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Effect of Crop Establishment Methods and Weed Management Practices on Productivity and Bioenergetics of Rice

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ABSTRACT

Background: SRI and aerobic rice are one of the techniques of growing rice under water scarcity areas where meeting water requirement is becoming a global threat. Weeds are another threat to yield of rice irrespective of different establishment methods. Until checked, it can decline rice yield and quality up to more than 70%. SRI and aerobic rice have different densities of weeds and integrated weed management can be applied to suppress the weeds. Considering the current scenario, research was conducted to investigate growth, yield and bioenergetics of rice under different establishment methods and weed management.

Methods: The experiment entitled "Effect of crop establishment methods and weed management practices on productivity and bioenergetics of rice" was carried out in split plot design with main plots, *viz*., M_1- aerobic rice (AR) and M_2- system of rice intensification (SRI) and five subplots W_1- pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb post-emergence (bispyribac-sodium @20 g a.i ha^{-1}) (PE+POE), W_2- pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb cono weeding at 15, 30 and 45 DAT/ DAS (PE+CW), W_3- weed free (WF), W_4- weedy check (WC), W_5- stale seedbed followed by post-emergence herbicide (bispyribac-sodium 10% SC 20 g a.i ha^{-1}) (SSB+POE) in split plot design with three replications taking the variety 'Pusa Basmati-1121' as a test crop.

Result: Among the establishment methods, SRI recorded significantly higher growth attributes like plant height and dry matter production and yield attributes like number of panicles per hill, panicle length, number of grains per panicle, test weight, grain yield, straw yield, biological yield, and harvest index. Among the weed management treatments, WF recorded significantly higher growth attributes like plant height, number of tillers per hill, dry matter production and yield attributes like number of panicles per hill, panicle length, number of grains per panicle, test weight, grain yield, straw yield, biological yield, and harvest index that was followed by treatment PE+CW. Maximum net return and B:C ratio was observed in the treatment combinations M_2W_2- SRI + (PE+CW). The maximum total energy input was found in the treatment combination M_1W_1- AR+ (PE+POE) and the maximum total energy output was found in the treatment combination M_2W_3- SRI + WF. The energy intensiveness was observed to be maximum in the treatment combination M_1W_4- AR + WC and the maximum energy efficiency index was observed in the treatment combination M_2W_3- SRI+WF.

Key words: B:C ratio, Bioenergetics, Nutrient, Weed, Yield.

INTRODUCTION

Rice cultivation consists an integral part of the agricultural economy of India which is the 2nd largest rice producer in the world. In most areas of India, there is a transition towards less water-demanding crops instead of rice because of water scarcity. This calls for alternative rice-growing techniques that emphasise increased water and crop productivity. Evidences support that conservation of water through aerobic rice systems can be 35-45% while through the SRI system it can be 50-70%. Improvement in the water efficiencies have made both the methods popular in different areas which provide an opportunity to grow rice in lesser water consumption.

Weeds offer major barrier to rice production regardless of the rice establishment methods because they might compete for resources (Ramesh *et al*., 2022a). The yearly loss of rice grain production due to heavy weed infestation in India is around 15 million tonnes (Pratap *et al*., 2021). In aerobic conditions, weed infestation higher compared to SRI system which is further higher than under flooded rice cultivation. Instead of relying on a single strategy, integrated weed management (IWM) can be adopted to control weed that not only makes weed management effective but also reduces selection pressure to avoid herbicide resistance. IWM needs to be studied more in diverse global contexts to effectively manage weeds and reduce the risk of the establishment of herbicide-resistant weeds.

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MATERIALS AND METHODS

The field experiment entitled "Effect of crop establishment methods and weed management practices on productivity and bioenergetics of rice" was conducted at Agricultural Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab. The experiment, was in split-plot design with three replications and consisted two main plots M_1- aerobic rice (AR) and M_2- system of rice intensification (SRI) and five subplots W_1- pre-emergence (pendimethalin @1kg a.i ha^{-1}) fb post-emergence (bispyribac-sodium @20 g a.i ha^{-1}) (PE+POE), W_2- pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb cono weeding at 15, 30, and 45 DAT/ DAS (PE+CW), W_3- weed free (WF), W_4- weedy check (WC), W_5- stale seedbed followed by post-emergence herbicide (bispyribac-sodium 10% SC 20g a.i ha^{-1}) (SSB+POE). Variety 'Pusa Basmati-1121' that is commonly grown in Punjab region was used as test crop. The recommended dose of N, P and K was 105:30:30 kg ha^{-1} for aerobic rice and 120:60:40 kg ha^{-1} for the SRI system of rice. The sowing of aerobic rice was done at 20 × 20 cm^2 apart, and seeds were planted at a depth of 2-2.5 cm at seed rate of 30 kg ha^{-1}. In SRI, transplanting of Dapog-raised seedlings was done after 15 days of sowing of aerobic rice at the spacing of 25 × 25cm^2 on puddled soil. Irrigation method consisted alternate drying and wetting in SRI while aerobic was kept complete rainfed.

Stale seedbed was maintained by ploughing and lightly irrigating the field, 15 days before sowing of crop that was followed by rotavating and puddling at 2 days before sowing in aerobic and SRI beds respectively. Pre-emergent herbicide was given on the day of sowing that was followed by post-emergent at 28 DAT in both the systems as per the treatment requirements. Before the cono-weeding a light irrigation was given to the treatments to bring it to the moisture content sufficient to implement the action.

Growth parameters were taken from the tagged plants at each given stage, *i.e.*, 30, 60 while harvesting and yield parameter reading was taken from net plot area. Harvest index was calculated by dividing economic yield with the biological yield as given below:

$$HI\% = [EY/BY)] \times 100$$

Where,
HI= Harvest index.
EY= Economic yield (grain) (kg/ha).
BY= Biological yield (grain+straw) (kg/ha).

Gross return net return and B:C ratio was calculated by the given formula:

Gross returns = Value of the product (Grain + Straw)

Net returns (₹/ha) (NR) =

Gross returns (GR) – Cost of cultivation (CoC)

$$\text{B:C ratio} = \frac{\text{NR (₹/ha)}}{\text{CoC (₹/ha)}}$$

With the standard value suggested by Binning *et al.* (1983) and Gopalan *et al*. (1976), the energy input was calculated treatment-wise from seed to seed for each item of operation and estimated in megajoule/ha (MJ/ha). With the standard values suggested by Binning *et al*. (1983) and Devsenapathy *et al*. (2009), the energy output was computed from the total produced and estimated in megajoule/ha (MJ/ha). The energy efficiency index quantifies the rate of energy input to energy production and was calculated as given by Burnet, (1982):

$$\text{Energy intensiveness} = \frac{\sum_{i=1}^{n} Ei}{\sum_{i=1}^{n} (Pi\ Yi)}$$

Where,
Ei = Energy input for crop.
Pi = Price of the crop (₹/kg).
Yi = Grain yield of the crop (kg/ha).

The observations recorded during the course of investigation were tabulated and subjected to analysis of variance techniques as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes

Studies on the pattern of growth in terms of plant height (Table 1) revealed that different establishment methods influenced the plant height significantly at 30 and 60 DAT of the growth stage. Significantly higher height was observed with SRI (36.81 and 78.28 cm at 30 and 60 DAT respectively). This could be due to enhanced nutrient uptake, optimum intra-plant competition and better resource allocation in plants under SRI where optimum plant spacing was maintained. The present result corroborates with Sangramsingh *et al*. (2022).

Among the weed management treatments, WF had significantly higher plant height which was followed by PE+CW (41.25, 83.16 and 114.12 at 30, 60 DAT and harvest respectively). Lesser competition from weeds at the critical phases of plants could be the reason behind the increased plant height. This finding is in conformity with the results of Hashim *et al*. (2022).

Significantly higher tillers were observed in SRI at 60 DAS (28.97) and harvest (25) while it was non-significant at 30 DAS. SRI recorded significantly higher number of tillers throughout the entire growth phases which was because of transplanting single seedling/hill that gets ample spaces to tiller profusely. On the other hand, the tillers did not come out efficiently in aerobic rice considering the water and space constraints.

Among different weed management treatments, significantly higher number of tillers m^{-2} was recorded with WF at only 60 DAT and harvest (36.72 and 32 respectively) possibly because of weed-free treatments being best compared to other treatments, which led to their higher

Table 1: Growth attributes as influenced by different establishment methods and weed management.

Treatments	Growth attributes								
	Plant height (cm)			Number of tillers hill^{-1}			Dry matter accumulation (g/m^2)		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Establishment method									
M_1 - Aerobic rice	33.54	71.68	96.80	6.48	22.80	21.09	221.29	536.78	1641.37
M_2 - System of rice Intensification	36.81	78.28	106.91	7.49	28.97	25.00	231.73	623.80	1934.49
SEm (±)	0.21	0.23	2.07	0.70	0.45	0.32	1.32	2.97	11.91
$CD_{(p=0.05)}$	1.25	2.34	NS	NS	2.90	1.96	9.34	30.22	65.54
Weed management									
W_1- Pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb post-emergence (bispyribac-sodium @20 g a.i ha^{-1})	35.69	73.61	113.13	6.78	29.50	23.39	221.72	587.94	2227.78
W_2- Pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb cono weeding at 15, 30 and 45 DAT/ DAS (PE+CW)	41.25	83.16	114.12	8.61	34.05	28.61	245.33	726.22	2524.66
W_3- Weed free	43.72	88.83	117.47	9.66	36.72	32.00	249.33	763.11	2652.33
W_4- Weedy check	25.56	59.69	70.77	4.22	8.33	12.33	202.55	351.53	506.05
W_5- Stale seedbed followed by post -emergence herbicide (bispyribac -sodium 10% SC 20 g a.i ha^{-1}	29.67	69.60	93.80	5.66	20.83	18.89	226.51	472.64	1029.83
SEm (±)	1.50	3.33	3.28	0.74	1.66	1.23	2.95	4.13	12.25
$CD_{(p=0.05)}$	4.49	9.98	9.85	2.23	4.98	3.70	14.83	24.39	87.74

uptake of available nutrients efficiently that enhanced the chlorophyll content and thus photosynthesis which led to the production of a more significant number of tillers. This was statistically at par with PE+CW (34.05 and 28.61 at 60 DAT and harvest respectively). The findings concur with those of Kumar *et al*. (2022).

Significantly higher dry matter accumulation was observed in treatment SRI (231.73, 623.80 and 1934.49 g/m^2 at 30, 60 DAT and harvest respectively. A higher generation of dry matter was the outcome of an increased nutrient uptake and better assimilation of nutrients indicating better health of plants. The end result agrees with Sarkar *et al*. (2020). Among the weed management, significantly higher dry matter accumulation was recorded with WF (249.33, 763.11 and 2652.33 g/m^2 at 30, 60 DAT and harvest respectively), which was followed by PE+CW (245.33, 727.22 and 2524.78 g/m^2 at 30, 60 DAT and harvest respectively). Higher dry matter accumulation is the cumulative result of no crop and weed competition and hence better nutrient uptake and assimilation of photosynthates. The results are in conformation with Hussain *et al*. (2022).

Yield and yield attributes

The number of panicles hill^{-1}, panicle length, number of grains per panicle indicated yield increased with the application of progressive weed management techniques under various establishment (Table 2). SRI was reported to have significantly higher number of panicles/hill (20.13) and number of grains per panicle (79.99). Panicle length and test weight was also observed to be higher in treatment SRI (25.72 cm and 27 g resp.) but they could not reach to the level of significance.

Among different weed management treatments, number of panicles hill^{-1}, panicle length, and number of grains per panicle showed significantly higher result in WF treatment (27.17, 28.52 cm and 96.07 resp.), which were followed by treatment PE+ CW (25.44, 27.12 cm and 90.03 resp.). After controlling weeds, nutrients continued to be available, and biomass was divided up among the reproductive sections. The larger quantity of grains per panicle suggests that effective assimilate translocation to the sink may have caused the sound filling of grains. Test weight of grains could not show significant effect due to weed management.

Significantly higher value for grain yield and straw yield was recorded in treatment, SRI (2588.60 kg/ha), which was the result from higher yield attributes such as the number of panicles per hill, panicle length, grains per panicle and test weight. Similar results were obtained by Nazir *et al*. (2022). Among the different weed management treatments, grain yield and straw yield was significantly affected in the order, WF (3490.55 and 7558.67 kg/ha resp.) > PE+CW (3392.22 and 7428.28 kg/ha resp.) > PE+POE (2216.11and 5847.78 kg/ha resp.) > SSB+POE (1398.22 and 4195.18 kg/ha resp.) > WC (1067.54 and 3326.56 kg/ha resp.). The increase in yield is due to less weed competition between crops because of integrated weed management treatments. Similar results were confirmed by Singh *et al*. (2022) and Subramanian *et al*. (2021). The harvest index was observed to be higher with

Table 2: Yield attributing characters and yield as affected by treatments.

Treatments	No. of panicles hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)
Establishment method							
M_1 - Aerobic rice	17.80	23.15	69.55	27.00	2037.06	5343.38	27.60
M_2- System of rice Intensification	20.13	25.72	79.99	27.00	2588.80	5999.21	30.14
SEm (±)	0.95	0.59	1.61	0.01	8.58	11.99	-
$CD_{(p=0.05)}$	1.67	NS	9.82	NS	52.22	72.96	-
Weed management							
W_1- Pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb post-emergence (bispyribac-sodium @ 20 g a.i ha^{-1})	20.39	23.35	76.97	27.01	2216.11	5847.78	27.48
W_2- Pre-emergence (pendimethalin @1 kg a.i ha^{-1}) fb cono weeding at 15, 30 and 45 DAT/ DAS (PE+CW)	25.44	27.12	90.03	27.02	3392.22	7428.28	31.35
W_3- Weed free	27.17	28.52	96.07	27.03	3490.55	7558.67	31.59
W_4- Weedy check	6.50	18.02	47.17	26.95	1067.54	3326.56	24.29
W_5- Stale seedbed followed by post -emergence herbicide (bispyribac -sodium 10% SC 20 g a.i ha^{-1}	15.33	23.17	63.60	26.98	1398.22	4195.18	25.00
SEm (±)	1.35	1.01	5.77	0.01	16.40	18.21	-
$CD_{(p=0.05)}$	4.05	3.02	17.31	NS	49.17	54.61	-
Interaction (M × W)							
SEm (±)	0.97	1.42	8.17	0.01	23.19	25.76	-
$CD_{(p=0.05)}$	2.12	NS	NS	NS	69.54	77.23	-

Table 3: Economics and bioenergetics as affected by treatments.

Treatments	Economics		Bioenergetics			
	Net returns (Rs/ha)	B:C ratio	Total energy input (MJ/ha)	Total energy output (MJ/ha)	Energy eficiency index	Energy intensiveness (MJ/Rs)
M_1W_1	62021.47	1.40	18963.04	102084.25	5.38	0.20
M_1W_2	93478.75	2.07	18753.72	130358.78	6.95	0.15
M_1W_3	83683.62	1.49	18539.49	132633.24	7.15	0.15
M_1W_4	6327.53	0.15	18454.99	53914.72	2.92	0.45
M_1W_5	14919.44	0.34	18799.29	64693.99	3.44	0.36
M_2W_1	53728.37	0.99	17564.8	109263.88	6.22	0.18
M_2W_2	127782.56	2.32	17355.48	155079.53	8.94	0.10
M_2W_3	124611.61	1.89	17141.25	158955.64	9.27	0.10
M_2W_4	6660.68	0.13	17056.75	60634.97	3.55	0.34
M_2W_5	23137.45	0.42	17401.05	81293.14	4.67	0.25

PE+CW among different weed management treatments, followed by WF and a lower harvest index was observed with WC. Similar trends were confirmed by Dangol *et al*. (2020).

Economics and bioenergetics

Treatment combinations, SRI+ WF were found to have the highest cost of cultivation and gross returns. The treatment combination M_2W_2 (SRI+PE+CW) had the highest net returns and B: C ratio (2.58) (Table 3). Bohra *et al*. (2021) confirmed similar findings.

Bioenergetics was calculated for the treatment combinations (Table 3) in terms of energy input (MJ/ha), energy output (MJ/ha), total energy efficiency (%) and energy intensiveness (MJ/Rs) and it indicates the output of the treatments in terms of energy. The total energy input was found to be higher in the treatment combination AR+PE+POE (18963.04 MJ/ha). Variations in the energy inputs is obvious due to the variation in the types of resources. The lower energy input was observed in the combination SRI+WC (17056.75 MJ/ha). Similar trends were confirmed by Paramesha *et al*. (2022).

The total energy output was higher in the treatment combination SRI+WF (158955.64 MJ/ha). Higher output of the economic product and by-product in these treatment combinations of might be the reason for the high energy output. In contrast, the lowest energy output was observed in the treatment combination AR+WC (53914.72 MJ/ha). This might be due to the lowest economic and by-product obtained. The same results were confirmed by Singh *et al*. (2016).

A higher energy efficiency index was observed in the treatment combination SRI+WF (9.27) which might be due to the increase in the grain yield of the irrespective treatment combinations. The lower energy efficiency index was observed in the treatment combination AR+SSB+POE (3.44), which might be due to the higher energy input and lowest grain yield obtained from the respective treatment. This conclusion is consistent with those of Bohra and Kumar (2015). The energy intensiveness was observed to be lower in the treatment combination SRI+ WF and SRI+ PE+CW (0.10 MJ/Rs). The higher energy intensiveness was observed in the treatment combination AR+WC (0.45 MJ/Rs), which is indicative of the maximum energy implied in the treatment combination.

CONCLUSION

In the experiment treatment SRI was found superior among the establishment methods while weed free was superior among the weed management treatments that led to higher growth and yield attributes. The treatment combinations SR+PE+CW (127782.56 ₹/ha) showed the highest net returns and B:C ratio (2.32) while SRI+WF (256025.1 MJ/ha) reported maximum total energy output, energy efficiency index (14.94) and the reduced energy intensiveness (0.10 MJ). SRI and PE concluded to performed better under the Punjab conditions that was followed by SRI and PE+CW. Higher growth attributes and yield were the result of better spacing, optimum inter and intra-plant competition and better weed control in the respective treatments.

Conflict of interest

The authors declare the existence of no conflict of interest.

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