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Research Papers

Productivity and energetic of rice (*Oryza sativa*) based cropping systems under sub-tropical condition of Jammu

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ABSTRACT

A field experiment was conducted at Chatha, Jammu during 2006 to 2008 to find out energy-efficient rice based cropping system among different crop sequences. The best sequence crops performed in the system were mainly rice (*Oryza sativa.* L.) var. 'IET-1410', 'PC-19', garlic (*Allium sativum* L.) var. local, Cowpea (*Vigna unguicculatta* L.) var. 'Pusa Komal', potato (*Solanum tuberosum* L.) var. 'Kufri Badasah', onion (*Allium cepa* L.) var. 'N-53', marigold (*Tagetes erecta.* L) var. 'Pusa Narangi', Frenchbean (*Phaseolus vulgaris* L.) var. contender, maize (*Zea mays* L.) var. 'Kanchan', greengram (*Vigna radiata* L.) var. 'SML-818'. Out of ten crop sequences, rice-garlic-cowpea recorded the highest average rice equivalent yield (46.37 t/ha) with B:C ratio of 2.59 followed by rice-potato-onion (33.96 t/ha) and rice-marigold-frenchbean (29.31 t/ha). Rice-potato-maize+greengram required higher energy input (62,887 MJ/ha) and specific energy (2.59 MJ/kg), whereas energy output and average energy use efficiency was recorded the highest in existing rice-wheat system (2,66,188/MJ/ha) and rice-barseem for fodder-last cut for seed (11.46), respectively. However, average energy productivity was recorded highest in rice-garlic-cowpea (1.29 kg/MJ) followed by rice-marigold-frenchbean (0.83 kg/MJ).

Key words : Diversification, Energy Productivity, Energy Output, Energy Use Efficiency, Specific energy

Energy is the basic need of human life and main stay of our nation economy. India will need a total energy of two billion calories to feed its alarmingly increasing population of about 1,000 million for production of more than 200 million tonnes of food grain by 2000 A.D. (Mittal and Dhawan 1988). Solutions for the energy crises are slightly dependent on the technology of low energy used.

The era of cheap energy is now ending and the populace is becoming energy consumption conscious, due to rising cost of energy. The energy use in crop production has not been given adequate importance in earlier years, but the time has come, where more focus is to be given on renewable and non commercial source of energy, which are actively involved in crop production processes using intensive energies directly or indirectly. Agriculture in a way is an energy conversion industry. Through photosynthesis plant transform solar and chemical energy derived from the soil into storable chemical energy as carbohydrates, proteins, fats and all cellulose. Excessive use of energy results in high unit cost of production, loss of profitability and market competitiveness.

It is essential to convert energy rapidly to a common equivalent. The tonne of coal equivalent (t.c.e.) are such a unit and has been adopted by the United Nation (UN) bodies. Since the chemical composition of coal is not fixed quantity, it is necessary to assume representative figure (Devasenapathy et al. 2009). Inclusion of some crops in diversification would reduce the energy production as they are poor converters of it, therefore suitable cropping systems needs to be designed so that apart from higher productivity and profitability it must be efficient converter of energy. Hence, in the present investigation 10 rice based intensified crops were included to replace the higher input energy required conventional rice-wheat system under irrigated conditions.

MATERIALS AND METHODS

An experiment was conducted at farming systems research, centre, SKUAST-Jammu, Chatha under All India Coordinated Research Project on Integrated Farming Systems, during *kharif* 2006-07, 2007-08 and 2008-09 in randomized block design with 4 replications. The soil was clay loam having pH 8.1, organic carbon (0.55%) and available N, P and K of 216.2, 23.0 and 118.9 kg/ha, re-

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spectively. The experiment comprises of 10 different treatments of rice based cropping systems having varying crop duration. Rice varieties were sown under recommended package of practices under irrigated conditions. Fertilizer particularly N, P and K were supplied as per recommended dose of crops. Full dose of phosphorus and potassium and half dose of nitrogen was applied at the time of ploughing in all the crops. Half of the N was applied for each crop at appropriate stage. In rice and wheat at tillering and panicle initiation, in berseem at each cut, in marigold at 25 and 50 days after transplanting, in maize at knee-high and tesseling stages, in garlic at 45 DAS. In case of potato, remaining 50% recommended dose of N was applied at earthing, in corriander at flowering, in onion at initiation of bulb, in radish at the time of root formation, in cabbage at the time of head formation and in cowpea and lady's figure one month after sowing. The total rainfall of 1,313 and 1,127 mm received during 2006-07 and 2007-08, respectively. During *kharif* season, rice varieties of different durations 'IET-1410' (short duration), 'PC-19' (medium duration) and 'Jaya' (long duration) were transplanted after normal puddling in 3rd week of July, whereas during *rabi* season the crops mainly wheat (PBW-343), berseem' (Mescavi), garlic (Local), marigold (Pusa Narangi), pea (Arkel), corriander (Local) cabbage (Golden acre), potato (Kufri-sindhuri/Kufri badshah) and in summer, onion (N-53), radish (Pusa-chetki), cowpea (Pusa komal), Frenchbean (contender), lady's finger (Hissar unnat), hybrid maize (Kanchan) and greengram (SML-818) were sown in a sequence. Berseem under Jammu conditions is a five cut crop out of which four cuts of *rabi* sown berseem were utilized for fodder purpose and the fifth cut of the crop was allowed to grow for seed production, which extended up to summer season. Three cuts of corriander crops were used for vegetable/table purpose and instead of last cut the crop was allowed to grow for seed production, which extended up to summer season. The yield obtained from winter and summer crops were converted into rice equivalent yield by multiplying yield with prevailing price of produce and divided by price of rice in different years. Prevailing farm gate prices of produce were used to workout the economics of different systems.

Energy values of various input and outputs used in the experimentation are presented in Table 1 (Devasenapathy *et al.* 2009). The energy input for a particular cropping system was calculated as the summation of energy requirement for a human, diesel, seed, herbicide, FYM, and chemical fertilizers used in that system.

The energy use efficiency (EUE) and specfic energy (SE) were worked out as per Dazhong and Pimental (1984)

$$\text{EUE} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{SE} = \frac{\text{Total system input (MJ/ha)}}{\text{Rice equivalent yield (MJ/ha)}}$$

Energy output efficiency (MJ/ha/day) and Energy productivity were obtained by

$$\text{Energy output efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Duration of the System (Days)}}$$

Table 1. Energy values of various inputs and outputs used in system based crop diversification

Particulars	Units	Equivalent energy (MJ)
Inputs		
Human labour	Man-hour	1.96
Diesel	Litre	56.31
Elerctric motor [Distribute the weight of the machinery equally over total life span of the machinery (in hours)]	kg	64.80
Chemical Fertilizers		
N	kg	60.60
P_2O_5	kg	11.1
K_2O	kg	6.7
*Farm Yard manure	kg	0.3
Chemicals		
(i) Superior Chemicals (chemicals requiring dilution at the time of application)	kg	120
(ii) Inferior chemicals (chemicals not requiring dilution at the time of application	kg	10
Seed	kg	14.7
Out put		
Rice grain	kg	14.7
Wheat grain	kg	14.7
Rice straw	kg	12.5
Wheat straw	kg	12.5
*Barseem	kg	18.0
Potato	kg	3.60
Onion	kg	1.60
Methi	kg	0.8
Raddish	kg	1.6
Garlic	kg	1.6
Cowpea	kg	1.9
Marigold	kg	0.5
French bean	kg	1.9
Pea	kg	14.7
Bhindi	kg	1.9
Coriander	kg	0.8
Cabbage	kg	0.8
Maize cobs	kg	14.7
Greengram	kg	14.7

*Dry weight basis
Source: Devasenapathy *et al.* (2009)

$$\text{Energy productivity} = \frac{\text{Rice Equivalent Yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

RESULTS AND DISCUSSION

Energy input

Energy requirement for rice based cropping system was computed for individual years and pooled over years (Table-2). The total input energy required in different cropping systems were in order of rice-potato- maize +greengram (65,472 MJ/ha) followed by rice-potato-onion (62,887 MJ/ha), rice-cabbage-onion (40,836MJ/ha) and rice-garlic-cowpea (35,833 MJ/ha), where as in case of existing rice-wheat system, total input energy required was estimated to be 24,455 MJ/ha. Among the various inputs, chemically provided highest energy varied from 61 % in rice-marigold-frenchbean system to 31% in rice-potato-onion. The highest energy in terms of human labour were found in rice-methi-raddish (6,648 MJ/ha) owing to three to four repetitive cuts and manual threshing of methi for seed. While the existing rice-wheat system required total input energy of 24,435 MJ/ha with highest of total input energy through fertilizer (61%), human labour (14.75%), diesel (11.05%) and seed (8.41%) respectively, which might be due to the higher fertilizer requirement of existing system. In case of total input energy used, highest was found in rice-potato- maize+greengram followed by rice-potato-onion, rice-cabbage-onion and rice-garlic-cowpea, which was 1.68, 1.57, 0.67 and 0.47 times higher, over existing rice-wheat cropping system, there by indicated the efficient utilization of space concept in these systems. Same findings were reported by Channabasavanna et al. (2007).

Productivity

Rice equivalent yield (REY) of different rice based cropping systems (table 3) indicated that during 2006-07 and 2008-09, among the various cropping systems, rice-garlic-cowpea recorded the highest REY of 79.8 t/ha and 38.3 t/ha, respectively and occupy the land for 317 days in a year, followed by rice-potato-onion (REY 39.7 t/ha during 2006-07 and 32.7 t/ha during 2008-09 with an average crop duration of 293 days. Whereas during 2007-08, rice-marigold-frenchbean recorded the highest REY of 30.1 t/ha with an average crop duration of 309 days followed by rice-potato-onion (29.5 t/ha) and rice-cabbage-onion (24.2 t/ha), which is mainly owing to avoiding fallow in high intensity cropping system during summer, while pooled data on different rice-based cropping sequences indicated that rice-garlic-cowpea recorded the highest rice equivalent yield (46.4 t/ha) with B:C ratio of 2.59 followed by rice-potato-onion (33.9 t/ha) and rice-marigold-french bean (29.3 t/ha). However, the lowest REY of (11.1 t/ha) was obtained from rice-wheat with B:C ratio of 1.77 followed by rice-corriander (11.7 t/ha) and rice-berseem for fodder-berseem for seed (11.8 t/ha). Rice-garlic-cowpea sequence recorded REY of 21.0 t/ha because of low farm gate price of garlic during the year 2007-08. Similar results were recorded by Thakur et al. (2009)

Energy output

Existing rice-wheat system recorded higher energy output (2,66,188 MJ/ha) during three crop cycles (table 3), which was followed by rice-potato-maize+greengram (2,47,775 MJ/ha) and rice-potato-onion (2,21,302MJ/ha), whereas rice-garlic-cowpea and rice-marigold-frenchbean realized the lowest energy out put of 1,56,875 and 1,38,708 MJ/ha, respectively than existing rice-wheat cropping sequence, but REY observed was higher by 316% in rice-garlic-cowpea and 164% in rice-marigold-frenchbean, respectively over the existing system. These results are in agreement with those of Kumar et al. (2005).

However, lowest energy balance was recorded in rice-

Table 2. Pattern of energy values (x10^{3}MJ/ha) in various inputs in system based crop diversification treatments

Treatment	Human Labour	Diesel	Seed	Herbicides	Irrigation	Farm yard manure	Chemical fertilizer	Total input MJ
Rice-Wheat	3.6	2.7	2.1	0.3	0.2	0.6	14.9	24.4
Rice-Berseem-Seed	3.9	2.7	1.0	0.3	0.2	0.9	7.1	16.1
Rice Potato-Onion	6.3	4.7	30.1	0.5	0.2	1.8	19.2	62.8
Rice-Methi-Radish	6.6	4.7	0.8	0.4	0.3	0.9	16.4	30.1
Rice-Garlic-Cowpea	6.4	4.4	9.0	0.3	0.2	1.1	14.5	35.3
Rice-Marigold-F. Bean	5.3	4.4	1.9	0.7	0.2	1.2	21.6	35.3
Rice-Pea-Bhindi	5.3	4.7	1.2	0.7	0.3	1.2	16.3	29.9
Rice-Corriander-Seed	5.6	2.7	1.0	0.3	0.2	0.9	8.0	18.7
Rice-Cabbage-Onion	6.2	4.1	9.6	0.5	0.2	1.5	18.8	40.9
Rice-Potato-Maize+Greengram	5.5	4.4	30.3	0.5	0.2	1.4	23.2	65.5

Table 3. Rice equivalent yield and energy pattern under various rice based diversification treatments

Treatment	REY (t/ha)				B:C	Duration (days)				Energy output (×10³MJ/ha)				Energy Balance (×10³MJ/ha)			
	2006-07	2007-08	2008-09	mean	ratio	2006-07	2007-08	2008-09	mean	2006-07	2007-08	2008-09	mean	2006-07	2007-08	2008-09	Mean
Rice-Wheat	11.3	12.6	9.5	11.1	1.77	256	257	266	260	246.4	293.1	259.1	266.2	221.9	268.7	234.6	241.7
Rice-Berseem-Seed	10.4	12.5	12.4	11.8	1.82	279	288	319	295	135.0	179.3	236.6	183.6	119.0	163.3	220.6	167.6
Rice Potato-Onion	39.7	29.5	32.7	34.0	1.42	283	291	305	293	221.6	205.3	237.1	221.3	158.7	142.4	174.2	158.4
Rice-Methi-Radish	20.7	21.1	21.1	21.0	1.67	307	334	337	326	118.2	146.0	262.0	175.4	88.1	115.9	231.9	145.3
Rice-Garlic-Cowpea	79.8	21.0	38.3	46.4	2.59	319	284	348	317	150.1	155.4	165.1	156.9	114.3	119.6	129.2	121.0
Rice-Marigold-F. Bean	30.7	30.1	27.1	29.3	1.57	311	307	309	309	107.3	148.5	160.4	138.7	72.0	113.1	125.1	103.4
Rice-Pea-Bhindi	14.8	13.3	17.0	15.1	0.77	312	338	349	333	158.0	194.2	206205	186.1	128.3	164.6	176.5	156.5
Rice-Corriander-Seed	11.7	9.4	13.9	11.7	1.67	262	272	284	272	100.1	112.3	152.8	121.7	81.4	93.6	134.1	103.0
Rice-Cabbage-Onion	33.7	24.2	22.9	26.9	1.46	267	308	297	291	151.0	144.3	171.5	155.6	110.2	103.4	130.4	114.8
Rice-Potato-Maize+Greengram	33.2	22.3	22.9	26.1	1.13	283	291	318	297	196.1	286.2	261.0	247.7	130.7	220.7	195.5	182.3

Table 4. Energy Use Efficiency (EUE) and energy productivity of rice based diversified treatments during three years.

Treatment	EUE				Specific Energy (MJ/kg)				Energy output efficiency (×10³ MJ/ha/day)				Energy Productivity(kg/MJ)			
	2006-07	2007-08	2008-09	mean	2006-07	2007-08	2008-09	mean	2006-07	2007-08	2008-09	mean	2006-07	2007-08	2008-09	mean
Rice-Wheat	10.07	11.99	10.59	10.88	2.16	1.94	2.59	2.23	0.96	1.14	0.97	1.02	0.46	0.52	0.39	0.45
Rice-Berseem-Seed	8.42	11.19	14.76	11.46	1.54	1.28	1.29	1.37	0.48	0.64	0.84	0.66	0.65	0.78	0.77	0.73
Rice Potato-Onion	3.52	3.26	3.77	3.52	1.58	2.13	1.92	1.88	0.78	0.71	0.78	0.75	0.63	0.47	0.52	0.54
Rice-Methi-Radish	3.92	4.84	8.69	5.82	1.45	1.43	1.43	1.44	0.39	0.44	0.78	0.53	0.69	0.70	0.70	0.70
Rice-Garlic-Cowpea	4.19	4.34	4.61	4.38	0.45	1.71	0.94	1.03	0.47	0.55	0.47	0.49	2.23	0.59	1.07	1.29
Rice-Marigold-F. Bean	2.96	4.12	4.46	3.85	1.15	1.17	1.30	1.21	0.34	0.47	0.51	0.44	0.87	0.85	0.77	0.83
Rice-Pea-Bhindi	5.33	6.56	6.96	6.28	2.00	2.22	1.74	1.99	0.51	0.57	0.59	0.55	0.50	0.45	0.57	0.51
Rice-Corriander-Seed	5.35	6.00	8.17	6.51	1.59	2.00	1.34	1.65	0.38	0.41	0.54	0.44	0.63	0.50	0.74	0.62
Rice-Cabbage-Onion	3.70	3.53	4.20	3.81	1.21	1.69	1.78	1.56	0.57	0.47	0.58	0.54	0.82	0.59	0.56	0.66
Rice-Potato-Maize+Greengram	3.00	4.37	3.99	3.78	1.97	2.94	2.86	2.59	0.69	0.98	0.82	0.83	0.51	0.34	0.35	0.40

coriander for vegetable and last cut extended for seed production (1,03,014 MJ/ha) and the highest was recorded in existing rice-wheat cropping system (2,41,733 MJ/ha). Rice-berseem for fodder and last cut extended for seed purpose recorded higher energy use efficiency (11.46 %) (Table 5), which was owing to realization of more herbage yield used as fodder (3 cuts) and last cut was restricted and was allowed to grow for seed purposes. Minimum energy use efficiency was realized in rice-potato-onion (3.52 %), which was due to high input energy requirement and comparatively low out put energy (Kumar *et al.* 2005).

Specific Energy, Energy output efficiency and Energy Productivity

Rice-potato-maize+greengram recorded the highest specific energy (2.59 MJ/kg) followed by conventional rice-wheat system (2.23 MJ/kg) (Table 4). This indicated these systems require higher inputs to produce a unit of produce (Channabasavanna *et al.* 2007), recorded the similar results. Rice-garlic-cowpea, consumed very low input to produce a unit of produce (0.45 MJ/kg and 0.94 MJ/kg during 2006-07 and 2008-09, respectively) than the existing rice wheat system, which recorded 2.23 MJ/kg of specific energy. The highest average value of energy output efficiency was recorded highest in rice-wheat system (1,025 MJ/ha/day). Similar results were recorded by Nanda *et al.* (2008). However, energy productivity was recorded highest in rice-garlic-cowpea (1.29 kg/MJ), followed by rice- marigold-french bean (0.83. kg/MJ), which might be due to higher REY values in these systems. This confirmed the findings of Nanda *et al.* (2008). Energy productivity was found lowest in rice-potato-maize+greengram (0.40 kg/MJ) mainly because of higher input energy used (65,472 MJ). Among the different cropping system adopted, rice-garlic-cowpea resulted the highest B:C ratio of 2.59 followed by rice-berseem (1.82) and rice-wheat (1.77).

Therefore, it is concluded that existing less energy productive rice-wheat cropping can be diversified with the highest energy productive crops mainly rice-garlic-cowpea, rice-marigold-frenchbean and rice-potato-onion, which can also realize the maximum profit per unit of land under subtropical condition of Jammu.

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