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Effect of Rice based Ultra High Intensity Cropping System Models on Energetics under Irrigated Sub-Tropics of Jammu

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ABSTRACT: To feed the world's growing population, more food needs to be produced either by expanding the net area under cultivation or intensifying cropping over the existing area. The use and cost of energy in agriculture have increased, making it necessary to make current agricultural practices more energy efficient. The present experiment was conducted at Research Farm, Faculty of Agriculture, SKUAST-Jammu, Main Campus, Chatha during *kharif* 2019 to summer season of 2020, to study the effect of rice based ultra high intensity cropping system models on energetics. The soil of the experimental site sandy loam in texture, slightly alkaline in reaction, but medium in organic carbon, available nitrogen, phosphorus and potassium with electrical conductivity in the safer range. The experiment comprised of five rice based cropping systems of cropping intensity varying from 300-600% *viz.* Rice (Basmati-370) – Wheat (HD-3086) – Cowpea (Lobia Super-60) having 300% cropping intensity, Rice (Basmati-564) – Potato (Kufri Badshah) – Wheat (Raj-3765) – Mixed fodder (Maize+Cowpea+Charri) having 400% cropping intensity, Rice (SJR-129) – Knolkhol (G-40) – Potato (Kufri Sindhuri) – Green gram (IPM-02-3) having 400% cropping intensity, Rice (Pusa-1121)– Radish (CR-45) – Green onion (Nasik Red) – French bean (Anupama) – Okra (Seli special) having 500% cropping intensity in relay cropping from French bean crop onwards) and Rice (IET-1410) – Fenugreek (JF-07) – Knolkhol (G-40) – Green onion (Nasik Red) – Dry onion (Selection-1) – Black gram (Pant U-19) having 600% cropping intensity in relay cropping from Knolkhol crop onwards. The experiment was conducted in randomized block design with four replications. Results revealed that the highest system energy input of 8.43 MJ ha^{-1} × 10^{4} was worked out on the basis of energy incurred for the inputs utilized in production of crops in cropping system T_4followed by system energy input of 7.10 MJ ha^{-1} × 10^{4}, 6.31 MJ ha^{-1} × 10^{4} and 6.17MJ ha^{-1} × 10^{4} with cropping systems T_3, T_5 and T_2, respectively whereas the lowest system energy input of 2.30 MJ ha^{-1} × 10^{4} was recorded in treatment T_1. Significantly highest system energy output was recorded under treatment T_4while treatment T_1recorded significantly lowest system energy output. Significantly highest system net energy returns (28.09MJ ha^{-1} × 10^{4}) was recorded under treatment T_4 while significantly lowest system net energy returns of 11.52MJ ha^{-1} × 10^{4} was recorded with treatment T_1. Significantly highest system energy efficiency, energy productivity and energy intensity were recorded with treatment T_1.

Keywords: Cropping systems, System energy output, System net energy returns, System energy productivity and Ultra high intensity.

INTRODUCTION

Global food demand is increasing as the world's population is increasing rapidly and will reach upto 9.6 billion by 2050 (Tripathi *et al.,* 2019). To feed the world's growing population, more food needs to be produced either by expanding the net area under cultivation or intensifying cropping over the existing area. In view of the limited scope for horizontal expansion to augment food production, the alternative is to concentrate on vertical growth by increasing the productivity of the available land area. An intensive cropping system should not only be highly productive and profitable but should also be stable over time. So, intensification of crops has been envisaged as a new strategy for enhancing and stabilizing productivity. Cereal based cropping systems, *viz.* rice-wheat and rice-rice are the major contributors to national food grain basket in India. Rice-wheat cropping system is being practiced in 13.50 million hectare across the Indo-Gangetic Plains of South Asia, contributing more than 30% and 40% to the total rice and wheat area, respectively (Gathala *et al*., 2011). Rice-wheat cropping system has been recognized as one of the most widely accepted cropping systems of the sub-tropical irrigated belt of the Union territory of Jammu and Kashmir. Since rice and wheat crops are the most promising crops of the irrigated sub-tropics of the UT of Jammu and Kashmir and it is not wise to sacrifice both of these crops in the intent to intensify the cropping systems and this cropping system is not energy efficient because it requires more energy. Therefore, it is pertinent that either of these two crops must be a part of the cropping systems which were considered for study to identify the highly intensive cropping systems involving other crops. The identification of short duration, high yielding cultivars of vegetable, pulse and fodder crops which fits well with different duration of rice types in different rice based cropping system models may help to realize more returns with maximum input use efficiency. Energy is one of the most valuable inputs in production oriented agriculture and mainstay of our nation's economy. Alarming increase in population of our country needs nine billion joules of total energy for producing more than 250 million tonnes of food grain. In crop production large share of energy is used for land preparation (20-25%), fertilizers (25-30%) and irrigation (25-35%), which require commercial non-renewable sources of energy like petroleum products (Shilpha *et al*., 2018). The non-renewable energy is expensive and liable to exhaust in near future and in the present agriculture, the steady decline in energy-use efficiency is a matter of great concern. Therefore, it is essential to rationalize use of energy through identification of suitable energy efficient cropping systems to overcome the looming energy crises.

MATERIALS AND METHODS

The experiment was conducted at Research Farm, Faculty of Agriculture, SKUAST-Jammu, Main Campus, Chatha during *kharif* 2019 to summer season of 2020. The soil of the experimental site sandy loam in texture, slightly alkaline in reaction, but medium in organic carbon, available nitrogen, phosphorus and potassium with electrical conductivity in the safer range. The experiment comprised of five rice based cropping systems of cropping intensity varying from 300-600% *viz.* Rice (Basmati-370) – Wheat (HD-3086) – Cowpea (Lobia Super-60) having 300% cropping intensity, Rice (Basmati-564) – Potato (Kufri Badshah) – Wheat (Raj-3765) – Mixed fodder (Maize+Cowpea+Charri) having 400% cropping intensity, Rice (SJR-129) – Knolkhol (G-40) – Potato (Kufri Sindhuri) – Green gram (IPM-02-3) having 400% cropping intensity, Rice (Pusa-1121)– Radish (CR-45) – Green onion (Nasik Red) – French bean (Anupama) – Okra (Seli special) having 500% cropping intensity in relay cropping from fourth crop onwards) and Rice (IET-1410) – Fenugreek (JF-07) – Knolkhol (G-40) – Green onion (Nasik Red) – Dry onion (Selection-1) – Black gram (Pant U-19) having 600% cropping intensity in relay cropping from third crop onwards. The experiment was conducted in randomized block design with four replications. All the crops under different rice based ultra high intensity cropping systems were raised as per package of practices recommended for different crops under irrigated sub-tropics of Jammu. The application of the fertilizers and manures to crops raised under different cropping systems were as per their respective recommended package of cultivation except for the nutrient requirement of crops in the systems which were met both through organic and inorganic sources as per INM recommendations i.e. of the total requirement of nitrogen, 25% was supplemented through farm yard manure on dry weight basis (ready to use) and 75% through inorganic sources, excluding pulse and vegetable crops. Among inorganic fertilizer sources, N, P and K were applied through urea, diammonium phosphate and muriate of potash, respectively. To calculate the system energy input, all inputs in the form of human labour, diesel, seed, water, organic manure, chemical fertilizer, herbicide, etc. used in different cropping systems were taken into consideration with the use of energy conversion factors and system energy input was expressed in MJ ha^{-1}. System energy output was calculated by the product of basmati-370 rice equivalent yield of the system with the energy equivalent of basmati-370 rice and was expressed in MJ ha^{-1}. The yield of different crops were converted into basmati-370 rice equivalent yield based on the prevailing market price of different crops. Basmati-370 rice equivalent yield was calculated by using the following formula.

$$\text{Basmati-370 rice equivalent yield (kg ha}^{-1}\text{)} = \text{Economic yield of crop (kg ha}^{-1}\text{)} \times \frac{\text{Price of crops whose yield has to be converted (Rs. kg}^{-1}\text{)}}{\text{Price of basmati-370 rice (Rs. kg}^{-1}\text{)}}$$

Basmati-370 rice equivalent system productivity was obtained by adding basmati rice-370 equivalent yields of different crops taken in cropping system and was expressed in kg ha^{-1}. The ratio of system energy output to system energy input was calculated to obtain system energy efficiency. System energy efficiency was calculated by subtracting system input energy from system output energy. System energy productivity was the ratio of basmati-370 rice equivalent yield of the system to system energy input and was expressed in kg MJ^{-1}. System energy intensity (MJ $Rs.^{-1}$) was determined as dividing system energy output by system cost of cultivation.

RESULTS AND DISCUSSION

A. System energy input

Data with respect to system energy input presented in Table 1 shows that the highest system energy input of 8.43 MJ ha^{-1} × 10^4 was worked out on the basis of energy incurred for the inputs utilized in production of crops in cropping system T_4 and it was followed by system energy input of 7.10 MJ ha^{-1} × 10^4, 6.31 MJ ha^{-1} × 10^4 and 6.17MJ ha^{-1} × 10^4 with cropping systems T_3, T_5 and T_2, respectively. The highest system energy input might be attributed to the utilization of more energy-rich inputs such as seed, fertilizer, irrigation, herbicides and labour requirement for the cultivation of radish, green onion, french bean, okra, potato, knolkhol, fenugreek and mixed fodder crops in these cropping systems. However, the lowest system energy input of 2.30 MJ ha^{-1} × 10^4 was recorded in treatment T_1. Sharma *et al.* (2014) reported that rice-potato + radish-onion + maize relay cropping system utilized higher energy inputs.

B. System energy output

Data on system energy output graphically presented in Table 1 and Fig. 1 shows that significantly highest system energy output of 36.52MJ ha^{-1} × 10^4 was recorded under treatment T_4 which was followed by treatments T_3, T_5 and T_2 with corresponding values of system energy output of 30.35MJ ha^{-1} × 10^4, 28.56MJ ha^{-1} × 10^4 and 24.66MJ ha^{-1} × 10^4, respectively. Further, the treatment $T_3$was found statistically at par with cropping system T_5 whereas treatment T_1 recorded significantly lowest system energy output of 13.82MJ ha^{-1} × 10^4. The treatment T_4 recorded significantly highest system energy output might be owing to the higher production potential of vegetable crops like french bean, green onion, radish and okra in this cropping system which proved effective in producing more basmati-370 rice equivalent yield energy output by increasing total production of the cropping system. These results were in conformity with the findings of Sharma *et al.* (2008) and Kachroo *et al.* (2012).

C. System energy efficiency

Data concerning system energy efficiency (Table 1) shows that significantly highest system energy efficiency (6.02) was recorded in treatment T_1 while significantly lowest system energy efficiency (4.00) was recorded with treatment T_2 which was found statistically at par with treatments T_3 (4.27), T_4 (4.33) and T_5 (4.53). The cropping system T_1 recorded significantly highest system energy use efficiency might be attributed to the reason that this cropping system maintained its superiority in energy output-input ratio in comparison to other cropping systems. However, significantly lowest system energy use efficiency recorded in treatment T_2 indicating that this system was inefficient with respect of energy produced per unit energy use. These results were in line with the findings of Saha and Ghosh (2010).

D. System net energy returns

A perusal of data with respect to system net energy returns shown in Table 1 and graphically depicted in Fig. 1 indicates that significantly highest system net energy returns (28.09MJ ha^{-1} × 10^4) was recorded in treatment T_4 while significantly lowest system net energy returns of 11.52MJ ha^{-1} × 10^4 was recorded with treatment T_1. The treatment T_4 was followed by cropping systems T_3, T_5 and T_2 with system net energy returns of 23.25MJ ha^{-1} × 10^4, 22.25MJ ha^{-1} × 10^4 and 18.49MJ ha^{-1} × 10^4, respectively. Significantly highest system net energy returns registered in treatment T_4 might be due to highly productive vegetable crops (such as radish, green onion, french bean and okra) brought about high energy output associated with this system.

E. System energy productivity

Data regarding system energy productivity (Table 1 and Fig. 2) shows that treatment T_1 registered significantly highest system energy productivity of 0.41 kg MJ^{-1} whereas significantly lowest system energy productivity of 0.27 kg MJ^{-1} was registered with treatment T_2 which was found statistically at par with cropping system T_3 (0.29 kg MJ^{-1}), T_4 (0.29 kg MJ^{-1}) and T_5 (0.31 kg MJ^{-1}). The cropping system T_1 was followed by treatment T_5 which was found statistically at par with treatment T_4 with the same system energy productivity value of 0.30 kg MJ^{-1}. Treatment T_1 recorded highest system energy productivity might be due to lesser energy inputs utilized for the cultivation of crops. The lowest system energy productivity recorded in treatment T_2 might be due to low basmati-370 rice equivalent system productivity and low energy input used in the system. Similar results were observed by Ray *et al.* (2009) and Singh *et al.* (2017).

F. System energy intensity

Data with respect to system energy intensity given in Table 1 and Fig. 2 reveals that significantly highest system energy intensity (1.14MJ $Rs.^{-1}$) was registered in treatment T_1 whereas significantly lowest system energy intensity of 0.70MJ $Rs.^{-1}$ was recorded in treatment T_4 which was found statistically at par with treatments T_5, T_3 and T_2 with system energy intensity of 0.77 MJ $Rs.^{-1}$, 0.79 MJ $Rs.^{-1}$ and 0.81MJ $Rs.^{-1}$, respectively.

Table 1: System energetics under rice based ultra high intensity cropping system models.

Treatments	System energy input (MJ ha^{-1} × 10^4)	System energy output (MJ ha^{-1} × 10^4)	System energy efficiency	System net energy returns (MJ ha^{-1} × 10^4)	System energy productivity (kg MJ^{-1})	System energy intensity (MJ $Rs.^{-1}$)
T_1: Rice (B-370) – Wheat (HD-3086) – Cowpea (Lobia Super-60)	2.30	13.82	6.02	11.52	0.41	1.14
T_2: Rice (B-564) – Potato (KufriBadshah) – Wheat (Raj-3765) – Mixed fodder (Maize+Cowpea+Charri)	6.17	24.66	4.00	18.49	0.27	0.81
T_3: Rice (SJR-129) – Knolkhol (G-40) – Potato (KufriSindhuri) – Green gram (IPM-02-3)	7.10	30.35	4.27	23.25	0.29	0.79
T_4: Rice (Pusa-1121) – Radish (CR-45) – Green onion (Nasik Red) –French bean (Anupama) – Okra (Seli special)	8.43	36.52	4.33	28.09	0.29	0.70
T_5: Rice (IET-1410) – Fenugreek (JF-07) – Knolkhol (G-40) – Green onion (Nasik Red) – Dry onion (Selection-1) – Black gram (Pant U-19)	6.31	28.56	4.53	22.25	0.31	0.77
SEm (±)	-	1.25	0.27	0.94	0.02	0.04
CD (5%)	-	3.85	0.83	2.91	0.07	0.12

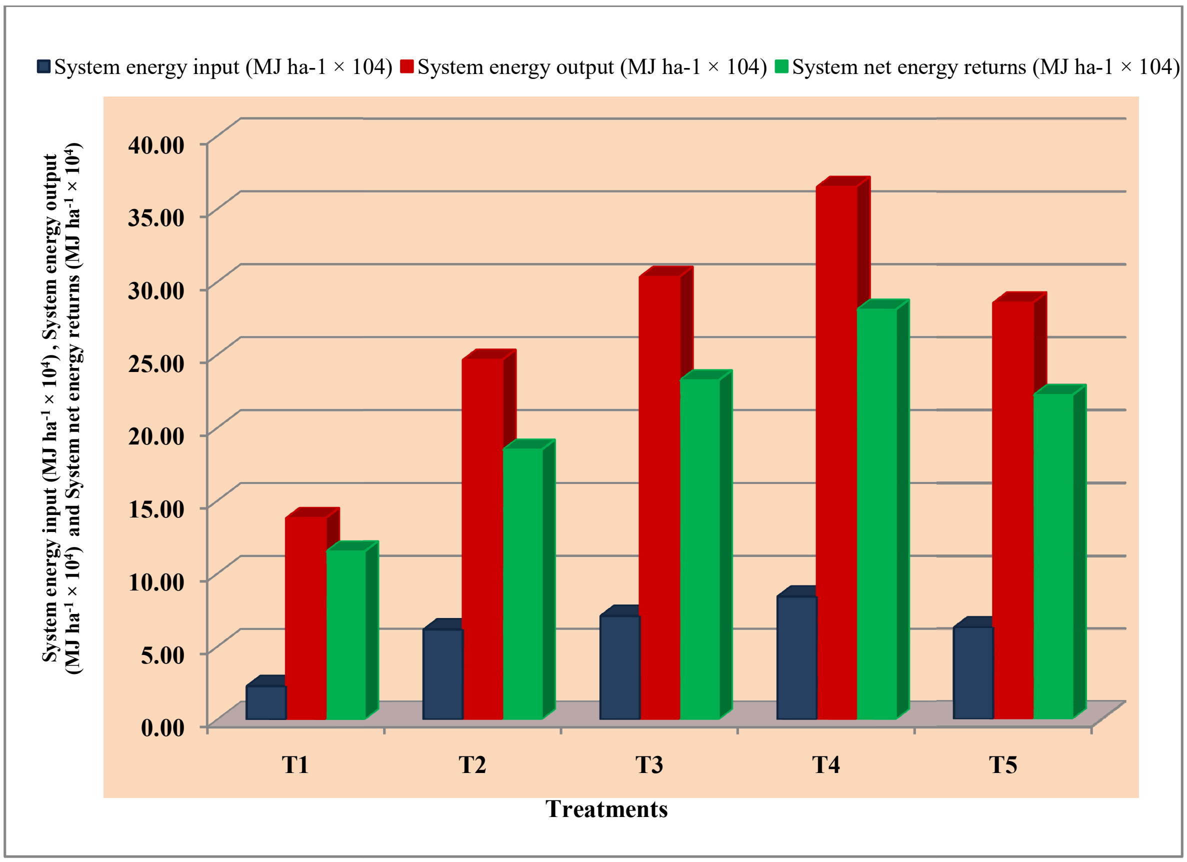

Fig. 1. Effect of rice based ultra high intensity cropping system models on system energy input (MJ ha^{-1} × 10^4), system energy output (MJ ha^{-1} × 10^4) and system net energy returns (MJ ha^{-1} × 10^4).

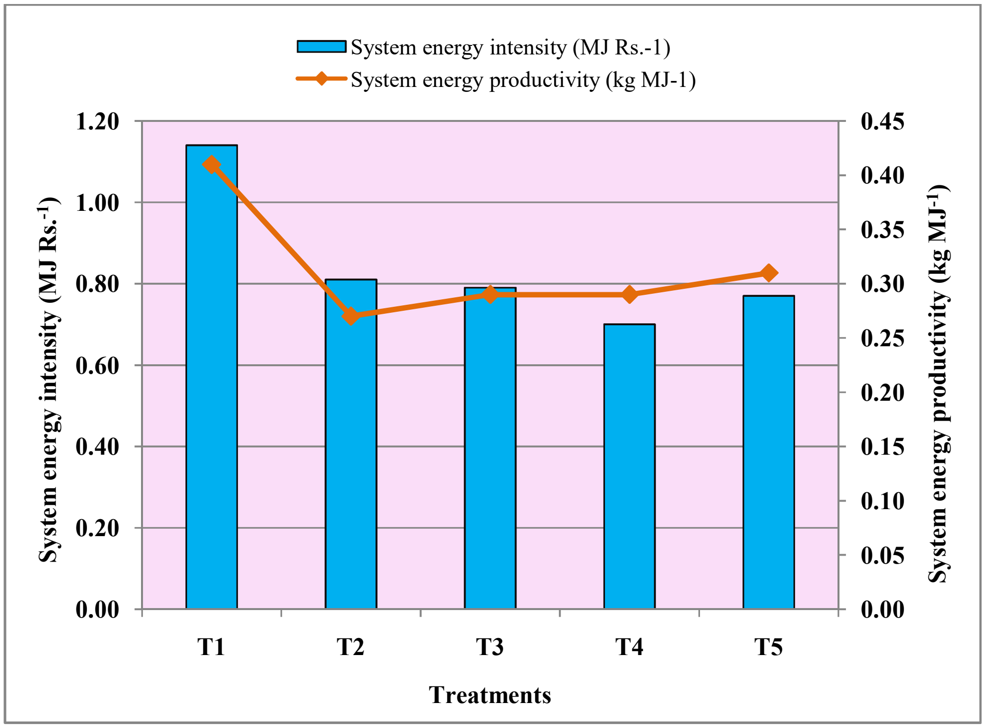

Fig. 2. Effect of rice based ultra high intensity cropping system models on system energy productivity (kg MJ^{-1}) and system energy intensity (MJ $Rs.^{-1}$).

The cropping system T_1 recorded significantly highest system energy intensity as compared to other cropping systems might be owing to the lower cost of cultivation of this system. These results corroborated with the findings of Mishra *et al.* (2013) and Sinha (2021).

CONCLUSION

Based on results obtained from one year study, it can be concluded that cropping system Rice (Pusa-1121) – Radish (CR-45) – Green onion (Nasik Red) – French bean (Anupama) – Okra (Seli special) having 500% cropping intensity recorded highest system energy input and significantly highest system energy output and system net energy returns, however, cropping system T_1 recorded significantly highest system energy efficiency, system energy productivity and system energy intensity.

FUTURE SCOPE

The present investigation must be continued at least for 3 to 4 years which may provide valuable information on energy indices under different rice based ultra high intensity cropping system models.

Conflict of interest. Authors have declared that no competing interests exist.

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