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Intensification and establishment techniques of rice-wheat system and influence on energy dynamics under irrigated condition

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Abstract
The field experiments were conducted during 2015-16 and 2016-17 at Norman E. Borlaug Crop Research Center, Pantnagar G.B Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar (Uttarakhand) India, to study crop intensification and establishment techniques to enhance productivity under irrigated rice- wheat system**.** Total input energy (55964 MJ/ha) and total output energy (1381739 and 1179456 MJ/ha), net energy (1326075 and 1123791 MJ/ha) and energy use efficiency (24.82 MJ/ha and 22.47 MJ/ha) during 2015-16 and 2016-17, respectively were estimated to be the highest with treatment T_9.The treatment T_1 [Rice (TPR) – Wheat] recorded the highest energy intensiveness (0.664 and 0.651 MJ/Rs.) while the lowest value was recorded in T_2 (0.424 and 0.416 MJ/Rs.) during 2015-16 and 2016-17, respectively. The highest specific energy was recorded in rice-wheat rotation (4095 MJ/ha and 4388 MJ/ha) whereas, the lowest was in T5 (1725 and 1759 MJ/ha) during both the years, respectively. The maximum energy productivity was recorded in T_5 (0.596 and 0.585 kg/MJ) during 2015-16 and 2016-17, respectively however it was at par with T4 during 2016-17. On the basis of two year experimentation it may be concluded among different intensification options, rice (DSR)-potato-cowpea was found to be the best in terms of overall system productivity.

Keywords: intensification, land configurations, rice-wheat and energy dynamics

Introduction
The rice-wheat is the principal cropping system in south Asian countries that occupies about 13.5 million hectares in the Indo-Gangetic Plains (IGP), of which 10 million hectares are in India. This cropping system is dominant in most Indian states, such as Punjab, Haryana, Bihar, Uttarakhand, Uttar Pradesh and Madhya Pradesh, and which contributes to 75% of the national food grain production (Gupta and Seth, 2007) [10]. Rice wheat cropping system is highly nutrient exhaustive and therefore, its continuous use has depleted inherent soil fertility, causing deficiency of several nutrients (Zia *et al.*, 1997) [17].

Crop intensification through other crops diversification of rice-based system to increase productivity per unit resource is very pertinent. Crop diversification shows lot of promises in alleviating these problems besides, fulfilling basic needs for cereals, pulses, oilseeds and vegetables and, regulating farm income, withstanding weather aberrations, controlling price fluctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity (Gill and Ahlawat, 2006) [7].

Crop intensification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops (Naresh *et al.*, 2012) [13]. The crop intensification has the main goal of increasing agricultural productivity in high-potential food crops and ensuring food security and self-sufficiency. Low productivity in an irrigated area is mainly attributed to lower intensification. In a vicious cycle, the low productivity continues to prevent farmers from using inputs, as many farmers barely produce sufficient food to feed their family, and therefore have no income with which to purchase yield enhancing inputs.

Bed planting in rice-wheat cropping systems may be a technique for improving resource use efficiency and increasing the yield. In this system, the land is prepared conventionally and raised bed and furrows are prepared manually or using a raised bed planting machine. Crops are planted in rows on top of the raised beds and irrigation water is applied in the furrows

between the beds. Growing wheat on raised beds though introduced in other countries of the Indo-Gangetic Plain few years ago but in Bangladesh, it is introduced very recently (Connor *et al.*, 2003b) [4].

Materials and Methods

The field experiments were conducted during 2015-16 and 2016-17 at Norman E. Borlaug Crop Research Center, G.B Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar (Uttarakhand) India, to study crop intensification and establishment techniques to enhance productivity under irrigated rice- wheat system**.** The soil of experimental field was loam in texture. The soil of experimental field was high in organic carbon, low in available nitrogen, high in phosphorus and medium in potassium with neutral in pH. The experiment was laid out in a randomized block design with nine treatments T_1 [Rice (Transplanted rice) – Wheat], T_2 [Rice (Transplanted rice) - Vegetable pea – Groundnut], T_3 [Rice (Direct seeded rice) - Vegetable pea - Maize (Grain)], T_4 [Rice (Direct seeded rice) - Potato -Cowpea (vegetable +fodder)], T_5 [Rice (Direct seeded rice) - Vegetable pea - Maize (cob + fodder)], T_6 [Rice (Direct seeded rice) - Yellow Sarson – cowpea], T_7 [Rice (Direct seeded rice) (Bed)+Sesbania (Furrow)- 2:1 -Vegetable pea (Bed) + Toria (Furrow)-2:1 - Maize (Bed) (cob + fodder) + Mentha (Furrow) 1:1, (Furrow irrigated raised bed, 45cm X30 cm)], T_8 [Soybean (Bed) +Rice (Direct seeded rice) (Furrow)-2:1 - Wheat + Mentha (3:1) - Continue (Narrow bed system, 60cm x 30 cm)], T_9 [Maize (Bed) (cob + fodder) + Cowpea (vegetable) (Bed) +Sesbania (Furrow)-2:1:2 - Vegetable pea + Toria-3:1 - Groundnut+Mentha-3:1(Broad bed furrow 105cm x 30 cm)] and replicated thrice. The crops were sown as per the package of practices recommended for different crops. The nine cropping sequence were evaluated for productivity. 'HKR-47' variety of rice, 'UP-2572' variety of wheat, 'Kashi kanchan' variety of cowpea, 'Suvarna' variety of maize (cob + fodder), 'Arkle' variety of vegetable pea, 'Uttara' variety of toria, 'KufriBahar (3797)' variety of potato, 'PS-1024' variety of soybean, 'PPS-1 'variety of yellow mustard, 'ICGS-11' variety of groundnut and 'Kosi' variety of mentha were used in experimentation.

Energy Dynamics

For estimation of energy input and output (expressed in MJ ha^{-1}) the each items of outputs, inputs and agronomic practices of different cropping system, converted in energy terms by using energy equivalents (Table 1) as suggested by Mittal and Dhawan (1988) [11], Baishya and Sharma (1990) [1], Panesar and Bhatnagar (1994) [14] and Singh *et al.*, (1997) [17]. Specific energy, energy productivity, energy intensiveness were calculated using the following formula as suggested by Mittal and Dhawan (1988) [11], Singh *et al.*, (1997) [17] and Burnett (1982) [2].

Energy use efficiency

Energy use efficiency was calculated by the following formula:

$$\text{EUE} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

Specific energy

Specific energy was calculated by the following formula:

$$\text{Specific energy (MJ/t)} = \frac{\text{energy input (MJ ha}^{-1})}{\text{Grain output (t ha}^{-1})}$$

Energy productivity

Energy productivity was calculated by the following formula:

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Grain output (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

Energy intensiveness

Energy intensiveness was calculated by the following formula:

$$\text{Energy intensiveness (MJ/Rs)} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Net energy returns

Net energy return was calculated by the following formula:

Net energy returns=Energy output (〖MJ ha〗^(-1))- Energy input (〖MJ ha〗^(-1))

Table 1: Energy equivalent of inputs, outputs and agronomic practices of different cropping systems

S.N.	Particulars	Energy equivalent (MJ / unit)	Reference
A	**Inputs**		
1.	Human labor	1.96/ hour	Yilmaz *et al*. (2005) [16], Ozkan *et al.* (2004)
2.	Machinery	62.70/ hour	Erdal *et al.* (2007) [5], Giamppietro *et al.* (1992) [6]
3.	Diesel fuel	56.31/ liter	Mohammadi *et al.* (2008), Erdal *et al.* (2007) [5],
4.	Chemical fertilizers		
	a. Nitrogen	66.14/ kg	Esengun *et al*. (2007) [5], Yilmaz *et al.* (2005) [16]
	b. Phosphorus	12.44/ kg	Esengun *et al.* (2007) [5], Yilmaz *et al.* (2005) [16]
	c. Potassium	11.15/ kg	Esengun *et al.* (2007) [5], Yilmaz *et al.* (2005) [16]
5.	FYM	303.10/ ton	Nagy (1999)
6.	Chemical		
	a. Herbicide	238/ liter	Gundogmus (2006) [9].
	b. Pesticide	199/ liter	Gundogmus (2006) [9].
	c. Fungicide	92/ liter	Gundogmus (2006) [9].
7.	Water for irrigation	1.02/ M^3	Mohammadi *et al*. (2008)
	Outputs		
1.	Wheat grain yield	14.48/kg	Giamppietro *et al.* (1992) [6].
2.	Rice grain yield	14.70/kg	Gopalan *et al*. (1978) [8] and Binning *et al.* (1983)

3.	Maize grain yield	15.10/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
4.	Soybean grain yield	18.14/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
5.	Yellow Sarson grain yield	22.72/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
6.	Vegetable pea grain yield	3.91/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
7.	Potato grain yield	4.06/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
8.	Cowpea grain yield	3.91/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
9.	Ground nut	23.70 /kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
10.	Mentha	2.06/kg	Gopalan *et al*. (1978) [8] and Binning *et al*. (1983)
11.	Fodder	18/ kg	Singh and Mittal, 1992 [15]
12	Stover	18 /kg	Singh and Mittal, 1992 [15]
13	Straw	12.5 /kg	Singh and Mittal, 1992 [15]
14	Green or dry product	18 /kg	Singh and Mittal, 1992 [15]

Results and Discussion

Total input energy

The highest total input energy was utilized by T_9 treatment having 55964 MJ/ha during both the years. It might be due to more use of input. The lowest was in T_6 treatment with 40300 MJ/ha during both the years. It could be due to lower use of inputs.

Total output energy

Total output energy was recorded maximum by T_9 treatment, having 1381739 and 1179456 MJ/ha during 2015-16 and 2016-17, respectively, however energy output during year 2016-17, was at par with treatment T_7 having 1128627 MJ/ha. It might be due to higher production potential of cropping sequence in contrary to Chaudhary *et al*. (2009) who reported the highest energy output in rice–potato–wheat system.The lowest was in T_1 treatment [Rice (TPR) – Wheat] with 310154 and 302705 MJ/ha during 2015-16 and 2016-17, respectively. It could be due to lower production of system. Similarly Chaudhary *et al*. (2009) was also reported the lowest input energy was in rice-wheat cropping system.

Energy use efficiency

The energy use efficiency was also the highest in T_9 having 24.82 MJ/ha and 22.47 MJ/ha during 2015-16 and 2016-17, respectively and the lowest was in T_1 treatment 6.98 MJ/ha and 6.81 MJ/ha during 2015-16 and 2016-17, respectively.

Specific energy

The highest specific energy was recorded in T_1 treatment with 4095 MJ/ha and 4388 MJ/ha during 2015-16 and 2016-17, respectively, whereas the lowest was in T_5 with value of 1725 and 1759 MJ/ha during 2015-16 and 2016-17, respectively, being at par with T_4. These results were in agreement with Chaudhary *et al.* (2009).

Energy intensiveness

The highest energy intensiveness was observed in T_1 [Rice (TPR) – Wheat] with 0.664 and 0.651 MJ/Rs. during 2015-16 and 2016-17, respectively. The lowest was in T_2 with the value of 0.424 and 0.416 MJ/Rs. during 2015-16 and 2016-17, respectively.

Energy productivity

The maximum energy productivity was recorded in T_5 with 0.596 and 0.585 kg/MJ during 2015-16 and 2016-17, respectively although it was at par with T_4 during 2016-17. Chaudhary *et al.* (2009) also reported the same findings. The lowest was reported in T_1 treatment [Rice (TPR) – Wheat], 0.244 and 0.228 kg/MJ during 2015-16 and 2016-17, respectively.

Net energy

The net energy was recorded highest in treatment T_9 with value of 1326075 and 1123791 MJ/ha during 2015-16 and 2016-17, respectively. It could be due to higher energy level of this cropping system. The results were in conformity with findings of Chaudhary *et al.* (2009). The lowest was in T_1 (265712 and 258263 MJ/ha during 2015-16 and 2016-17, respectively).

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