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Effect of Different Crop Establishment Methods and Weed Management Practices on Growth Indices and Yield of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted on Agronomy research farm of Acharya Narendra Deva University of Agriculture and Technology Kumarganj Ayodhya (Uttar Pradesh, India) during *Kharif* season 2021 and 2022. The experiment was laid out in split-plot-design with three replications. Four establishment methods *viz.,* Direct seeded rice, Drum seeder technique, Transplanted rice and System of rice intensification (SRI) were taken in main plot, and six weed management practices *viz.,* Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds DAS/DAT, Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds *fb* one hand weeding at 35 DAS/DAT, Bispyribac sodium (10%) 25 g

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a.i. ha^{-1} at 15 DAS/DAT, Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT, Weed free (Two hand weeding) and Weedy check in sub plot. Result revealed that significantly higher crop growth rate, relative growth rate, absolute growth rate, net assimilation rate and grain yield was recorded in system of rice intensification (SRI) during both the years of investigation. Among the weed management practices, higher value recorded with spray of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 days after sowing/days after transplanting *fb* one hand weeding at 35 DAS/DAT.

Keywords: growth indices; herbicides; system of rice intensification; weed.

1. INTRODUCTION

Rice (*Oryza sativa* L.) belongs to Poaceae family and is relished as staple food by majority (more than 60%) of the world's population. Rice plays a pivotal role in Indian agriculture, as it is the principal food crop for more than 70 per cent of the world population. Among the cereal crops, it serves as the principal source of nourishment for over half of the global population. Uttar Pradesh is the largest rice growing state only after West Bengal in the country.

Crop established in rice largely affects the initial stand and uniformity. The System of Rice Intensification (SRI) is a package of distinctive practices affecting seedling transplanting, water management, weed control along with increased use of organic nutrients. The SRI consists of a set of management practices that were mainly developed in areas with scarcity of water and labour. Direct-seeded rice can be done after conventional tillage under wet or dry soil conditions. It can also be done in zero-tilled soil or with minimum tillage operations. Direct seeded crops require less labor and tend to mature earlier than transplanted crops.

Weed infestation and competition are severe in puddled drum seeded rice as compared to transplanted rice because of the simultaneous growth of both crops and weeds. Reduction in yield to the tune of 34 per cent in transplanted rice, 45 per cent in direct seeded low land rice and 67 per cent in upland rice due to weeds were reported by Muthukrishnan et al. [1].

2. MATERIALS AND METHODS

The field experiment was conducted during kharif seasons of 2021 and 2022 at Agronomy Research farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (Uttar Pradesh, India), which is situated at latitude of 26˚47′ North and longitude 82˚12′ East and at an altitude of 113 metre above mean sea level. The climate of the site is semi-arid with hot summer and cold winter with average rainfall received during the cropping period (June-September) was 796.9 mm. The experiment was laid out in split-plot-design with three replications. Four establishment methods *viz.,* Direct seeded rice; Drum seeder technique; Transplanted rice and System of rice intensification (SRI) were taken in main plot, and six weed management practices *viz.,* Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds DAS/DAT, Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds *fb* one hand weeding at 35 DAS/DAT, Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT, Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT, Weed free (Two hand weeding) and Weedy check in sub plot. Soil was sampled before sowing/transplanting and after harvest of the crop to know the fertility status of the experimental field. The growth analysis was done as per standard procedures.

2.1 Crop Growth Rate

The rate of dry matter production per unit land area per unit time or crop growth rate (CGR) was worked out by using the following formula proposed by Watson [2] and expressed as g/m^2/day.

$$\mathrm{CGR} = \frac{1}{\mathrm{A}} \times \frac{\mathrm{W_2} - \mathrm{W_1}}{\mathrm{T_2} - \mathrm{T_1}}$$

Where,

W_1 and W_2 are dry matter of crop (g) at time t_1 and t_2 respectively.
P= Ground area covered by crop (m^2).

2.2 Relative Growth Rate

The rate of increase in dry weight per unit dry weight of crop expressed in g/g/day was calculated using the following formula suggested by Blackman [3].

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are dry weight (g) of crop at time t_1 and t_2 respectively.

2.3 Absolute Growth Rate

Absolute growth rate is expressed in g/day was calculated as follow;

$$AGR = \frac{W_2 - W_1}{T_2 - T_1}$$

Where,

W_2 and W_1 are the total dry weight of the plant (g) at time t_2 and t_1, respectively.

2.4 Net Assimilation Rate

Net Assimilation Rate is expressed in g/cm^2/day was calculated by using the formula as suggested by Williams [4] and expressed as mass /unit leaf area per unit time (g/cm^2/day).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e LA_2 - Log_e LA_1}{LA_2 - LA_1}$$

Where,

W_1 and W_2 is dry weight of plant at time t_1 and t_2 respectively. LA_1 & LA_2 is the leaf area at times T_1 and T_2 respectively.

2.5 Grain Yield (q ha^{-1})

The harvest of net plot area was threshed manually and yield was recorded plot wise and computed as q/ha.

3. RESULTS AND DISCUSSION

Crop Growth Rate (CGR) was significantly affected by crop establishment methods and weed management practices at 30-60, 60-90 and 90-120 days after sowing/days after transplanting during both the year of investigation (Table 1). Data revealed that maximum crop growth rate (19.28 and 19.90, 10.26 and 10.23, 6.79 and 6.81 during 2021 and 2022 respectively) recorded under SRI method which was at par with transplanting method and significantly higher than rest of the treatments. However, the lowest CGR (10.25 and 10.44, 9.40 and 9.34, 6.20 and 6.21) was recorded with Direct Seeded Rice (DSR) at all the stages of crop growth. CGR showed a continuously increasing trend throughout the vegetative stage this might be due to better vegetative growth under system of rice intensification at all the stages thus improving the crop growth rate [5,6].

Among the weed management practices weed free (two hand weeding) recorded maximum crop growth rate (19.65 and 20.26, 10.78 and 10.27, 7.17 and 7.20 during 2021 and 2022 respectively) which was at par with application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT while, significantly higher than rest of the treatments during both years. This might be because of the facts that rate of dry matter accumulation per unit time was directly linked with crop weed completion, happened during the course of crop growth period. The results are in close conformity with Gill and Walia [7].

Relative Growth Rate: Relative Growth Rate (RGR) was significantly affected by crop establishment methods and weed management practices at 30-60, 60-90 and 90-120 days after sowing/days after transplanting during both the year of investigation (Table 2). Data revealed that maximum relative growth rate at 30-60 DAT/DAS after that downfall recorded at successive stages during both the years of experimentation. Data further reveals that maximum RGR (36.33 and 40.73) under SRI method between 30-60 DAS/DAT while, at 60-90 and 90-120 DAS/DAT maximum RGR (14.15 and 13.81, 6.84 and 6.77) was recorded under DSR method which was significantly higher than rest of the treatments during 2021 and 2022, respectively. The results are in accordance with RGR recorded significantly higher values with DSR method over rest of the methods. This might due to compare percent of dry matter accumulation more in DSR as compare to SRI method. The results are in conformity with findings of Rashid and Datta (1986).

Among the weed management practices weed free (two hand weeding) recorded maximum relative growth rate (40.21 and 40.86) at 30-60 which was at par with application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT during both years and application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT recorded maximum relative growth rate (12.17 and 11.94,

Table 1. Crop growth rate (g m^{-2} day^{-1}) at different growth stages of rice as influenced by establishment method and weed management practices

Treatments	Crop growth rate (g m^{-2} day^{-1})					
	30-60		60-90		90-120	
	2021	2022	2021	2022	2021	2022
Methods of establishment - (Main plot)						
M_1: Direct Seeded Rice (DSR) dry seed	10.25	10.44	9.40	9.34	6.20	6.21
M_2: Drum seeder technique	15.76	15.92	9.74	9.68	6.42	6.43
M_3: Transplanted Rice	17.92	18.09	10.06	9.75	6.66	6.67
M_4: System of Rice Intensification (SRI)	19.28	19.90	10.26	10.23	6.79	6.81
SEm ±	**0.301**	**0.308**	**0.173**	**0.172**	**0.114**	**0.114**
LSD (P=0.05)	**1.04**	**1.06**	**0.58**	**0.59**	**0.39**	**0.39**
Weed management practices - (Sub plot)						
W_1: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds	13.95	14.11	9.25	9.15	6.09	6.14
W_2: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds *fb* one hand weeding at 35 DAS/DAT	15.90	16.01	10.09	10.00	6.68	6.73
W_3: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT	16.28	16.41	10.43	10.33	6.90	6.96
W_4: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT	18.56	18.60	10.71	10.95	7.10	6.89
W_5: Weed free (Two hand weeding)	19.65	20.26	10.78	10.27	7.17	7.20
W_6: Weedy check	10.50	11.13	7.95	7.82	5.19	5.23
SEm ±	**0.283**	**0.284**	**0.170**	**0.170**	**0.113**	**0.113**
LSD (P=0.05)	**0.80**	**0.81**	**0.48**	**0.48**	**0.32**	**0.32**

Table 2. Relative growth rate (g g^{-1} day^{-1}) at different growth stages of rice as influenced by establishment method and weed management practices

Treatments	Relative growth rate (g g^{-1} day^{-1} x 10^{-3})					
	30-60		60-90		90-120	
	2021	2022	2021	2022	2021	2022
Methods of establishment - (Main plot)						
M_1: Direct Seeded Rice (DSR) dry seed	26.15	28.03	14.15	13.81	6.84	6.77
M_2: Drum seeder technique	34.97	36.37	11.60	11.37	5.90	5.85
M_3: Transplanted Rice	37.15	38.14	11.00	10.62	5.68	5.68
M_4: System of Rice Intensification (SRI)	36.33	40.73	10.68	10.36	5.56	5.46
SEm ±	**0.543**	**0.665**	**0.193**	**0.189**	**0.099**	**0.097**
LSD (P=0.05)	**1.87**	**2.30**	**0.66**	**0.65**	**0.34**	**0.33**
Weed management practices - (Sub plot)						
W_1: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds	33.43	33.69	12.04	11.76	6.05	6.05
W_2: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds *fb* one hand weeding at 35 DAS/DAT	35.97	36.21	12.01	11.80	6.07	6.08
W_3: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT	36.47	36.71	12.17	11.94	6.13	6.14
W_4: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT	31.95	39.34	11.49	11.61	5.88	5.65
W_5: Weed free (Two hand weeding)	40.21	40.86	11.12	10.46	5.73	5.73
W_6: Weedy check	23.86	28.99	12.30	11.68	6.10	6.00
SEm ±	**0.625**	**0.662**	**0.208**	**0.204**	**0.105**	**0.105**
LSD (P=0.05)	**1.78**	**1.89**	**0.595**	**0.58**	**0.30**	**0.229**

6.13 and 6.14) at 60-90, 90-120 during 2021 and 2022 respectively which was significantly higher than rest of the treatments. It might be because of the facts that rate of dry matter accumulation per unit time was directly linked with crop weed competition, happened during the course of crop growth period. The results are in close conformity with Matloob et al. [8].

Absolute Growth Rate (AGR): Absolute Growth Rate (AGR) was significantly affected by crop establishment methods and weed management practices at 30-60, 60-90 and 90-120 days after sowing/days after transplanting during both the year of investigation (Table 3). Data revealed that maximum absolute growth rate (1.26 and 1.31, 0.65 and 0.67, 0.16 and 0.18 during 2021 and 2022 respectively) recorded under SRI method which was significantly higher than rest of the treatments. This might due to the better growth of plant height. The results are in close conformity with Gill et al. [9].

Among the weed management practices weed free (two hand weeding) recorded maximum absolute growth rate (1.40 and 1.48, 0.68 and 0.71, 0.16 and 0.21 during 2021-22 and 2022-23 respectively) which was at par with application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT during both years. This might be because of the facts that rate of dry matter accumulation per unit time was directly linked with crop weed completion, happened during the course of crop growth period. The results are in close conformity with Gill and Walia [7].

Net Assimilation Rate (NAR): Net Assimilation Rate (NAR) was significantly affected by crop establishment methods and weed management practices at 30-60, 60-90 and 90-120 days after sowing/days after transplanting during both the year of investigation (Table 4). Data revealed that maximum net assimilation rate (5,06 and 5.62) at 30-60 recorded under SRI method while, at 60-90 and 90-120 DAS/DAT recorded maximum NAR (2.15 and 2.16, 1.74 and 1.73) under drum seeder technique, respectively which was significantly higher than rest of the treatments during both years of experimentation. This might due to compare percent of dry matter accumulation more in drum seeder technique as compare to SRI method. Similar finding also reported by Singh et al. [10].

Table 3. Absolute growth rate (g day^{-1}) at different growth stages of rice as influenced by establishment method and weed management practices

Treatments	Absolute growth rate (g day^{-1})					
	30-60		60-90		90-120	
	2021	2022	2021	2022	2021	2022
Methods of establishment - (Main plot)						
M_1: Direct Seeded Rice (DSR) dry seed	1.00	1.02	0.57	0.58	0.141	0.145
M_2: Drum seeder technique	1.12	1.19	0.60	0.63	0.150	0.156
M_3: Transplanted Rice	1.19	1.27	0.63	0.66	0.156	0.180
M_4: System of Rice Intensification (SRI)	1.26	1.31	0.65	0.67	0.160	0.181
SEm ±	**0.017**	**0.023**	**0.011**	**0.011**	**0.002**	**0.002**
LSD (P=0.05)	**0.061**	**0.078**	**0.038**	**0.037**	**0.008**	**0.009**
Weed management practices - (Sub plot)						
W_1: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds	0.97	1.00	0.56	0.58	0.141	0.144
W_2: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds fb one hand weeding at 35 DAS/DAT	1.09	1.12	0.60	0.61	0.147	0.155
W_3: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT	1.22	1.26	0.63	0.65	0.157	0.164
W_4: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT fb one hand weeding at 35 DAS/DAT	1.36	1.45	0.67	0.70	0.166	0.182
W_5: Weed free (Two hand weeding)	1.40	1.48	0.68	0.71	0.169	0.211
W_6: Weedy check	0.83	0.87	0.53	0.55	0.130	0.136
SEm ±	**0.022**	**0.021**	**0.011**	**0.011**	**0.002**	**0.002**
LSD (P=0.05)	**0.063**	**0.059**	**0.032**	**0.033**	**0.007**	**0.008**

Table 4. Net assimilation rate (g cm^{-2} day^{-1}) and Grain yield (q ha^{-1}) at different growth stages of rice as influenced by establishment method and weed management practices

Treatments	Net assimilation rate (g cm^{-2} day^{-1})						Grain yield (q ha^{-1})	
	30-60		60-90		90-120			
	2021	2022	2021	2022	2021	2022	2021	2022
Methods of establishment - (Main plot)								
M_1: Direct Seeded Rice (DSR) dry seed	2.98	3.17	2.14	2.15	1.73	1.72	42.50	43.01
M_2: Drum seeder technique	4.63	4.74	2.15	2.16	1.74	1.73	50.90	51.40
M_3: Transplanted Rice	5.03	5.21	2.11	2.07	1.72	1.71	54.80	55.00
M_4: System of Rice Intensification (SRI)	5.06	5.62	2.09	2.11	1.70	1.70	56.40	57.61
SEm ±	**0.085**	**0.090**	**0.036**	**0.036**	**0.029**	**0.029**	**0.874**	**0.965**
LSD (P=0.05)	**0.29**	**0.31**	**0.12**	**0.12**	**0.10**	**0.10**	**3.02**	**3.33**
Weed management practices - (Sub plot)								
W_1: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds	3.84	4.20	2.04	2.03	1.65	1.65	46.80	47.31
W_2: Penoxsulam 22.5 g ha^{-1} at 2-3 leaf stage of weeds fb one hand weeding at 35 DAS/DAT	4.59	4.70	2.17	2.18	1.77	1.78	51.41	51.91
W_3: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT	4.60	4.76	2.20	2.20	1.79	1.80	53.80	54.31
W_4: Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT fb one hand weeding at 35 DAS/DAT	5.25	5.22	2.23	2.30	1.82	1.75	57.10	57.60
W_5: Weed free (Two hand weeding)	5.33	5.70	2.20	2.11	1.79	1.80	58.99	59.60
W_6: Weedy check	2.97	3.44	1.87	1.87	1.49	1.50	38.81	39.81
SEm ±	**0.078**	**0.088**	**0.037**	**0.038**	**0.030**	**0.030**	**0.941**	**0.988**
LSD (P=0.05)	**0.22**	**0.25**	**0.10**	**0.10**	**0.08**	**0.08**	**2.68**	**2.82**

Among the weed management practices weed free (two hand weeding) recorded maximum net assimilation rate (5.33 and 5.70) at 30-60 while, application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT recorded maximum net assimilation rate (2.23 and 2.30, 1.82 and 1.80) at 60-90, 90-120 during 2021 and 2022 respectively which was significantly higher than rest of the treatments. The results are in close conformity with Singh et al*.* [10].

Grain yield (q ha^{-1}): Grain yield was significantly affected by crop establishment methods and weed management practices during both the years of investigation. Data revealed that maximum grain yield (56.40 and 57.61, during 2021 and 2022 respectively) recorded under SRI method which was significantly higher than rest of the treatments and at par with transplanted rice. However, the lowest grain yield (42.50 and 43.01) was recorded with direct seed rice (DSR). Yield is the functions of inter relationship of growth in vegetative phase and yield attributes. Higher yield under SRI methods was due to better crop growth and development resulting into higher values of yield attributes which increase the grain yield. The results were similar of Yadav and Singh [11].

Among the weed management practices weed free (two hand weeding) recorded maximum grain yield (58.99 and 59.60, during 2021 and 2022 respectively) which was at par with application of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 DAS/DAT *fb* one hand weeding at 35 DAS/DAT while, significantly higher than rest of the treatments during both years. Such type of results with respect to grain yield were recorded on the lines of growth and yield attributes recorded with the respective treatment. These finding are well supported by Yadav and Singh [12].

4. CONCLUSIONS

Conclusively, System of rice intensification (SRI) with spray of Bispyribac sodium (10%) 25 g a.i. ha^{-1} at 15 days after sowing/days after transplanting *fb* one hand weeding at 35

DAS/DAT recorded the higher value of growth indices and grain yield under Agro-climatic condition of Eastern Uttar Pradesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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