Effect of Different Weed Management Practices on Growth and Yield of Aerobic Rice (Oryza sativa L.)

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Effect of Different Weed Management Practices on Growth and Yield of Aerobic Rice (*Oryza sativa* L.)

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ABSTRACT

The field investigation was conducted at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bangalore during 2017 to study the effect of different weed management practices on growth and yield of rice under aerobic condition. The experiment was laid out in a randomized complete block design (RCBD) with 11 treatments and three replications. The results revealed that among different weed management practices, stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early post-emergent (PoE) spray + one intercultivation (IC) @ 40 DAS recorded significantly higher grain yield (5987 kg ha^{-1}), straw yield (9944 kg ha^{-1}), productive tillers per hill (42.50), panicle length (25.40 cm), 1000 grain weight (26.27 g) and nutrient uptake by crop (134.22, 43.95 and 131.55 kg NPK ha^{-1}, respectively), while it recorded lower weed count (10), weed dry weight (6.88 g/0.25 m^2) and nutrient uptake by weeds (7.63, 1.51 and 4.93 kg NPK ha^{-1}, respectively). However, it was on par with straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as PoE , pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as pre-emergent (PE) spray *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE, pendimethalin 30 per cent EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE and pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practices. Higher net returns and higher benefit-cost ratio was obtained with the application of pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice.

Keywords: Weeds, rice, yield, weed control efficiency, weed index, economics

RICE is the world's most important staple food crop for more than half of the world's population, occupying a prime place after wheat and is the main source of carbohydrate, protein and calories for a large section of the population. More than 90 per cent of the world's rice is produced and consumed in Asia, where 60 per cent of the world population lives. Globally, rice occupies an area of 147 million hectares with production of 525 million tonnes. In India, it is produced in an area of 46.19 million hectares with a production of 106.29 million tonnes and productivity of 2462 kg ha^{-1}. In Karnataka, rice covers an area of 1.34 million hectares with 9.35 million tonnes production per annum and productivity of 3098 kg ha^{-1} (Anon., 2014). It is cultivated in different ecosystems in different ways. Rice consumes 4000-5000 litres of water to produce one kilogram grain, which is three times higher than other cereals. Saturated soil culture, intermittent irrigation, alternate wetting and drying and aerobic rice are water-use related technologies which save the water in rice production considerably. These new techniques are revolutionizing the age-old idea that rice is a semi-aquatic crop, grow well in water, but recent developments demonstrate that rice can also be grown in dry soils under non-flooded conditions called "aerobic rice". Aerobic rice cultivation is a method in which rice is grown in well-drained, non-puddled and non-saturated soils. Under appropriate management practices, the yield obtained under aerobic condition is on par with transplanted puddled rice with an average of 8 to 10 t ha^{-1}. There is 60 per cent savings in water use and reduced cost of production. Besides, reduced methane emission under the aerobic system by 80-85 per cent keeping the environment safe (Dileepkumar, 2017).

In aerobic rice cultivation, the seeds are sown directly in the field. During germination, both rice and weed seeds germinate together and competition for resources starts from day one, as a result, weed infestation and competition cause more damage in direct seeded aerobic rice condition as compared to the traditional system of rice cultivation. To obtain higher yield under aerobic rice cultivation, maintaining optimum plant density and adequate weed management plays an important role otherwise, the yield loss is to an extent of 40-82 per cent due to crop-weed competition (Sunil *et al.,* 2010). The traditional method of weed management practices is widely adopted for weed management in aerobic rice. These practices are tedious, time-consuming, labour intensive, expensive and impossible to practice over an extensive area. Further, due to labour scarcity and the high cost of labour due to rapid industrialization and urbanization, traditional weed management practices are being difficult. Therefore, to ensure high yield, effective weed control at the right time with right method is need of the hour.

Materials and Methods

A field experiment was conducted at Zonal Agricultural Research Station, UAS, GKVK, Bangalore during 2017 to study the effect of different weed management practices on growth and yield of aerobic rice. The experiment was laid out in RCBD design with eleven treatments and three replications. The net plot size was 3.25 m x 2.5 m. The recommended dose of FYM (10 t ha^{-1}) was applied 15 days prior to sowing and fertilizer dose of 100: 50: 50 kg N, P_2O_5, K_2O ha^{-1} was applied through urea, single superphosphate and muriate of potash, respectively. The 50 per cent of N was applied as basal dose and remaining 50 per cent was applied in two splits *i.e.,* at tillering and panicle initiation stages. Whereas, phosphatic and potash fertilizers were applied as basal dose at the time of sowing.

The experimental site was red sandy loam with acidic pH (6.93), EC (0.36 dSm^{-1}), medium in organic carbon (0.58 %), available nitrogen (362 kg ha^{-1}), P_2O_5 (43 kg ha^{-1}) and K_2O (289 kg ha^{-1}). Rice seeds were sown directly by dibbling at the rate of 7 kg ha^{-1} by following 25 cm x 25 cm spacing. The aerobic rice variety used wasMAS 946-1. Treatments consisted of stale seedbed technique *fb* two IC at15 and 30 DAS (T_1); stale seed bed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early post-emergent spray (T_2); stale seed bed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS (T_3); straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC @ 30ml a.i. ha^{-1} as PoE (T_4); live mulch with dhaincha @ 25 kg ha^{-1} (T_5); live mulch with horsegram @ 30 kg ha^{-1} (T_6); pendimethalin 30 per cent EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (T_7); pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (T_8); pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (T_9); weed free check (T_{10}) and weedy-check (T_{11}). Weed density and weed dry weight were recorded at 30, 60, 90 DAS and at harvest. Weed density was recorded in 0.5 m × 0.5 m quadrate randomly at one spot in each plot. Weeds were uprooted, washed with tap water, sun-dried, oven-dried at 65 °C for 48 hours. After attaining the constant weight, the samples were weighed and expressed in grams per 0.25 m^2. The plants from net plot were cut at two inches above the ground, sun-dried for three days and threshed. The grain and straw dry weight from net plot was recorded and expressed as kg ha^{-1}. The square-root transformation of original data of weeds were done for statistical analysis as described by Cochran and Cox (1957).

Results and Discussion

Effect of weed management practices on weed density and weed dry weight

The experimental plots were infested by different grasses, broad leaved weeds and sedges. Among the grassy weeds, *Echinochloa colona, E. crussgalli, Digitaria sanguinalis, D. marginata, Eragrostis pilosa, Eleusine indica* and *Dactyloctenium aegyptium* were predominant. Among the broad leaved weeds, *Amaranthus viridis, Oldenlandia corymbosa, Parthenium hysterophorus, Commelina benghalensis, Acanthospermum hispidum, Borreria hispida, Portulaca oleracea, Achyranthes aspera, Cleome monophylla, C. gynandra, Ipomoea sepiaria, I. carnea, Sida cordifolia, Cassia tora* and *Crotalaria pallida* and *Cyperus rotundus* among sedges were predominant. All the treatments resulted in significant reduction in total weed density and total weed dry weight over weedy check during the course of the experiment (Table I).

TABLE I

Total weed density (no.) and weed dry weight (g/0.25m^2) at different stages in rice as influenced by weed management practices

Treatments	30 DAS		60 DAS		90 DAS		At harvest	
	Weed density	Weed dry weight	Weed density	Weed dry weight	Weed density	Weed dry weight	Weed density	Weed dry weight
T_1	3.17 (9.67)	0.85 (0.23)	4.00 (15.67)	2.75 (7.08)	4.60 (20.67)	3.33 (10.61)	4.70 (21.67)	3.72 (13.34)
T_2	3.23 (10.67)	0.89 (0.30)	4.23 (17.67)	2.84 (7.58)	4.81 (23.00)	3.55 (12.10)	4.92 (24.00)	3.82 (14.10)
T_3	1.60 (2.33)	0.76 (0.08)	2.77 (7.33)	1.54 (1.88)	3.08 (9.00)	2.56 (6.05)	3.24 (10.00)	2.72 (6.88)
T_4	1.93 (3.33)	0.77 (0.10)	2.97 (8.33)	1.61 (2.13)	3.16 (10.00)	2.65 (6.54)	3.34 (11.00)	2.83 (7.49)
T_5	3.81 (14.67)	0.98 (0.47)	4.71 (22.67)	3.10 (9.12)	5.19 (27.00)	3.71 (13.27)	5.37 (28.67)	4.16 (16.78)
T_6	3.72 (13.33)	0.94 (0.38)	4.36 (18.67)	2.98 (8.44)	4.27 (19.00)	3.61 (12.56)	5.32 (28.00)	3.96 (15.21)
T_7	2.54 (6.00)	0.81 (0.15)	3.63 (12.67)	1.71 (2.42)	3.85 (14.33)	2.70 (6.78)	3.85 (14.33)	2.91 (7.96)
T_8	2.16 (4.33)	0.79 (0.12)	3.24 (10.00)	1.66 (2.26)	3.45 (11.67)	2.68 (6.71)	3.61 (12.67)	2.87 (7.79)
T_9	2.65 (7.00)	0.82 (0.17)	3.66 (13.00)	1.76 (2.60)	4.10 (16.67)	2.77 (7.20)	4.36 (18.67)	3.26 (10.14)
T_{10}	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{11}	4.00 (15.67)	1.14 (0.80)	10.20 (104.00)	4.93 (23.83)	11.25 (126.33)	8.41 (70.49)	11.36(128.67)	9.35 (87.04)
S.Em.±	0.05	0.01	0.08	0.05	0.10	0.05	0.09	0.06
CD at 5%	0.15	0.04	0.24	0.15	0.30	0.15	0.27	0.18

Values in parentheses are original values; data analyzed using transformation -”x + 0.5

Stale seed bed technique fb two IC at 15 & 30 DAS **(T_1)** ; Stale seed bed technique fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early post-emergent spray **(T_2)**; Stale seed bed technique fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE+one IC at 40 DAS **(T_3)**; Straw mulch at 6 t ha^{-1}fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as PoE **(T_4)** ; Live mulch with dhaincha at 25 kg ha^{-1} **(T_5)**; Live mulch with horsegram at 30 kg ha^{-1} **(T_6)** ; Pendimethalin 30 % EC at 1.5 L ha^{-1} as PE fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE **(T_7)**; Pyrazosulfuron ethyl 10 % WP at 35 g a.i. ha^{-1} as PE fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE **(T_8)** ; Pyrazosulfuron ethyl 10 % WP at 35 g a.i. ha^{-1} as PE +one IC as per package of practice (PoP) **(T_9)**; Weed free **(T_{10})** and Weedy-check **(T_{11})**.

The results revealed that stale seed bed technique *fb* bispyribac sodium 10 per cent SC at 30 ml a.i. ha^{-1} as early PoE+one IC at 40 DAS recorded significantly lower weed count and lower weed dry weight at 30 DAS (2.33 & 0.08 g/ 0.25 m^2), 60 DAS (7.33 and 1.88 g/0.25 m^2), 90 DAS (9.00 and 6.05 g/0.25 m^2) and at harvest (10 and 6.88 g/0.25 m^2) followed by straw mulch at 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC at 30 ml a.i. ha^{-1} as PoEat 30 DAS (3.33 and 0.10 g/0.25 m^2), 60 DAS (8.33 and 2.13 g/0.25 m^2), 90 DAS (10.00 and 6.54 g/0.25 m^2) and at harvest (11 and 7.49 g/0.25 m^2).

Significantly lower number of weeds and weed dry weight were due to efficient control of the weeds at all stages of crop growth period. Whereas, significantly higher weed population, the total dry weight of grasses, broad leaved weeds, sedges registered with a weedy check. The results are in conformity with the findings of Ranjith, 2007; Khaliq *et al.* (2012); Prashanth *et al*. (2016) and Chakraborti *et al*. (2017). Stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS achieved the higher weed control efficiency (92.09 per cent). Whereas, it was lower (0 per cent) in weedy check and 80.72 per cent in live mulch with dhaincha @ 25 kg ha^{-1} (Table II).

Weed control efficiency is a measure of the efficiency of weed control methods in restricting the weed growth. It was due to better control of weeds during rice growth period which resulted in lower total

TABLE II

Yield attributes, yield, weed control efficiency and weed index in aerobic rice as influenced by different weed management practices

Treatments	Productive tiller $hill^{-1}$	Panicle length (cm)	1000 grain weight (g)	Grain yield (Kg Ha^{-1})	Straw yield (Kg Ha^{-1})	WCE (%)	WI (%)
T_1	24.50	20.93	22.01	4819	8336	84.68	21.39
T_2	22.97	19.87	21.06	4771	8218	83.80	22.16
T_3	42.50	25.40	26.27	5987	9944	92.09	2.33
T_4	41.70	25.13	25.73	5965	9890	91.39	2.69
T_5	21.57	18.00	19.85	4399	8124	80.72	28.24
T_6	22.30	18.67	20.26	4491	8160	82.52	26.74
T_7	40.90	24.67	25.20	5923	9851	90.86	3.36
T_8	41.23	24.93	25.47	5948	9872	91.05	2.96
T_9	40.17	24.27	24.53	5845	9921	88.35	4.64
T_{10}	43.37	25.87	27.00	6129	10031	100.00	0.00
T_{11}	1.70	10.86	16.33	496	864	0.00	91.91
S.Em.±	0.69	0.36	0.56	79	149	-	-
CD at 5%	2.05	1.08	1.65	235	442	-	-

Stale seed bed technique fb two IC at 15 & 30 DAS (**T_1**) ; Stale seed bed technique fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early post-emergent spray (**T_2**); Stale seed bed technique fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE+one IC at 40 DAS (**T_3**); Straw mulch at 6 t ha^{-1}fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as PoE (**T_4**) ; Live mulch with dhaincha at 25 kg ha^{-1} (**T_5**); Live mulch with horsegram at 30 kg ha^{-1} (**T_6**) ; Pendimethalin 30 % EC at 1.5 L ha^{-1} as PE fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE (**T_7**); Pyrazosulfuron ethyl 10 % WP at 35 g a.i. ha^{-1} as PE fb bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE (**T_8**) ; Pyrazosulfuron ethyl 10 % WP at 35 g a.i. ha^{-1} as PE +one IC as per package of practice (PoP) (**T_9**); Weed free (**T_{10}**) and Weedy-check (**T_{11}**). WCE= Weed control efficiency, WI=Weed index.

weed population and its dry weight. The lower weed control efficiency was due to poor control of weeds resulted in higher weed population and higher weed dry weight. In the present investigation, the higher yield loss recorded was up to an extent of 91.91 per cent as indicated by weed index value due to high crop-weed competition (Table II). The results are in conformity with the findings of Mahajan *et al. (*2009); Yaduraju & Rao (2013); Prashanth, *et al*. (2016) and Chandu *et al*. (2018).

Effect of weed management practices on rice yield and its attributes

The grain and straw yield of rice were significantly influenced by different weed management practices. Among the different treatments, weed-free check recorded significantly higher rice grain and straw yield (6129 kg ha^{-1} and 10031 kg ha^{-1}, respectively) as compared to the rest of the treatments. Among different weed control treatments, stale seed bed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS significantly increased rice grain and straw yield (5987 kg ha^{-1} and 9944 kg ha^{-1}, respectively) as compared to other treatments. However, it was on par with straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as PoE (5965 kg $ha^{-1}$and 9890 kg ha^{-1}, respectively); pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (5948 kg ha^{-1} and 9872 kg ha^{-1}, respectively); pendimethalin 30 per cent EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (5923 kg ha^{-1} and 9851 kg ha^{-1}, respectively) and pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE +one IC as per package of practice (5845 kg ha^{-1} and 9921 kg ha^{-1}, respectively). Stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS recorded significantly higher grain yield due to higher yield attributing parameters *viz*., productive tillers (42.50), panicle length (25.40 cm) and 1000 grain weight (26.27 g). Superior yield components with stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS was attributed to efficient and well-timed weed management which reduced the weed population and their dry weight which led to higher weed control efficiency during early stage of crop growth and facilitated the crop to have sufficient space, light, nutrient and moisture which ultimately resulted in increased grain and straw yield and yield attributes. Whereas, lower grain and straw yield were noticed in a weedy check (496 kg ha^{-1} and 864 kg ha^{-1}, respectively) owing to severe crop-weed competition which resulted in the reduction of growth and yield components of rice. These results are in conformity with the findings of Bhurer *et al*. (2013); Chandu *et al*. (2018) and Vaishali *et al*. (2018).

Effect of weed management practices on nutrient uptake by crop and weeds

The nutrient uptake by the crop is inversely proportional to nutrient uptake by weeds due to competition for the nutrients (Table III). Among different weed control treatments, stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS registered significantly higher nutrient uptake by crop (134.22, 43.95 and 131.55 kg NPK ha^{-1}, respectively) in comparison with other treatments. However, it was on par with straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as PoE (132.16, 42.07 and 129.96 kg NPK ha^{-1}, respectively), pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (130.50, 40.95 and 128.33 kg NPK ha^{-1}, respectively); pendimethalin 30 per cent EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE (127.73, 39.78 and 126.80 kg NPK ha^{-1}, respectively). Higher nutrient uptake by crop in the above treatments was mainly attributed to lower weed density and their dry weight which helped the crop to grow in weed-free environment and absorb more nutrients from the soil. Whereas, weedy check registered significantly lower nutrient uptake by crop (9.41, 2.02 and 8.52 kg NPK ha^{-1}, respectively) due to higher crop-weed competition for resources. These results are in line with Sunil *et al.* (2010); Chauhan and Seth (2013) and Chakraborti *et al*. (2017).

The nutrient uptake by weeds revealed that significantly lower nutrient removal was noticed with

TABLE III

Nutrient uptake by crop and weeds as influenced by weed management practices in aerobic rice

Weed management practices	Nutrient uptake (Kg ha^{-1}) Crop			Weed		
	N	P	K	N	P	K
T_1: Stale seedbed technique *fb* two IC at 15 and 30 DAS	96.63	26.21	94.63	22.40	4.15	16.64
T_2: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early post-emergent spray	91.09	24.08	90.58	25.95	2.40	16.97
T_3: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS	134.22	43.95	131.55	7.63	1.51	4.93
T_4: Straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE	132.16	42.07	129.96	8.56	1.65	5.47
T_5: Live mulch with dhaincha @ 25 kg ha^{-1}	76.43	19.69	81.16	35.28	3.54	15.31
T_6: Live mulch with horsegram @ 30 kg ha^{-1}	83.55	21.76	84.85	28.74	3.75	12.83
T_7: Pendimethalin 30 % EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	127.73	39.78	126.80	11.04	1.73	5.78
T_8: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	130.50	40.95	128.33	10.73	1.65	5.65
T_9: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice	126.03	38.08	123.76	14.66	2.23	7.33
T_{10}: Weed free	138.43	45.93	136.39	0.00	0.00	0.00
T_{11}: Weedy check	9.41	2.02	8.52	192.37	49.60	179.78
S.Em.±	2.60	0.60	1.94	0.71	0.15	0.41
CD at 5%	7.18	1.79	5.72	2.10	0.45	1.21

stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE+one IC @ 40 DAS (7.63, 1.51 and 4.93 kg NPK ha^{-1}, respectively) followed by straw mulch @ 6 t ha^{-1} *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as PoE (8.50, 1.65 and 5.47 kg NPK ha^{-1}, respectively). The lower nutrient uptake by weeds in these treatments was due to lower weed density and their dry weight as a result of better control of weeds. Whereas, weedy check recorded maximum uptake of nutrients by weeds (192.37, 49.60 and 179.78 kg NPK ha^{-1}, respectively). This was due to poor control of weeds, which facilitated the weeds to utilize nutrient to the maximum extent. Similar results were also reported by Kumar & Ladha (2011); Gupta *et al.* (2015) and Prashanth *et al.* (2016).

Economics of weed management practices

Higher net returns and benefit-cost ratio was obtained with the application of pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (` 64051 and 2.60, respectively) and stale seed bed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha$^{-1}$ as early PoE + one IC @ 40 DAS ( ` 63818 and 2.56, respectively). The increase in net returns in the above-mentioned treatments was attributed to higher grain yield and straw yield, lower cost of weed management and better control of weeds

TABLE IV

Economics of aerobic rice as influenced by weed management practices

Weed Management Practices	Cost of Cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B : C Ratio
T_1: Stale seedbed technique *fb* two IC @ 15 and 30 DAS	39194	85008	45814	2.17
T_2: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early post-emergent spray	39299	83898	44599	2.13
T_3: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS	40899	104717	63818	2.56
T_4: Straw mulch at 6 t ha^{-1} *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE	44099	104304	60205	2.37
T_5: Live mulch with dhaincha @ 25 kg ha^{-1}	38294	78164	39870	2.04
T_6: Live mulch with horsegram @ 30 kg ha^{-1}	37634	79599	41965	2.12
T_7: Pendimethalin 30 % EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	40999	103628	62629	2.53
T_8: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	40283	104028	63745	2.58
T_9: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice	39378	101904	64051	2.60
T_{10}: Weed free	39994	106986	66992	2.68
T_{11}: Weedy check	36794	8736	-28058	-0.24

throughout the crop growth period. There was a net loss in weedy check (` 28058) due to lower grain and straw yield as a result of greater crop-weed competition. Similar observations were also made by Arul *et al.* (2011) and Chakraborti *et al.* (2017). The stale seedbed technique *fb* bispyribac sodium 10 per cent SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS recorded significantly higher grain and straw yield of rice which resulted in lower net returns and lower benefit-cost ratio. Due to the high cost of herbicide and intercultivation the cost of cultivation was high and net returns was low (Table IV).

Based on the above results, it could be concluded that application of pyrazosulfuron ethyl 10 per cent WP @ 35 g a.i. ha^{-1} as pre-emergent spray + one intercultivation @ 40 DAS resulted in obtaining higher grain yield (5845 kg ha^{-1}), net returns (` 64051) and benefit cost ratio (2.60), apart from suppressing the weeds below the economic threshold in aerobic rice.

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