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Growth and yield of rice (*Oryza sativa*) under different establishment methods and weed management practices in Uttarakhand

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ABSTRACT

An experiment was conducted during the rainy (*kharif*) seasons of 2021 and 2022 at the Norman E. Borlaug (NEB) Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand to study the effect of different establishment methods and weed management practices on growth and yield of rice (*Oryza sativa* L.). The study was carried in a split plot design with 3 replications. In main plot 4 rice establishment methods and in sub plot 4 weed management practices were included. The results revealed that significantly higher grain yield was recorded in mechanical line sowing (S_2) over rest of the treatment. According to the pooled data analysis of grain yield the per cent increase in mechanical line sowing (S_2) over broadcasting (S_1), raised bed system (S_3) and semi-dry system (S_4) was 23.1%, 17.6% and 8.1%, respectively. Among the different weed management practices grain yield was recorded maximum in W_3 (pre emergence herbicide followed by two manual weeding) treatment which showed at par results with W_2 (pre emergence followed by post emergence herbicide) treatment. The per cent grain yield increase in pre emergence herbicide followed by two manual weeding (W_3) over manual weeding (W_1), pre emergence followed by post emergence herbicide (W_2) and mechanical weeding (W_4) was 19.3%, 0.75% and 31.7%, respectively. Weed density was recorded minimum in mechanical line sowing (S_2) and raised bed system (S_3). At panicle initiation stage significantly lower weed density was recorded in mechanical line sowing (S_2). However, among the weed management practices manual weeding (W_1) and pre emergence herbicide followed by two manual weeding (W_3) treatments recorded at par. Weed dry weight remain non-significant under different rice establishment methods during active tillering as well as panicle initiation stage.

Keywords: Establishment methods, Growth, Weed density, Weed dry weight, Weed management practices, Yield

Rice (*Oryza sativa* L.) is known as "Global Food" as half of the world population depends on it for daily energy requirement (FAO 2018). In India about 46 Mha area comes under rice cultivation with a production of 129.7 Mt (Ministry of Agriculture and Farmers Welfare 2022). India contributes 21.5% of the global rice production and stands second after China. However, rice demand is increasing and the estimated increase is 26% and 50% in global rice production to meet the requirements of the burgeoning population by 2035 and 2050, respectively (IRRI 2020).

In Asia about 50% of total irrigation water is consumed in rice production which also include major part of fresh water. Traditionally, for rice cultivation puddling is an important process in which soil aggregates are broken down under saturated conditions which led to the change in physical, chemical and biological properties of soil. Increasing scarcity of irrigation water and labour acted as a major force for the adoption of alternate establishment methods that helps to eliminate the negative impact of puddling and drudgery of transplanting. Paddy cultivation in wet direct seeding system of establishment can save substantial number of labours but it has very low water saving potential. However, dry sowing of rice (DSR) is more common in areas where rice cultivation is totally dependent on rainfall (Chauhan and Johnson 2009) and with good management practices, dry direct seeding gives comparable or even higher yield than that of puddled transplanted rice with less water inputs (Bhaskar *et al.* 2022). Direct seeding also contributes up to 50% less labour requirement in crop establishment and it could be even more if the seeding is done mechanically.

Weed competition is the major factor for yield reduction in dry DSR. Although various pre-emergence herbicides provide good control of grassy weeds, but due to continuous use of these herbicides there is a shift in weed flora and

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evolution of herbicide resistant in weeds. Hence, crop selective, new generation, low dose micro-herbicides are gaining popularity among farmers for their promising role in weed control. The present study was planned to evaluate the performance of low dose herbicides under different rice establishment methods.

MATERIALS AND METHODS

The field study was carried out during the rainy (*kharif*) seasons of 2021 and 2022 at Norman E. Borlaug (NEB) Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29° N, 79.29° E and an altitude of 243.84 m amsl), Uttarakhand. The site of experiment flourishes in Tarai belt of Shivalik range of Himalayan foot hills. Soil at the experimental site was silty loam in texture with *p*H (7.8), low available N (227 kg/ha), medium available P (19.6 kg/ha) and medium in available potassium (202 kg/ha).

The experiment was laid out in split plot design and replicated thrice. The gross plot area was 4.0 m × 5.0 m and the net plot area was 3.0 m × 4.0 m. Four methods of rice establishment methods, viz. S_1, broadcasting (scattered seed manually); S_2, mechanical line sowing (sowing by furrow opener); S_3, raised bed system (1.0 m raised bed having 4 rows at 20 cm spacing with 80/20 cm dimension) and S_4, semi-dry system (sowing in dry soil and wetting was done after 1 month of sowing) were laid out in main plots. In sub plot 4 weed management practices were W_1, manual weeding (3 times, uprooting the weeds by hand or cutting with the help of sickle); W_2, pre emergence followed by post emergence herbicide (Pendimethalin @1 kg a.i./ha followed by Bispyribac Sodium @250 ml/ha in 500 litre of water); W_3, pre emergence herbicide (Pendimethalin @1 kg a.i./ha) followed by 2 manual weeding and W_4, mechanical weeding (cono-weeder 2–3 times from 25 DAS at 10–15 days of interval). Experimental field was prepared with the help of tractor drawn implements. The field was ploughed followed by 3 harrowing and then levelling was done. Paddy variety, Pant Dhan-24 was the test crop with the seed rate of 50 kg/ha for S_1 treatment and for S_2, S_3, S_4 treatment it was 25 kg/ha. Recommended dose of fertilizer @135:42:46 NPK kg/ha was applied in the field through urea, single super phosphate and muriate of potash. One third of N and full P and K were applied as basal and remaining dose of N were split into two half and applied at maximum tillering and panicle initiation stage. To manage Khaira disease two spray of zinc @5 kg with 2.5 kg slaked lime dissolved in 500 litre/ha of water were done at 15 and 25 days after sowing. Observations for growth studies were recorded from the third row on the both sides of the plot and marked as the sampling row. Weeds were sampled from each plots at active tillering and panicle initiation stages randomly by using a quadrate of size 50 cm × 50 cm (0.02/m^2) area. The weed density of each species of weeds were expressed as number/m^2 and the data were statistically analysed after subjecting the values to square root transformation. The data on yield attributes of rice were recorded at the time of harvesting. Harvesting was done manually when 90% of grains of the panicle were matured.

RESULTS AND DISCUSSION

There was significant effect of different rice establishment methods and weed management practices over weed density and weed dry weight (Table 1). According to the pooled data analysis weed density at active tillering stage was recorded minimum in S_2 establishment methods which was at par with S_3 and significantly lower number of weeds then S_1 and S_4. Under different weed management practices W_3 recorded significantly lower weed density than the rest of the treatments. Maximum weed density was recorded in S_1 treatment it might be due to uneven seed distribution which resulted in uneven seed germination and crop stand and were unable to compete with weeds. However, in the rest of the establishment methods seeds were sown in lines which helped in even crop stand at early stage and in result it provides the smothering effect on weed plant which leads to low weed density (Kaur and Singh 2017, Saha *et al.* 2021).

At panicle initiation stage in the pooled data analysis significantly lower weed density was recorded in S_2 treatment. However maximum weed density was found at par in S_1 and S_3 treatments. Among different sub plot treatments lowest weed density was recorded in W_1 which was at par with W_3 treatment and maximum weed density was recorded in W_4 in pooled data analysis. It might be due to weeding with cono-weeder which was not efficient at the initial stages of crop growth due to which weeds established themselves for the later stage and resulted in higher crop weed competition (Patel *et al.* 2018, Cordeau *et al.* 2021, Raj *et al.* 2022).

Effect of rice establishment methods were non-significant on weed dry weight at active tillering and panicle initiation stages during both the years of experiment and in pooled data analysis. In sub plots under different weed management practices, lower weed dry weight was recorded in W_2 and W_4 treatments, both were statistically similar. However, at panicle initiation stage weed management practices failed to impact on weed dry weight during both the years of experimentation.

Crop yield is a combination of various plant characters (germination, tillers, fertile panicles and 1000-grain weight) and all these characters are affected by environmental factors. Number of tillers will give an estimate of panicle bearing stalks. Several environmental factors, such as variety, light, temperature, water availability, spacing and fertilization practices influence tillering. Tillers/m^2 were significantly affected by different methods of rice establishment and weed management practices. On the basis of pooled data analysis maximum tillers/m^2 were recorded in S_2 treatment which was at par with S_4 treatment. Significantly minimum tillers/m^2 were recorded in S_1 treatment. Under different weed management practices maximum tillers/m^2 were recorded in W_3 treatment which was at par with W_2 treatment. Significantly lower tillers/m^2 were recorded in W_4 treatment (Table 2). In S_1 treatment seeds were placed manually by

Table 1 Effect of rice establishment methods and weed management practices on weed density and weed dry weight at active tillering and panicle initiation stages in rice

Treatment	Weed density (weeds/m²)						Weed dry weight (g/m²)					
	At active tillering stage (30 DAS)			At panicle initiation stage (60 DAS)			At active tillering stage (30 DAS)			At panicle initiation stage (60 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Rice establishment methods												
S_1	8.7	8.3	8.5	6.9	6.7	6.8	7.0	6.9	7.0	6.2	6.1	6.1
	(84)	(77)	(81)	(54)	(50)	(52)	(48.1)	(46.9)	(47.5)	(37.7)	(37.2)	(37.5)
S_2	6.9	6.5	6.7	5.1	5.1	5.1	7.0	6.9	7.0	6.1	6.0	6.0
	(56)	(47)	(52)	(32)	(32)	(32)	(48.1)	(46.9)	(47.5)	(36.4)	(35.6)	(36.0)
S_3	7.1	6.7	6.9	7.0	6.8	6.9	7.0	6.9	7.0	6.0	6.0	6.0
	(58)	(52)	(55)	(54)	(51)	(53)	(49.1)	(47.9)	(48.6)	(36.1)	(36.1)	(36.1)
S_4	7.0	7.0	7.0	5.9	6.1	6.0	7.1	7.0	7.0	6.2	6.1	6.1
	(53)	(57)	(55)	(40)	(42)	(41)	(49.9)	(48.8)	(49.4)	(37.7)	(36.6)	(37.2)
SEm±	0.1	0.1	0.1	0.2	0.2	0.1	0.04	0.03	0.02	0.06	0.04	0.03
CD (P=0.05)	0.4	0.4	0.2	0.6	0.6	0.4	NS	NS	NS	NS	NS	NS
Weed management practices												
W_1	6.6	6.1	6.4	4.9	4.7	4.8	7.1	7.0	7.1	6.2	6.1	6.2
	(44)	(38)	(41)	(25)	(23)	(24)	(49.6)	(48.4)	(49.0)	(38.0)	(36.8)	(37.5)
W_2	5.9	5.8	5.9	5.0	5.8	5.4	7.1	6.9	7.0	6.1	6.1	6.1
	(36)	(33)	(35)	(25)	(24)	(25)	(48.8)	(47.5)	(48.2)	(36.5)	(36.9)	(36.7)
W_3	5.3	5.0	5.2	4.8	4.8	4.8	7.2	6.8	7.1	6.2	6.0	6.1
	(28)	(25)	(27)	(24)	(23)	(24)	(50.5)	(45.3)	(49.9)	(37.7)	(36.2)	(36.9)
W_4	11	11.7	11.4	10.3	10.2	10.3	6.9	7.0	7.0	6.0	6.0	6.0
	(144)	(138)	(141)	(107)	(104)	(106)	(46.5)	(49.3)	(47.9)	(35.7)	(35.6)	(35.7)
SEm±	0.2	0.2	0.2	0.2	0.2	0.1	0.04	0.04	0.02	0.06	0.04	0.04
CD (P=0.05)	0.7	0.6	0.4	0.5	0.6	0.3	0.1	0.1	0.08	NS	NS	NS

Treatment details are given under Materials and Methods.

broadcasting which led to uneven seed distribution and resulted in poor establishment, growth and lower tillers. In line sowing, seeds were placed uniformly at fixed spacing that resulted in uniform population which helped the crop to utilize more solar radiation and more root development lead to increased water and nutrient uptake and reflected in healthier plants with increased height and tillering (Raj *et al.* 2014, Ram *et al.* 2014, Theerthana *et al.* 2021). Line sowing also facilitated the intercultural practices (weed management) which reduced the plant weed competition and increased nutrient uptake.

On the basis of pooled data analysis significantly higher and lower number of panicles/m² were recorded in S_2 and S_1 treatments, respectively. Among different weed management practices maximum number of panicles/m² were recorded in W_3 which was at par with W_2 and significantly minimum number of panicles/m² were recorded in W_1 treatment (Table 2). Good crop management practices helped in optimum tillering which facilitates synchronous panicle initiation, flowering, maturity and uniform panicle size. Thousand grain weight was recorded significantly higher in S_2 treatment and significantly lower in S_4 treatment in pooled data analysis. Thousand grain weight is genetic factor but may influence by different environmental conditions. Under different methods of establishment maximum number of tillers were formed where seed placement with proper spacing gave a chance to meet out all the growth and developmental requirement of crop without any competition (Tao *et al.* 2016). In sub plot under different weed management practices significantly higher 1000-grain weight was recorded in W_3. However it was minimum in W_3 treatment which was at par with W_1 treatment. W_3 treatment gave maximum number of tillers which also lead to maximum number of panicle/m² and due to less weed competition more 1000-grains weight resulted in maximum grain yield (Satapathy *et al.* 2017).

Grain yield was significantly higher in S_2 treatment and significantly lower in S_1. Among different weed management practices maximum grain yield was recorded in W_3 which was found at par with W_2 treatment. However significantly lower grain yield was recorded in W_4 treatment (Table 2). This might be due to increase in the number of tillers, panicles and leaf area which subsequently increased the dry matter accumulation resulted in increased grain yield. Higher yield in mechanical line sowing as compare to remaining establishment methods may be due to proper

Table 2 Effect of rice establishment methods and weed management practices on growth and yield of rice

Treatment	Tillers/m²			No. of panicles/m²			1000-grains weight (g)			Grain yield			Straw yield			Harvesting index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Rice establishment method																		
S_1	233	236	235	230	236	233	25.8	23.4	24.6	34.27	35.26	34.77	40.18	41.79	40.99	0.45	0.45	0.45
S_2	291	296	294	289	296	293	25.9	23.5	24.7	41.67	43.94	42.81	46.41	50.30	48.36	0.47	0.46	0.47
S_3	269	276	273	269	273	271	24.7	22.9	23.8	35.80	37.00	36.40	39.02	40.78	39.90	0.47	0.47	0.47
S_4	273	290	282	271	284	278	23.8	22.3	23.1	37.15	42.03	39.59	39.90	46.38	43.14	0.48	0.47	0.48
SEm±	8	2.1	5.1	8	3	2	0.5	0.03	0.04	0.99	0.54	0.48	1.43	0.88	0.66	0.002	0.002	0.001
CD (P=0.05)	29	7.6	15.52	26	10	6	1.5	0.13	0.11	3.42	1.91	1.44	4.96	3.12	1.99	0.005	0.008	0.004
Weed management practices																		
W_1	261	269	265	259	268	264	24.6	22.8	23.7	34.32	37.37	35.85	38.25	42.65	40.45	0.47	0.46	0.47
W_2	273	291	282	277	284	281	25.2	23.3	24.3	41.21	43.71	42.46	44.16	48.13	46.15	0.48	0.47	0.48
W_3	284	287	286	279	284	282	25.9	23.2	24.6	41.53	44.02	42.78	46.15	49.87	48.01	0.47	0.46	0.47
W_4	247	251	249	245	252	249	24.5	22.7	23.6	31.83	33.12	32.47	36.95	38.61	37.78	0.46	0.46	0.46
SEm±	7	1.9	3.6	6	2	2	0.3	0.04	0.04	0.08	0.53	0.31	1.08	0.84	0.51	0.002	0.003	0.002
CD (P=0.05)	22	5.8	8.9	18	5	5	1.0	0.13	0.11	2.34	1.55	0.87	3.14	2.47	0.45	0.006	0.007	0.005

Treatment details are given under Materials and Methods.

placement of seeds to soil, quicker tiller initiation leading to longer tillering period and made it possible to record maximum number of effective tillers/m^2 with higher number of panicles, which led to higher grain yield (Singh *et al.* 2006). Due to less weed infestation rice plants got the opportunity to establish properly and less completion with weeds resulted in more leaf area, more photosynthetic area and more translocation of photosynthates to the panicle and more numbers of panicles/m^2 which ultimately resulted in increased grain yield. In pooled data analysis straw yield was significantly higher in S_2 treatment and minimum straw yield was recorded in S_3 treatment which was at par with S_1 treatment. Among different weed management practices significantly higher and lower straw yield was recorded in W_2 and W_4 treatments, respectively. Low weed infestation leads to proper crop establishment in the earlier stages of crop growth which led to increase tiller production and root proliferation for better water and nutrient absorption. This resulted in increased straw yield (Singh and Singh 2010). During both the year harvest index were remain statistically similar in S_2, S_3 and S_4. Significantly low harvest index was found in S_1. Under weed management practices maximum harvest index was recorded in W_2 which was at par with W_3 and W_1 during both the growing season and in pooled data analysis (Table 2).

From the results of the present study it can be concluded that in Uttarakhand mechanical line sowing (S_2) method of rice establishment resulted in significantly higher growth, yield attributes and yield due to lower weed population, dry weight and lower crop weed competition. However, among the weed management practices, pre emergence herbicide followed by two manual weeding (W_3) was able to effectively reduce weed density and dry weight and resulted in higher yield attributes and grain yield. The results with pre emergence herbicide followed by two manual weeding (W_3) treatment was found statistically similar to pre emergence followed by post emergence herbicide (W_2) method of weed management.

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