ha/day)	Water Use Efficiency (kg/m^3)	Land use efficiency (%)
Cropping sequences					
Rice-rice	19	6.43	119	6.73	68.5
Jute-rice-wheat	19	6.96	103	15.96	89.0
Jute-rice-baby corn-jute (leafy vegetable)[§]	66	7.13	724	34.86	93.2
Jute-rice-garden pea	30	6.93	346	27.01	80.0
Jute-rice-mustard[¥]-mung[§]	24	7.66	238	24.27	94.5
Nutrient and crop residue incorporation					
75% RDF + No crop residue	30.50	7.52	279.6	21.32	
75% RDF + with crop residue	31.75	7.20	298	21.43	
100 % RDF + No crop residue	31.85	6.78	321.4	21.92	
100 % RDF + with crop residue	32.02	6.60	324.8	22.34	

¥: Mustard was sown in zero tillage: §crop was sown in relay with previous crop in sequence. # crop residue of rice, wheat and corn @ 3 t/ha and pea and mung @ 2t/ha incorporated in their respective cropping sequences

Economics:

The higher cost of cultivation (Rs.104.8 ×10^3) was recorded under J-R-Gp followed by J-R-W (Rs.102.6 ×10^3) cropping system (Table 5). Comparatively higher cost of cultivation incurred when crop residue incorporated in soil due to extra cost involved in residue incorporation practice. Higher benefit cost ratio (3.09-3.51) was recorded with J-R-Bc-Vj followed by J-R-Gp (2.06-2.14)cropping system. The lowest benefit-cost ratio was recorded in R-R cropping system. Benefit cost ratio was higher under 100% RDF with crop residue in all cropping systems except R-R and J-R-W cropping systems.

Table 5: Cost of cultivation and benefit cost ratio different cropping system under nutrient and crop residue incorporation (mean of two year)

Cropping sequences	75% RDF +No crop residue		75% RDF + with crop residue		100 % RDF + No crop residue		100 % RDF + with crop residue	
	Cultivation cost (Rs×10^3)	B:C	Cultivation cost (Rs×10^3)	B:C	Cultivation cost (Rs×10^3)	B:C	Cultivation cost (Rs×10^3)	B:C
Rice-rice	70.3	1.29	72.8	1.48	71.7	1.5	74.2	1.38
Jute-rice-wheat	102.6	1.31	10.5	1.3	104.0	1.38	106.5	1.28
Jute-rice-baby corn-jute (leafy egetable)§	93.0	3.09	95.0	3.47	94.1	3.47	96.1	3.51
Jute-rice-garden pea	104.8	2.06	107.3	2.0	106.5	2.12	109.0	2.14
Jute-rice-mustard¥-mung§	95.2	1.76	97.2	1.89	96.6	1.78	98.6	1.94

¥: Mustard was sown in zero tillage: §crop was sown in relay with previous crop in sequence. # crop residue of rice, wheat and corn @ 3 t/ha and pea and mung @ 2t/ha incorporated in their respective cropping sequences

CONCLUSION

Hence, it may be concluded that among five cropping system under study, higher system productivity was in J-R-Bc-Vjcropping system followed by J-R-Gp. Higher water use efficiency, production efficiency and economic efficiency was also in J-R-Bc-Vj cropping system followed by J-R-Gp, while, higher energy use efficiencyand land use efficacy were in J-R-M-Mu followed by J-R-Bc-Vj cropping systems. Among nutrient management practices, hgher system productivity of all crop systems was recorded with 100 % RDF with crop residue incorporation. However, it was at par with 75% RDF with crop residue and100% RDF. This indicated that 25% nutrients may be saved by adding crop residue in different jute based cropping system besides crop residue has beneficial effect on soil quality in long run.

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