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Cost effective agronomic management practices to enhance the productivity of direct seeded rice

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Abstract
A field experiment was conducted at S. G. College of Agriculture and Research Station, Jagdalpur, IGKV, Chhattisgarh during *Kharif* season 2022 to study the effect of different crop establishment methods and weed management practices to enhance the productivity if direct seeded rice. The result revealed that treatment S2 produced significantly taller plant, more number of tillers, higher dry matter, highest grain yield, straw yield and HI and it was on par with treatment S2; in contrast treatment S1 produced maximum number of plant population in case of different weed management practices. In case of weed management practice, plant height, number of tillers, plant dry matter, economic yield, straw yield and HI was recorded significantly higher in treatment W1 among all the treatments it was on par with treatment W3, but net return and benefit cost ratio was found significantly highest for treatment combination of S2 × W3.

Keywords: Weed management, establishment methods, economics

Introduction
More than 60% of the world's population depends on rice (*Oryza sativa* L.), a member of the poaceae family, subfamily Oryzoidea, tribe Oryzae, with chromosome number 24 (2n = 24). Rice is especially significant in Southeast Asian nations. The only cereal crop that can be cultivated in water is rice, and it is the crop that uses the most water overall (FAO, 2004) [5]. Since it has been produced for more than 6,000 years, rice has had a significant global economic, social, and cultural impact (Pathak *et al*., 2018) [9].
It is estimated that 509.29 million metric tons of rice will be produced in 2022–23 on an area of 165.22 million hectares worldwide (Anonymous, 2022a) [1]. India is the second-largest producer and consumer of rice in the world, producing 127.93 million metric tons on 45 million hectares with a productivity of about 23.9 qha^{-1} in 2021–22 (Anonymous, 2022b) [2]. The "Rice Bowl of India" is Chhattisgarh's well known moniker. In Chhattisgarh, rice is grown on an average area of 3.6 million ha, with state production fluctuating depending on rainfall from 1.2 to 1.6 t ha^{-1}. The Chhattisgarh Plain, the Bastar Plateau and the northern hill region are the three agro ecological zones in the state. The adoption of agricultural production systems, soil topography, rainfall intensity and distribution, irrigation, and other factors vary substantially between these zones (Pandey *et al*., 2010) [7].
Faster and more effective planting, improved soil quality, increased water shortage tolerance, decreased methane emissions, and even higher revenue in locations with a guaranteed water system are all advantages of DSR (Singh *et al.*, 2016) [14]. When compared to manual and mechanical transplanting techniques, rice planting, which needed less labour and was more efficient, produced more panicles in a shorter amount of time (Deng *et al*., 2020) [4].
The majority of the 1800 species considered to be rice weeds belong to the cyperaceae and poaceae families. The relative abundance of weed species in rice crops has changed as a result of direct seeding. Particularly well suited to DSR situations are *Echinochloa spp*., *Ischaemum rugosum, Cyperus divormis, and Fimbristylis miliacea*. In order to choose members of the weed flora specifically, it is essential to understand how different species respond differently to post-sowing water regimes in terms of germination and establishment. A major risk to the viability of the production system is posed by the rapid emergence of "weedy" (red) rice, which is rice that is phenotypically identical to cultivars but displays undesirable agronomic traits (Rao and Nagamani, 2007) [12]. There are several reasons for low rice productivity; the most important is weed infestation.

Rice crops suffer more from weed competition than other cereal crops. Weeds compete with crop plants for moisture, nutrients, light, space and other growth factors, resulting in a significant yield loss. The degree of competition and extent of yield losses vary greatly with rice cultures (Parmeshwari and Srinivas, 2014) [8].

With drum and direct seeding techniques, however, because there is no size difference between the crops and weed plants and because standing water has a suppressive impact on weed development at crop establishment, there is less weed infestation than with traditionally puddled transplanted rice. Weeds are a significant biological obstacle to increasing rice productivity when using the direct seeding method. Unchecked weeds diminish the production of rice by 96% when it is direct seeded, 61% when it is wet seeded, and 40% when it is transplanted (Kim and Pyoni, 1998) [6]. Therefore, early weed management is required in direct seeding situations in order to increase grain yield and the application efficiency of applied input by the crop.

Materials and Methods

The experiment was conducted at SG College of Agriculture and Research Station, Jagdalpur (CG) during *Kharif* season 2022. The experiment was laid out in split – plot design with three replications. The main plot treatment consists of three different crop establishment methods, such as S1 (Broadcasting), S2 (Dry seeded line sowing) and S3 (Mechanized line sowing of seeds by drum seeder) and in sub plots four different weed management practices, such as W1 (Manual weeding three times), W2 (Pre-emergence herbicide application of Pyrazosulfuron Ethyl 10% WP @ 200 g ha^{-1} + post-emergence herbicide application of Bispyribac sodium @ 250 ml ha^{-1}), W3 (Pre-emergence herbicide application of Pyrazosulfuron Ethyl 10% WP @ 200 g ha^{-1} + manual weeding two times) and W4 (Absolute control). Soil of the experimental site was clay loam (*Alfisol*) in texture with acidic in nature and medium organic matter and low, low and high available NPK (kg ha^{-1}) respectively.

Results and Discussion

Plant height (cm)

Plant height was significantly affected due to different treatment are presented in Table 1. The data reveals that treatment S2 (Line sowing) produced significantly taller plant at all the growth stages except at 30 DAS and it was found statistically on par with S2 (Line sowing) at harvest. As regards weed management practices, treatment W1 recorded significantly taller plant with other treatments and at 30 DAS plant height was recorded non-significant due to different treatments. The findings of the present investigation also get solid support in the norms of Singh and Singh, (2010) [13].

Interaction between establishment methods and weed management on plant height was recorded significant effect due to different treatments. Treatment S2 (Line sowing) recorded significantly taller plant at 60 DAS with W1, W2, W3 and W4 Table 2. At 90 DAS, S2 × W1, W3 and W4 shows significantly taller plant and it had on par with S3 × W1 and W3 respectively and S3 × W2 was found significantly taller plant which was at par with S2 × W2 at 90 DAS Table 3. Plant height at harvest also produce significant interaction effect due to different treatments are presented in Table 4. The data reveals that S2 × W1, W2 and W4 produce significant taller plant which was found similar result with S3 × W1 whereas S3 × W4 found statistically taller plant at 90 DAS which was found similar to the S2 × W3 and W4.

It was observed that rice without weed competition recorded a maximum plant height (cm), because of the use of more space by rice plants, and an initial canopy closure due to greater competitive capacity. Unweeded control recorded the lowest growth parameters, which may be due to greater physical compression and competition with the increasing weed population. Similar findings were also reported by Saha *et al.*, (2021) [13], Pavithra *et al.*, (2021) [10], Bhurer *et al.*, (2013) [3], Rao *et al.*, (2007) [12], and Singh *et al.*, (2007) [15].

Number of tillers ($hill^{-1}$)

Number of tillers significantly increases with increase of growth stages are presented in Table 5. Treatment S2 produced significantly more number of tiller at all the growth stages than the S1 and S3 but it was found on par with treatment S3 at 30, 60 and 90 DAS. in case of weed management practices, at 30 DAS it had not produced significant difference among all the weed management practices but numerically higher number of tiller was recorded in treatment W1 followed by W2. At 60, 90 DAS and at harvest, treatment W1 produced maximum number of tillers per hill compare to all other treatment at 60, 90 DAS and at harvest. This result is in conformity with the findings of Pavithra *et al.*, (2021) [10].

Interaction effect on number of tillers due to different growth stages was found significant and it is presented in Table 6, 7 and 8. The data reveals that interaction between establishment methods and weed management practices, found significantly in treatment S × W1, W2, W3 and W4 which was on par with treatment S3 × W1, W2, W3 and W4 at 60, S3 × W2, W3 and W4 at 90 DAS and S3 × W4 at harvest.

Dry matter accumulation (g $hill^{-1}$)

The data present in Table 9. Shows that treatment S2 produced significantly higher dry matter accumulation at all the growth stages due to establishment methods except at 30 DAS but it had found on par with treatment S3 at 60 DAS whereas at 30 DAS, dry matter accumulation did not affect due to different establishment methods however in case of weed management practices treatment W1 was found significantly higher dry matter accumulation. Similar findings were reported by Pavithra *et al.*, (2021) [10].

Interaction between different establishment methods × weed management practices, show significantly higher in S3 × W1 and W2 but it was produced similar result with S2 × W1 and W2. Treatment S3 × W3 and W4 was found significantly higher der matter accumulation which was found on par with S3 × W3 and W4 at 60 DAS Table 10. Dry matter accumulation at 90 DAS and at harvest are presented in Table 11 and 12. The data reveals that interaction between establishment methods × weed management practices are recorded significantly higher in treatment S2 × W1, W2, W3 and W4 which had produced similar result for S3 × W4 at harvest.

Test weight, Grain yield, straw yield and Harvest index

Treatment S2 produced significantly highest economic yield, straw yield and harvest index under different establishment method and lowest economic yield and HI was found in treatment S1. In case of weed management practices, W1 was recorded significantly highest grain yield, straw yield and HI among all weed management practices but HI was found statistically on par with W3 whereas, lowest economic yield

and HI was recorded in Treatment W4 Table 13.
The findings regarding the attributes of the yield and the yield that changed as a result of the establishment methods are closely in agreement with those findings previously reported by Pavithra *et al*., (2021) [10].
Interaction effect between establishment methods and weed management practices, on grain yield, straw yield and HI are presented in Table 14, 15 and 16. Treatment S2 × W1, W2, W3 and W4 produced significantly higher interaction effect than the S1 and S3 in grain yield, Straw yield and HI but it had found significantly at par in harvest index with S3 × W1, S1 × W3 but establishment methods × W4 was not found significant effects. Test weight did not affect due to different establishment methods and weed management practices. This is similar to the results of Singh *et al.*, 2005 [16], Pavithra *et al*., (2021) [10], Bhurer *et al.*, (2013) [3].

Table 1: Effect of different establishment methods and weed management practices on plant height

Treatment	Plant height (cm)			
	30DAS	60DAS	90DAS	At harvest
Establishment methods				
S1 Broadcasting	27.08	55.53	86.96	93.65
S2 Line sowing	27.47	65.94	97.34	101.97
S3 Drum seeding	27.41	63.20	95.09	100.71
S.Em±	0.20	0.24	0.38	0.21
CD at 5%	NS	0.97	1.54	0.84
CV %	13.38	10.62	13.68	7.24
Weed management practices				
W1 Three manual weeding	27.36	68.97	100.54	105.68
W2 Pre + post emergent herbicide	27.14	58.74	93.55	98.66
W3 Pre + two manual weeding	27.79	64.92	98.09	103.26
W4 Absolute control	27.00	53.59	80.34	87.50
S.Em±	0.27	0.39	0.46	0.38
CD at 5%	NS	1.18	1.38	1.14
CV %	15.40	15.04	14.37	11.52

Table 2: Interaction between establishment methods and weed management practices on plant height at 60 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	62.01	53.37	57.40	49.32
S2 Line sowing	73.72	63.40	69.08	57.55
S3 Drum seeding	71.19	59.44	68.28	53.89
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.48	2.14		15.04

Table 3: Interaction between establishment methods and weed management practices on plant height at 90 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	92.17	86.53	90.51	78.64
S2 Line sowing	105.36	96.59	102.71	84.68
S3 Drum seeding	104.07	97.53	101.04	77.71
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.76	2.59		14.37

Table 4: Interaction between establishment methods and weed management practices on plant height at harvest

Treatment	W1	W2	W3	W4
S1 Broadcasting	98.52	93.86	95.42	86.79
S2 Line sowing	109.77	102.76	107.08	88.26
S3 Drum seeding	108.74	99.36	107.27	87.46
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.42	2.06		11.52

W1- Three manual weeding, W2- Pre + post emergent herbicide, W3- Pre + two manual weeding and W4- Absolute control

Table 5: Effect of different establishment methods and weed management practices on tillers

Treatment	Tillers hill^{-1}			
	30DAS	60DAS	90DAS	At harvest
Establishment methods				
S1 Broadcasting	1.08	2.64	3.18	3.33
S2 Line sowing	1.24	3.58	4.21	4.32
S3 Drum seeding	1.22	3.44	3.99	4.05
S.Em±	0.01	0.04	0.07	0.02
CD at 5%	0.03	0.16	0.29	0.06
CV %	2.91	7.68	12.78	2.77
Weed management practices				
W1 Three manual weeding	1.19	3.95	4.86	4.92
W2 Pre + post emergent herbicide	1.19	2.93	3.51	3.61
W3 Pre + two manual weeding	1.18	3.58	4.03	4.23
W4 Absolute control	1.16	2.42	2.78	2.84
S.Em±	0.02	0.05	0.07	0.02
CD at 5%	NS	0.13	0.22	0.07
CV %	4.12	7.48	11.48	3.58

Table 6: Interaction between establishment methods and weed management practices on tillers at 60 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	2.98	2.46	2.82	2.30
S2 Line sowing	4.51	3.27	4.04	2.49
S3 Drum seeding	4.36	3.05	3.89	2.47
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.08	0.25		7.48

Table 7: Interaction between establishment methods and weed management practices on tillers at 90 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	3.67	3.14	3.54	2.39
S2 Line sowing	5.72	3.80	4.33	3.00
S3 Drum seeding	5.18	3.59	4.23	2.95
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.14	0.43		11.48

Table 8: Interaction between establishment methods and weed management practices on tillers at harvest

Treatment	W1	W2	W3	W4
S1 Broadcasting	3.93	3.29	3.68	2.41
S2 Line sowing	5.54	3.92	4.74	3.07
S3 Drum seeding	5.28	3.62	4.27	3.03
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.03	0.13		3.58

W1- Three manual weeding, W2- Pre + post emergent herbicide, W3- Pre + two manual weeding and W4- Absolute control

Table 9: Effect of different establishment methods and weed management practices on dry matter accumulation

Treatment	Dry matter accumulation (g hill^{-1})			
	30DAS	60DAS	90DAS	At harvest
Establishment methods				
S1 Broadcasting	0.32	2.90	14.18	25.28
S2 Line sowing	0.35	3.47	20.05	32.45
S3 Drum seeding	0.33	3.45	18.70	30.68
S.Em±	0.01	0.02	0.09	0.06
CD at 5%	NS	0.08	0.37	0.23
CV %	5.47	3.49	7.64	3.64
Weed management practices				
W1 Three manual weeding	0.37	3.93	21.86	36.56
W2 Pre + post emergent herbicide	0.33	2.98	16.20	28.51
W3 Pre + two manual weeding	0.34	3.63	20.26	32.46
W4 Absolute control	0.30	2.55	12.26	20.35
S.Em±	0.01	0.05	0.12	0.12
CD at 5%	0.03	0.16	0.36	0.35
CV %	5.47	8.74	8.45	6.49

Table 10: Interaction between establishment methods and weed management practices on dry matter accumulation at 60 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	3.30	2.83	3.22	2.25
S2 Line sowing	4.21	2.93	3.96	2.79
S3 Drum seeding	4.26	3.19	3.72	2.62
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.04	0.28		8.74

Table 11: Interaction between establishment methods and weed management practices on dry matter accumulation at 90 DAS

Treatment	W1	W2	W3	W4
S1 Broadcasting	17.49	12.20	16.45	10.59
S2 Line sowing	24.52	18.82	23.09	13.78
S3 Drum seeding	23.59	17.57	21.23	12.41
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.19	0.66		8.45

Table 12: Interaction between establishment methods and weed management practices on dry matter accumulation at harvest

Treatment	W1	W2	W3	W4
S1 Broadcasting	30.93	22.77	28.41	19.00
S2 Line sowing	40.76	32.64	35.16	21.22
S3 Drum seeding	37.99	30.12	33.81	20.82
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.12	0.63		6.49

W1- Three manual weeding, W2- Pre + post emergent herbicide, W3- Pre + two manual weeding and W4- Absolute control

Table 13: Effect of different establishment methods and weed management practices on economic yield and harvest index

Treatment	Test weight (g)	Yield (kg ha^{-1})		
		Grain	Straw	HI (%)
Establishment methods				
S1 Broadcasting	25.37	3191.25	4649.58	40.60
S2 Line sowing	26.01	3825.25	5080.79	42.47
S3 Drum seeding	25.92	3603.57	4950.25	41.75
S.Em±	0.31	19.94	15.30	0.18
CD at 5%	NS	80.38	61.70	0.73
CV %	4.17	116.08	75.78	9.77
Weed management practices				
W1 Three manual weeding	26.16	4423.09	5762.22	43.35
W2 Pre + post emergent herbicide	25.64	3550.33	5205.44	40.52
W3 Pre + two manual weeding	25.85	4280.89	5730.94	42.67
W4 Absolute control	25.41	1905.78	2875.56	39.89
S.Em±	0.37	30.11	21.78	0.23
CD at 5%	NS	90.17	65.21	0.70
CV %	4.31	151.84	93.40	10.89

Table 14: Interaction between establishment methods and weed management practices on grain yield

Treatment	W1	W2	W3	W4
S1 Broadcasting	3882.67	3304.67	3753.00	1824.67
S2 Line sowing	4821.33	3864.33	4656.67	1958.67
S3 Drum seeding	4565.28	3482.00	4433.00	1934.00
Interaction (E×W)	S.Em±	CD at 5%		CV %
	39.88	165.00		151.84

Table 15: Interaction between establishment methods and weed management practices on straw yield

Treatment	W1	W2	W3	W4
S1 Broadcasting	5497.67	4886.67	5479.00	2735.00
S2 Line sowing	5980.00	5396.33	5961.83	2985.00
S3 Drum seeding	5809.00	5333.33	5752.00	2906.67
Interaction (E×W)	S.Em±	CD at 5%		CV %
	30.61	119.99		93.40

Table 16: Interaction between establishment methods and weed management practices on harvest index

Treatment	W1	W2	W3	W4
S1 Broadcasting	41.39	40.34	40.64	40.03
S2 Line sowing	44.64	41.73	43.86	39.64
S3 Drum seeding	44.01	39.50	43.53	39.98
Interaction (E×W)	S.Em±	CD at 5%		CV %
	0.36	1.30		10.89

W1- Three manual weeding, W2- Pre + post emergent herbicide, W3- Pre + two manual weeding and W4- Absolute control

Table 17: Effect of different establishment methods and weed management practices on Economics

Treatment	Economics		
	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C Ratio
Establishment methods			
S1 Broadcasting	70535	30329	1.73
S2 Line sowing	83116	43510	2.06
S3 Drum seeding	78633	39027	1.95
S.Em±			0.01
CD at 5%			0.02
Weed management practices			
W1 Three manual weeding	96812	51284	2.13
W2 Pre + post emergent herbicide	77632	39592	2.04
W3 Pre + two Manual weeding	93514	51386	2.22
W4 Absolute control	41753	8225	1.25
S.Em±			0.01
CD at 5%			0.04

Table 18: Interaction between establishment methods and weed management practices on benefit cost ratio

Treatment	W1	W2	W3	W4
S1 Broadcasting	1.88	1.88	1.96	1.18
S2 Line sowing	2.30	2.23	2.41	1.29
S3 Drum seeding	2.20	2.02	2.30	1.27
Interaction (E×W)	S.Em±	CD at 5%		
	0.01	0.06		

Conclusion

On the basis of a one year study during Kharif 2022 at Bastar Plateau, the experiment on the effect of different establishment methods and weed management practices concluded that:

Among the different establishment methods, treatment S2 (line sowing), exhibited better expression in respect of crop growth and yield and yield attributing characters, GR, NR, BCR as compared to treatment S1 (broadcasting). However, S3 (drum seeding) was also recorded as significantly superior to treatment S1 (broadcasting of seeds).

Among the different weed management practices, treatment W1 (Manual weeding three times at 20, 40, and 60 DAS) showed greater expression in terms of crop growth parameters, yield attributing characters and yield as compared to the treatments *viz.*, W2, W3 and it was also recorded significantly superior to the treatment W4 – weed control.

Economics, i.e., net returns and benefit cost ratio, were significantly higher in treatment W3 (Pre-emergence herbicide application of Pyrazosulfuron Ethyl 10% WP @ 200g ha-1 + manual weeding two times) due to different weed management practices.

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