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RESEARCH ARTICLE

Black rice cultivars as a component of integrated weed management in direct-seeded rice at Nagaland

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ABSTRACT

Black rice also known **"***Chakhao*" in Manipuri language is unique due to its purplish black colour because of its high anthocyanin content and its multiple health benefits. Weeds are of major concern as they compete severely with black rice and to minimize adverse impact of weeds on black rice, integration of different weed management strategies including competitive cultivars and herbicides are required as components of weed management. Hence a study was conducted with an objective to identify effective integrated weed management method to manage weeds and improve productivity of black rice. The highest growth, yield attributes and yield of black rice was recorded with hand weeding (HW) twice at 15 and 30 days after seeding (DAS) and was closely followed by pre-emergence application (PE) of pretilachlor 1.0 kg/ha followed by (*fb*) HW at 40 DAS. Among cultivars, Chakhao poireiton and Wairi chakhao recorded maximum and minimum growth, yield attributes and yield, respectively. The lowest weed density, biomass and nutrient depletion was observed with hand weeding twice at 15 and 30 DAS and cultivar Chakhao poireiton which also recorded the highest cost of cultivation and gross returns during both the years.

Keywords: Bispyribac-sodium, Black rice, Hand weeding, Pretilachlor, Weeds and Integrated Weed management

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most significant cereal crops worldwide with 90% of the world's rice cultivation occurring in Asia (Lei and Yuan 2019). Rice is providing nourishment to more than half of the world population and is known as one of the significant crops (Bin and Zhang 2023). Worldwide demand for rice is expected to increase by more than 40% by 2050 to meet the requirements of the growing population (Mohammed *et al.* 2021, Rao 2022). Black rice, also known as forbidden rice, is drawing attention in recent times for to its nutraceutical properties like antioxidant, fiber, vitamins, anticarcinogenic and mineral content (Kushwaha *et al.* 2016). Among the different rice establishment methods, the success of upland direct-seeded rice (DSR) is significantly hampered by weed competition since weeds are denser in this system as compared to a transplanting, because of the lack of standing water during the initial stages (Rao *et al.* 2007). Therefore, management of weeds is of outmost importance to achieve higher outcome in direct-seeded rice (Rao and Matsumoto 2017) as weeds cause around 67% loss in yield of DSR (Kashyap *et al.* 2019). Weeds are very diverse and complex in the rice field and it is advisable to integrate different weed management practices instead of using a single management practice (Rao *et al.* 2014, 2020). Competitive cultivars of rice are characterized with higher early vigour, increased leaf area, biomass accumulation, increased ground cover by canopy, more tillering, increased height and early maturity (Ramesh *et al.* 2017, Dhillon *et al.* 2021). Additionally, different weed competitive abilities differ with the varied cultivars of rice based on their diverse morphological traits and it becomes crucial to grow cultivars that can have a smothering effect on weeds to reduce the negative effect on the main crop (Ramesh *et al.* 2017). Thus, inclusion of weed suppressing cultivars as a component of integrated weed management (IWM) strategies is of prime importance to maximize the crop yields. Hence a study was conducted with an objective to identify effective integrated weed management method, with rice cultivars and herbicides as components, to manage weeds and improve productivity of black rice.

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MATERIALS AND METHODS

The present study was conducted in the experimental field of School of Agricultural Sciences

(SAS), Medziphema Campus, Nagaland University during the *Kharif* season of 2021 and 2022. It lies in humid sub- tropical region with average rainfall ranging from 2000-2500 mm yearly. The mean summer ranging from 21ºC to 32 ºC and during winter temperature rarely goes below 8ºC due to high atmospheric humidity. Weather condition in the experimental farm varied throughout the growing duration. Total rainfall during the cropping season (from July to December) in 2021 and 2022 was 829.9 mm and 1070.8 mm respectively. The average maximum temperature in both years was recorded in August at 34.4°C and 34.1°C, and the lowest temperature was recorded in December at 11.4°C and 12.0°C respectively. The initial nutrient content of soil was analysed in the experimental field which resulted that the soil was highly acidic (pH 4.75) with high carbon content (1.52%) low levels of available Nitrogen, high level of phosphorous and medium potassium (250.55, 34.88, 148.21 kg/ha) respectively. The treatments were laid out in Split Plot Design (SPD) with four integrated weed management in the main plot *viz.* weedy check (control), hand weeding (HW) twice at 15 and 30 days after seeding (DAS), by pre-emergence application (PE) of pretilachlor 1.0 kg/ha followed by (*fb*) HW at 40 DAS and pretilachlor 1.0 kg/ha PE *fb* post-emergence application (PoE) of bispyribac-sodium 25 g/ha at 20 DAS; while four cultivars, *viz.* Chakhao poireiton, Chakhao amubi, Wairi chakhao and Khurukhul chakhao were assined in the sub-plots. Each of the experimental plot size was 4 × 3m. The seed rate of 80 kg/ha was used. Rice seed was directly sown maintaining a row-to-row distance of 20 cm and 10 cm for plant to plant. Irrespective of the treatments Farm Yard Manure (10 t /ha) was applied evenly on the entire field during its preparation. Fertilizers (Nitrogen, Phosphorous and Potassium) in the form of urea, SSP and MOP were applied uniformly in each plot. Urea was applied in split doses before sowing and at tillering stage while full doses of SSP and MOP were applied before sowing as basal application. Further, for observations on weeds studies, *viz.* weed density and weed biomass, 1 m^2 quadrat was randomly placed in each plot and observations were recorded using standard recommended procedures. Weed density and weed biomass square root transformed respectively for uniform results for statistical analysis of the data. Growth parameters, yield, economics and nutrient depletion were also recorded. The 5 % level probability of critical differences was used to compare significant differences between the treatment means.

RESULTS AND DISCUSSION

Effect on weeds

The tested weed management treatments significantly controlled the grasses, sedges and broad-leaved weeds at 40 DAS (**Table 1**). Pooled data from the two years experiment revealed minimum weed density and biomass with hand weeding twice at 15 and 30 DAS and it was closely followed by pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS which was at par with pretilachlor 1.0 kg/ha PE *fb* bispyribac-sodium 25 g/ha PoE at 20 DAS confirming the findings of Karthika *et al.* (2019). The maximum weed density and biomass was observed in weedy check, where weeds dominated the crops in utilizing all the required nutrients, light, moisture as also observed by Parihar *et al.* (2020).

Pooled data of observation at 40 DAS on weeds density and biomass also showed variations with different cultivars studied. Among the four cultivars,

Table 1. Effect of integrated weed management treatments with black rice cultivars as a component on weed density (no./m^2) weed biomass (g/m^2) at 40 days after sowing (DAS) (pooled data two years)

Treatment	Grasses		Sedges		Broad-leaved weed	
	Weed density	Weed biomass	Weed density	Weed biomass	Weed density	Weed biomass
Weed management						
Weedy check (control)	11.92(143.5)	7.45(55.7)	7.80(60.7)	7.46(55.6)	9.47(90.2)	8.03(64.8)
Hand weeding twice at15 and 30 DAS	6.20(41.0)	4.68(22.9)	4.48(20.2)	4.07(16.5)	5.46(31.2)	4.54(21.1)
Pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS	8.66(76.8)	6.05(36.9)	6.01(36.3)	5.82(34.1)	7.07(51.3)	5.58(32.0)
Pretilachlor 1.0 kg/ha PE *fb* bispyribac-sodium 25g/ha PoE at 20 DAS	8.78(78.3)	6.15(37.9)	6.31(39.8)	6.14(37.8)	7.00(50.3)	5.40(29.8)
LSD (p=0.05)	0.61	0.41	0.29	0.31	0.40	0.33
Cultivar						
Chakhao poireiton	7.33(60.3)	5.13(28.06)	5.39(30.50)	5.20(28.49)	5.67(34.83)	4.58(22.85)
Chakhao amubi	8.55(77.8)	5.94(35.90)	5.99(37.17)	5.72(33.97)	6.91(49.67)	5.67(33.57)
Wairi chakhao	10.45(113.3)	6.98(49.37)	6.91(48.83)	6.57(44.37)	8.78(78.67)	7.14(52.33)
Khurukhul chakhao	9.23(88.2)	6.28(39.97)	6.29(40.50)	5.99(37.08)	7.65(59.83)	6.16(38.97)
LSD (p=0.05)	0.68	0.45	0.38	0.38	0.38	0.30

Original values were subjected to square root transformation. Figures in parentheses are the original value; *PE- Pre emergence application, PoE- Post emergence application, DAS- days after sowing; *fb* - followed by

Cultivar Chakhao poireiton recorded lowest weed density and biomass which was followed with Chakhao amubi. The maximum weed density and biomass at 40 DAS was associated with rice cultivar Wairi chakhao.

Effect on growth and yield attributes

The two years pooled data of rice growth at 90 DAS and at rice harvest revealed maximum plant height, dry matter accumulation, The rice growth rate (CGR) and grain yield was highest with hand weeding twice at 15 and 30 DAS and it was closely followed with pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS (**Table 2**). This could be attributed to effective weed suppression by those treatments reducing intra and inter competition and favor on the growth and development of crop for various growth-related factors (Ahmed *et al.* 2020). The weedy check recorded the significantly lowest rice growth, yield attributes and yield due to severe weed competition throughout the growing period (Nazir *et al.* 2020).

Further, different cultivars also showed variations in growth and yield parameters at 90 DAS where highest plant height, dry matter and CGR was recorded with Chakhao poireiton and was statistically at par with Chakhao amubi. However, highest grain yield was observed with rice cultivar Chakhao poireiton. The lower growth parameters were recorded with rice cultivar Wairi chakhao, during both the years, which was statically at par with Khurukhul chakhao. The observed variation among different rice cultivars might be attributed to their varietal origin and environmental conditions during the growing season that could have impacted the overall differences among the cultivars as reported earlier by Kujur *et al.* (2017).

Effect on nutrient depletion

The treatment combinations of integrated weed management and different cultivars from the pooled data of two years revealed differences in nutrient depletion by weeds where minimum depletion of all the three nutrients (nitrogen, phosphorous and potassium) was with hand weeding twice at 15 and 30 DAS and with cultivar Chakhao poireiton (**Table 3**). This may have been due to timely control of weeds during the critical stages that created a favorable condition for the rice to use applied nutrients leading to prolific rice growth while keeping the weed growth under control (Sanodiya and Singh 2021). The treatment combination of weedy check with cultivar Wairi chakhao resulted in maximum depletion of the nutrients by weeds as uncontrolled weed growth led to higher weed density and biomass and greater competition with rice for nutrients (Sharma *et al.* 2018).

Economics

The highest cost of cultivation was incurred with hand weeding twice at 15 and 30 DAS (**Table 3**), due to higher requirement of labours for manual weeding and higher labor wages that increased labour cost for hand weeding (Yogananda *et al.* 2017). This was followed by pretilachlor 1.0 kg/ ha PE *fb* HW at 40 DAS. The highest gross return was observed with hand weeding at 15 and 30 DAS. Similar findings were reported by Gangireddy *et al.* (2019). The highest net returns were recorded with the above treatments in combination with the rice variety Chakhao poireiton. Among the cultivars, all four cultivars incurred the same cost of cultivation while Chakhao poireiton recorded maximum gross and net returns.

Correlation analysis

Table 2. Effect of integrated weed management treatments with black rice cultivars as component on growth parameters yield of black rice

Treatment	Plant height at 90 DAS			Dry matter accumulation (g/m^2) at 90 DAS			CGR at 60-90 DAS			Grain yield (kg/ha)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Weed management												
Weedy check (control)	76.44	78.17	77.31	12.18	12.29	12.24	11.97	12.12	12.05	1067	1086	1077
Hand weeding twice 15 and 30 DAS	100.21	101.99	101.10	19.45	19.82	19.64	19.97	20.48	20.23	1870	1873	1871
Pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS	92.74	93.79	93.26	16.05	16.41	16.23	15.99	16.45	16.22	1686	1693	1690
Pretilachlor 1.0 kg/ha PE *fb* bispyribac sodium 25g/ha PoE at 20 DAS	86.05	87.76	86.91	13.78	13.91	13.85	13.47	13.64	13.56	1268	1272	1270
LSD (p=0.05)	4.49	4.69	2.89	0.79	1.10	0.60	0.86	1.70	0.85	93.21	111.27	64.62
Cultivar												
Chakhao Poireiton	91.69	92.97	92.33	17.03	17.19	17.11	17.42	17.65	17.54	1553	1561	1557
Chakhao Amubi	89.43	91.46	90.45	15.87	16.14	16.01	16.03	16.36	16.20	1508	1520	1514
Wairi Chakhao	86.08	87.11	86.59	13.74	13.99	13.86	13.39	13.71	13.55	1389	1397	1393
Khurukhul Chakhao	88.25	90.18	89.21	14.82	15.12	14.97	14.57	14.98	14.77	1440	1446	1443
LSD (p=0.05)	3.80	4.16	2.75	0.78	0.66	0.50	1.27	1.12	0.83	62.52	62.64	43.11

*PE: pre-emergence application; PoE: post-emergence application; DAS: days after sowing; *fb:* followed by; CGR: crop growth rate

Table 3. Effect of integrated weed management treatments on nutrient depletion by weeds and economics of direct-seeded black rice

Treatment	Nitrogen (kg/ha)			Phosphorous (kg/ha)			Potassium (kg/ha)			Cost of cultivation ($x10^3$ Rs/ha)			Gross returns ($x10^3$ Rs/ha)			Net returns ($x10^3$ Rs/ha)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
W1C1	23.93	19.93	21.93	15.57	13.45	14.51	42.49	37.20	39.85	36.04	36.04	36.04	93.85	94.92	94.39	57.81	58.88	58.35
W_1C_2	29.20	34.02	31.61	18.87	20.43	19.65	53.40	55.63	54.51	36.04	36.04	36.04	91.76	94.07	92.92	55.72	58.03	56.88
W_1C_3	36.13	35.90	36.02	25.22	24.98	25.10	69.71	68.45	69.08	36.04	36.04	36.04	82.14	84.06	83.10	46.10	48.02	47.06
W_1C_4	34.13	33.90	34.02	20.28	22.08	21.18	57.32	60.32	58.82	36.04	36.04	36.04	85.78	86.82	86.30	49.74	50.78	50.26
W_2C_1	2.57	2.55	2.56	0.93	0.86	0.89	1.78	1.66	1.72	48.04	48.04	48.04	161.05	161.44	161.25	113.01	113.40	113.20
W_2C_2	4.35	4.00	4.17	1.46	1.43	1.44	2.89	2.70	2.80	48.04	48.04	48.04	155.97	156.15	156.06	107.93	108.11	108.02
W_2C_3	7.68	5.97	6.83	3.03	2.63	2.83	6.41	5.28	5.84	48.04	48.04	48.04	147.36	147.72	147.54	99.32	99.68	99.50
W_2C_4	4.77	5.04	4.90	1.88	1.92	1.90	3.80	3.85	3.83	48.04	48.04	48.04	150.07	150.58	150.32	102.03	102.54	102.28
W_3C_1	6.58	7.17	6.87	2.17	2.35	2.26	11.22	12.52	11.87	41.44	41.44	41.44	143.52	143.99	143.76	102.08	10.25	102.31
W_3C_2	9.23	8.65	8.94	3.30	2.89	3.10	16.16	14.67	15.41	41.44	41.44	41.44	141.57	142.63	142.10	100.13	101.19	100.66
W_3C_3	12.03	13.30	12.67	5.27	4.98	5.13	23.49	23.14	23.32	41.44	41.44	41.44	132.64	133.15	132.89	91.20	91.71	91.45
W_3C_4	11.73	10.55	11.14	4.34	3.68	4.01	20.69	18.23	19.46	41.44	41.44	41.44	136.81	137.06	136.94	95.37	95.62	95.50
W_4C_1	7.32	8.68	8.00	4.33	4.94	4.63	11.53	13.63	12.58	37.53	37.53	37.53	113.21	113.88	113.55	75.68	76.35	76.02
W_4C_2	10.36	11.22	10.79	6.27	6.64	6.45	16.33	17.26	16.80	37.53	37.53	37.53	107.72	108.26	107.99	70.19	70.73	70.46
W_4C_3	17.36	14.12	15.74	11.07	9.05	10.06	28.47	23.78	26.13	37.53	37.53	37.53	95.87	96.05	95.96	58.34	58.52	58.43
W_4C_4	11.74	12.84	12.29	7.31	7.34	7.32	18.69	19.72	19.21	37.53	37.53	37.53	102.36	102.58	102.47	64.83	65.05	64.94
LSD (p=0.05) (WxC)	3.23	4.62	2.74	1.33	2.58	1.41	3.73	6.63	3.71	-	-	-	-	-	-	-	-	-
LSD (p=0.05) (CxW)	3.74	5.67	4.41	1.55	2.96	2.21	4.46	7.99	5.95	-	-	-	-	-	-	-	-	-

*****W_1=Weedy check (Control), W_2=Hand weeding twice at 15 and 30 DAS, W_3=pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS, W_4=pretilachlor 1.0 kg/ha PE *fb* bispyribac-sodium 25 g/ha PoE at 20 DAS, C_1=Chakhao poireiton, C_2=Chakhao amubi, C_3=Wairi chakhao, C_4= Khurukhul chakhao; *PE- pre-emergence application, PoE- post-emergence application, DAS- days after sowing, *fb* - followed by

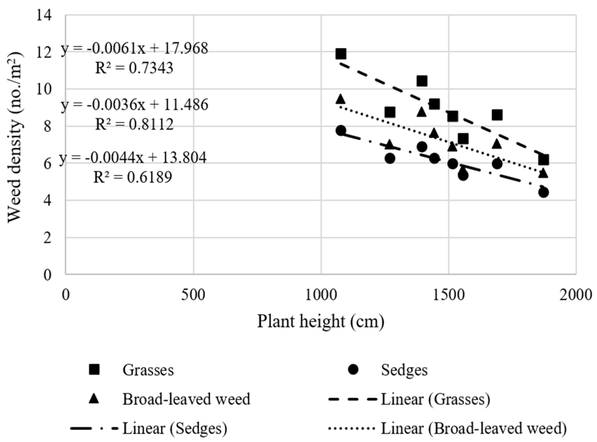

Figure 1. Relationship between rice plant height (cm) and weed density (no./m²)

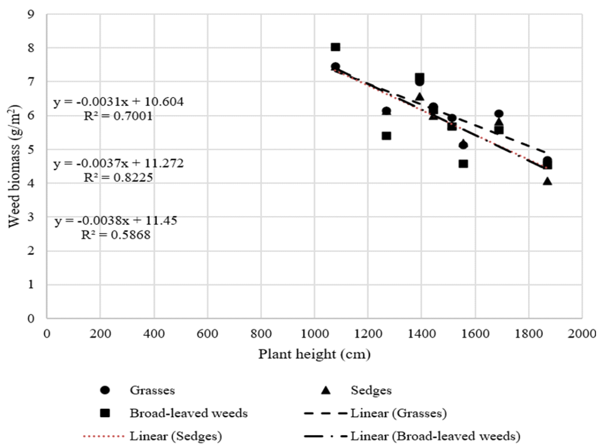

Figure 2. Relationship between rice plant height (cm) and weed biomass (g/m²)

There was a negative correlation between rice plant height and weed density. The coefficient of negative correlation between rice plant height and weed density and biomass indicates that weeds negatively impacted the crop growth and eventually reduced the yield (**Figure 1** and **2**)

Conclusion

During both the years, hand weeding twice at 15 and 30 DAS was effective in managing weeds but keeping in view of the continuous increased labour cost for hand weeding, it would be advantageous growing of black rice cultivar Chakhao poireiton with pretilachlor 1.0 kg/ha PE *fb* HW at 40 DAS for effectively and economically managing weeds in direct-seeded rice with higher rice yield and farmers income under Nagaland conditions.

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