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Assessment of physiological indices and energetics under different system of rice intensification in north western Himalayas

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Abstract: Field experiment was conducted at the research farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Rice and Wheat Research Centre, Malan during kharif 2013 with the objective to select the best seedling age and spacing of rice under system of rice intensification in terms of energetic and employment generation for mid hill condition of Himachal Pradesh. The experiment was laid out in 3 times replicated split plot design, assigning of three seedling ages (10, 17 and 24 days) and two spacings (20 cm x 20 cm and 20 cm x 15 cm) in main plots and four seedling vigours corresponding to four seeding rates (25, 30, 35 and 40 g/m^2) in sub plots. The leaf area per plant was significantly greater in 10 days seedling age and decreased with increase in age (P=0.05). Seedling rate did not affect leaf area index in all stages except 40 DAS when 35 g/m^2 seeding rate had maximum LAI. Seedling age did not significantly influence crop growth rate at any interval but it did relative growth rate and net assimilation rate between 40-70 and 70-100 DAS (P=0.05). 24 days old seedling resulted in significantly higher relative growth rate and net assimilation rate between 40-70 DAS followed by 17 days old seedlings. Maximum value of energy input (13.23) was recorded in 24 days seedling. The energy use efficiency (Energy output: input) varied from 10.6 to 11.1 under different treatments. Wider spacing supporting less plant population consumed 10 man days less than closer spacing of 20 cm x 15 cm.

Keywords: Energetics, Employment, SRI, Physiological Indices

INTRODUCTION

Agriculture is a continuous process of solar energy conversion into food, feed and fiber through photosynthesis. Old agriculture was based on scattering of seed on unprepared or occasionally prepared land in unplanned manner and accepting too little output that also if nature was kind enough. On the other hand, today's agriculture is well-planned application of energy to achieve desired results (Stout, 1990). Today the agriculture sector is one of the larger energy-consuming sectors, as agricultural production has many energy consuming operations such as tillage, intercultural, irrigation, application of fertilizers, agrochemicals for plant protection, harvesting, transportation etc. Mandal *et al.* (2002) reported that increase in mechanized level of operations for higher crop production increases the energy consumption.. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to provide a basis for conservation and to aid in making sound management and policy decisions.

Among the rice-growing countries India ranks first in area (43.8 m ha) and second in production (105.0 mt), next only to China. However, the average productivity of rice in India is only 3.44 t/ha against the global average of 4.0 t/ha (FAO, 2014).Rice is a semi aquatic plant and uses approximately 5000 liters of water to produce 1 kg of rice under puddle seeding condition and conventional methods of planting. Sustaining rice production under decreasing water availability and shrinking land area is becoming major challenge in mountain ecosystems. The possible way to increase the productivity of rice under organic management condition is through formulating better production technologies including the appropriate cultural practices along with high yielding rice genotypes. Avasthe *et al.* (2012) suggested that the system of rice intensification (SRI) holds a great promise in increasing the rice productivity. The productivity of a crop is related to the amount of growth attained and its partitioning into the different components especially the grain. Analysis of growth attributes provides an understanding of crop development and thereby the productivity. Keeping the above points in mind the present study was undertaken

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to analyse growth and energetics of SRI in relation to seeding date, spacing and seeding rate under mid hill conditions of Himachal Pradesh.

MATERIALS AND METHODS

Description of selected site: A field experiment was carried out during the *kharif* season of 2013 at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Rice and Wheat Research Centre, Malan situated ($32^0 07'$ N latitude, $76^0 23'$E longitude and 950 m altitude) in North Western Himalayas. The soil of the experimental field was silty clay loam in texture and acidic in reaction. During rice crop season, mean weekly maximum temperature ranged between 26.6 ^oC in 43^{rd} standard week (22-28 October) and 34.7 ^oC in 27^{th} standard week (2-8 July) during *kharif* 2013. Mean weekly minimum temperature ranged from 16.4 ^oC during 43^{th} standard week (29 October-4 November) to 22.1 ^oC in 27^{th} standard week (2-8 July) during the year of experimentation. In *kharif* 2013, total rainfall of 2506.1 mm was received in 140 days. Mean weekly relative humidity ranged from 69 % in October to 96 % in August.

Experimental design: The field experiment was conducted in split plot design with three replications. The six combinations of three seedling ages (10, 17 and 24 days) and two plant spacings (20 cm x 20 cm and 20 cm x 15 cm) were allocated to the main plots and seedlings of variable vigour obtained from various seeding rates (25, 30, 35 and 35 g/m^2) in nursery to four sub plots. The normal seed (dry) of HPR 2612 a recommended scented rice variety treated with bavistin (400:1) was sown in rows 10 cm apart using pre-planned seeding rates (viz. 25,30,35 and 40 g/m^2) in distinct seed beds on 16^{th} June 2013. The seedlings were transplanted at three stages viz., 10 (27^{th} June 2013), 17 (4^{th} July 2013) and 24(11^{th} July 2013) days after planting at a spacing of 20 cm x 20 cm and 20 cm x 15 cm as per treatment. The plots were regularly irrigated (as and when required) to keep the field moist throughout the crop season up to vegetative stage and water stagnation thereafter. For weed control butachlor 1.5 kg/ha was used at 4 days after transplanting. After harvesting, threshing, cleaning and drying the grain yield was expressed at 14% moisture. Straw yield was obtained by subtracting grain yield from the total biomass yield. Yield was expressed in t/ha. The leaf area was calculated in accordance with the method described by Gomez (1972) as below:

Leaf area = l x w x k

Where, l is the length, w is the maximum width of the middle tiller in each hill and k is the adjustment factor. The value of k was 0.75 except at maturity for which the value was 0.67. Accordingly,

Leaf area/hill = total leaf area of middle tiller x total number of tillers; and

LAI = Sum of leaf area/hill (cm^2) / area of land covered/hill (cm^2)

Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) of the crop were calculated by the formulae outlined by Watson (1962) as below:

$$\text{CGR } (g/day/m^2) = \frac{W_2 - W_1}{t_2 - t_1}$$;

$$\text{RGR } (g/g/day) = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$; and

$$\text{NAR } (mg/day/m^2) = \frac{\text{Log } e\, L_2 - \text{Log } e\, L_1}{t_2 - t_1} \text{ X } \frac{W_2 - W_1}{L_2 - L_1}$$

Where, W_2 and W_1 are the total dry weight and L_2 and L_1 are leaf area at times t_2 and t_1, respectively.

Energetics of rice production: The input energy was worked out for different inputs used and operation carried out. The direct energy consists of diesel, human power and electricity, while the indirect energy contains seed, farmyard manure and machinery (Singh *et al.,* 2007). The energy equivalent for different input and output are given in Table 1. Total physical output referred to sum of grain/seed and by-product yields. The output energy (MJ/ha) was obtained by multiplying the energy coefficient with grain and straw separately and then summing up these. Based on the energy equivalents of the inputs and output, energy indices were calculated as follow

Energy use efficiency = Gross energy output (MJ/ ha)/ Energy input (MJ/ha)

Energy productivity (kg/MJ) = [Total output (grain+straw) (kg/ha)]/Total energy input (MJ/ha)

Net energy output (MJ/ha) = Gross energy output (MJ/ ha) – Energy input (MJ/ha)

Energy intensity in physical terms (MJ/kg) = Total energy input (MJ/ha)/Total output (grain+straw)(kg/ ha)

Energy intensity in economic terms (MJ/) = Gross energy output (MJ/ha)/Cost of cultivation (INR/ha)

RESULTS AND DISCUSSION

Physiological indices

Leaf area index: The leaves of a plant are normally its main organ of photosynthesis and the total area of leaves per unit ground area, called leaf area index (LAI), has therefore been proposed by Watson (1947) as the best measure of the capacity of a crop producing dry matter and called it as productive capital. Leaf area index was worked out at 40, 70, 100 days and at maturity has been embodied in Table 2. Leaf area and leaf area index increased gradually up to 70 DAS, and thereafter declined. It decreased towards maturity which may be due to lesser leaf number as a result of senescence in early formed leaves. The result obtained from the present study is consistent with the results of Sharma and Haloi (2001) who stated that variation in leaf area might be attributed to the difference in number of leaves. Seedling age significantly affected the

Table 1. Energy equivalents for different inputs and outputs.

Particulars	Units	Equivalent energy (MJ)	Remarks
Man (adult)	Man-hour	1.96	-
Diesel	Litre	56.31	Includes cost of lubrication
Nutrient elements			
a. Nitrogen	kg	60.60	Estimated quantity of N, P_2O_5 and K_2O in the fertilizer
b. P_2O_5	kg	11.10	
c. K_2O	kg	6.70	
Chemicals/pesticides			Chemicals requiring dilution at the time of application
Agro -chemicals	kg	120.00	
Rice grain	kg	14.7	-
Rice straw	kg	12.5	-

Source: Mittal VK, Mittal JP and Dhawan KC. 1985. Research Digest on Energy Requirement in Agricultural Sector. Co-ordinating Cell AICRP (ERAS), College of Agricultural Engineering, PAU, Ludhiana.

leaf area index at 40 and 70 DAS. The leaf area index was significantly greater in 10 days seedling age and decreased with increase in age whereas 17 and 24 days old seedling age were at par with each other upto 70 DAS. At later stages, i.e. 100 DAS and at maturity stage leaf area index was statistically similar under all the seedling ages.

Spacing did not significantly influence leaf area index. But 20 cm x 15 cm spacing had an edge over 20 cm x 20 cm. Similar result was reported by Nayak *et al.* (2003) from Bhubaneswar where LAI was lower at wider spacing of 20 cm x15 cm compared to 15 cm x 15 cm during wet season. Seedling rate did not affect leaf area index in all stages except 40 DAS when 35 g/ m^2 seeding rate had maximum LAI. The other treatments had equal LAI.

Growth parameters: Crop growth rate (g/m^2/day), Relative growth rate (mg/g/day) and net assimilation rate (g/m^2/day) were worked out between 40-70, 70-100 DAS and 100 DAS- At maturity (Table 2). The RGR is a measure of dry matter accumulation/unit land area and per unit time. The RGR values showed a decreasing trend linearly up to harvest and a reduction at grain filling was due to the translocation of metabolites to the sink which is absolutely essential for better yield. The decline in RGR towards physiological maturity could be due to leaf shedding, shadow of upper leaves over the lower leaves which reduce the photosynthetic capacity of the lower leaves and finally loss of leaves due to pest attack (Banik *et al.,* 2009). The crop growth rate during early growth period was slow; it increased sharply and reached its peak during maturity i.e. 19.7 g/m^2/day. NAR had similar pattern as CGR. Rate of RGR declined with time and the corresponding minimum values were recorded as crop proceeded towards maturity. Similar result obtained by Jena et al (2010) where rate of RGR declined with time and the corresponding minimum value of 1.33 mg/g/ day was recorded during 90 DAT –harvest. Seedling age did not significantly influence CGR at any interval but it did RGR and net assimilation rate between 40-70 and 70-100 DAS. 24 days old seedling resulted in significantly higher RGR and NAR between 40-70 DAS followed by 17 days old seedlings). CGR, RGR and NAR were not significantly influenced under the seeding rate in the nursery and spacing in the field.

Energetics: A perusal of the data (Table 3) revealed no significant effect of seedling age on grain yield of rice which varied in the range of 5245-5416 kg/ha. Nursery seeding rate also did not significantly influence the yield attributes and there by grain and straw yield of rice.

The data on effect of seedling age, plant spacing and seeding rate on energetic of rice production are presented in Table 3. Data revealed marked variation in energy input due to production factors. Maximum value of energy input (13.31 GJ/ha) was recorded in 10 days seedling. Different seedling ages, spacing and seeding rates did not induce variation in gross and net energy output, energy use efficiency, energy productivity, and energy intensity in physical and economic terms. The energy use efficiency (Energy output: input) varied from 10.6 to 11.1 under different treatments. The output energy was determined by the amount and quality of harvestable biomass (Gelfand *et al*., 2010). In the present investigation the different factors viz. crop spacing and seedling age did not have any influence significantly on rice energetics.

Employment: Old seedling, being easy to handle, consumed less man power compared to younger seedlings. Wider spacing supporting less plant population consumed 10 man days less than closer spacing of 20 cm x 15 cm. Similarly, using high seed rates for raising seedlings (thick nursery), requiring smaller nursery area consumed less manpower than lower seeding rates (thin nursery).

Conclusion

Seedling age, plant spacing and seeding rate did not have any influence on energetic but had little bit effect on generating the manpower. Younger seedling due to delicate nature and closer spacing required more man days. Thus the farmer' can practice any of these cultural practices of his choice keeping in cost and availability of labour in consideration.

Table 2. Effect of seedling ages, spacing and seeding rates on physiological indices of rice under System of Rice Intensification.

Treatments	Leaf area index				CGR (gm/m^2)			RGR (mg/g/day)			NAR (gm/m^2)		
	40 DAS	70 DAS	100 DAS	At Maturity	40-70 DAS	70-100 DAS	100-At maturity	40-70 DAS	70-100 DAS	100-At maturity	40-70 DAS	70-100 DAS	100-At maturity
Seedling age (days)													
10	1.66	6.06	5.52	4.28	14.2	13.8	19.7	0.062	0.020	0.017	4.3	2.4	4.1
17	1.26	5.59	5.26	4.06	14.6	14.3	17.1	0.061	0.020	0.015	5.4	2.7	3.9
24	0.97	5.22	5.04	3.83	13.4	14.5	16.3	0.086	0.023	0.015	5.6	2.9	4.0
SEm±	0.09	0.19	0.18	0.22	0.35	0.44	1.27	0.002	0.001	0.001	0.22	0.11	0.33
LSD (P= 0.05)	0.28	0.58	NS	NS	NS	NS	NS	0.005	0.002	NS	0.69	0.34	NS
Spacing (cm)													
20 x 20	1.26	5.61	5.19	4.03	14.5	14.4	17.2	0.068	0.021	0.015	5.3	2.7	3.9
20 x 15	1.42	5.71	5.43	4.18	13.9	14.0	17.7	0.071	0.021	0.016	4.8	2.6	3.9
SEm±	0.07	0.15	0.15	0.18	0.28	0.36	1.04	0.001	0.001	0.001	0.18	0.09	0.27
LSD(P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Seeding rate (g/m^2)													
25	1.20	5.62	5.26	4.01	14.1	13.6	17.6	0.070	0.020	0.016	5.3	2.6	4.1
30	1.24	5.67	5.32	4.11	13.9	14.8	17.9	0.069	0.022	0.015	5.1	2.7	3.9
35	1.58	5.69	5.36	4.19	14.6	14.2	16.9	0.069	0.021	0.015	4.8	2.6	3.7
40	1.18	5.52	5.15	3.92	13.6	14.3	18.4	0.070	0.022	0.016	5.1	2.8	4.4
SE(m±)	0.09	0.26	0.25	0.20	0.34	0.47	0.93	0.002	0.001	0.001	0.31	0.11	0.28
LSD(P= 0.05)	0.27	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of seedling ages, spacing and seeding rates on yield, energetic and employment generation of rice production under System of Rice Intensification.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Energy Input (GJ/ha)	Energy Output (GJ/ha)	Net energy output (GJ/ha)	Energy use efficiency	Energy Productivity (kg/MJ)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (/MJ)	Employment (Man days)
Seedling age (days)										
10	5386	7415	13.31	145.46	132.30	10.93	0.97	1.03	4.53	113
17	5408	7528	13.27	147.10	133.98	11.09	0.99	1.02	4.63	110
24	5260	7146	13.23	140.88	127.81	10.65	0.95	1.06	4.50	108
SEm±	139.5	205.6	-	3.57	3.57	0.27	0.02	0.02	0.11	-
LSD (P= 0.05)	NS	NS	-	NS	NS	NS	NS	NS	NS	-
Spacing (cm)										
20 x 20	5413	7403	13.17	145.59	132.58	11.06	0.99	1.02	4.68	106
20 x 15	5245	7335	13.37	143.09	129.88	10.70	0.95	1.06	4.37	116
SEm±	113.9	167.8	-	2.92	2.92	0.22	0.02	0.02	0.09	-
LSD(P= 0.05)	NS	NS	-	NS	NS	NS	NS	NS	0.28	-
Seeding rate(g/m^2)										
25	5303	7253	13.39	142.63	129.49	10.65	0.96	1.05	4.45	113
30	5298	7569	13.23	146.54	133.43	11.07	0.98	1.03	4.59	112
35	5387	7283	13.18	143.84	130.78	10.92	0.97	1.04	4.55	110
40	5416	7346	13.27	144.91	131.76	10.92	0.97	1.04	4.63	108
SE(m±)	80.8	190.7	-	2.66	2.66	0.20	0.02	0.02	0.08	-
LSD(P= 0.05)	NS	NS	-	NS	NS	NS	NS	NS	NS	-

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