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RESEARCH ARTICLE

Weed management efficacy of herbicides and allelochemicals in direct-seeded rice

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ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station, Bangalore to quantify the effect of different herbicides and allelochemicals on weed density, weed biomass, yield and economics of direct-seeded rice. The post-emergence application (PoE) of bispyribac sodium 40 g/ha provided wide spectrum weed control with a weed control efficiency of 94.99% in 2020 and 95.01% in 2021, which was comparable to pre-emergence application (PE) of bensulfuron-methyl + pretilachlor 660 g/ha (93.24% in 2020 and 93.09% in 2021, respectively). The crop growth parameters and grain yield were highest with hand weeding at 20 and 40 days after seeding (DAS) (5.1 t/ha in 2020 and 5.2 t/ha in 2021) and it was at par with bispyribac-sodium 40 g/ha PoE (5.0 t/ha in 2020 and 5.0 t/ha in 2021) and bensulfuron-methyl + pretilachlor 660 g/ha PE (4.8 t/ha in 2020 and 4.9 t/ha in 2021). Among the allelopathic extracts tested, higher rice grain yield was recorded with *Eucalyptus* leaves extract (3.3 t/ha in 2020 and 3.7 t/ha in 2021). The highest B:C of 2.65 and 2.57 in 2020 and 2021, respectively was recorded with bispyribac-sodium 40 g/ha PoE.

Keywords: Allelopathy, Bensulfuron-methyl + pretilachlor, Bispyribac-sodium, Direct-seeded rice, Herbicides, Leaves extracts, Weed management

INTRODUCTION

Rice is grown over an area of 166.57 million hectares, producing 513.67 million tons with productivity of 4.60 t/ha, and occupies top position among all food crops grown worldwide. India is the second largest producer and consumer of rice in the world with a 47 million hectares area, 129.66 million tons total production and a productivity of 4.14 t/ha in 2021–2022 (USDA 2022). Rice accounts for 55% of the nation's cereal production and 43% of the calorie needs of more than two-thirds of the population, making it the most important food source in India (Kaur and Singh 2017).

The transplanting method is the most used rice establishment technique worldwide; however, it has high labour and water requirements (Mahajan and Chauhan 2016). The labor-intensive nature of manual transplanting during the busy season forces farmers to switch to direct-seeded rice (DSR) planting instead (Rao *et al.* 2007, 2017; Choudhary *et al.* 2017). Compared to rice transplanting, direct-seeded rice requires less water and labour. In addition to these DSR also has lower machine usage requirements, reduced methane emission levels (Chauhan *et al.* 2012), improves soil structure, early crop maturation by 7-10 days and facilitates timely sowing of succeeding crop (Roy 2016). However, due to the maintenance of saturated soil conditions at the time of sowing the weeds arises simultaneously as that of crop in direct-seeded rice. Weeds pose a serious threat to DSR by competing for nutrients, moisture, light and space with the crop from the time of emergence and throughout the growing season (Singh and Singh 2010). The extent of yield reduction in DSR ranges from 91.4 to 99 % (Chhokar *et al.* 2014). Hence weed management by herbicides is more crucial.

In recent years, apart from the herbicides use, the aqueous allelochemical extracts from different plant materials are being used as bioherbicides and it is considered to be an effective tool to minimize the reported adverse effects of herbicides (Amali *et al.* 2014). Hence, the present study was conducted to quantify the effect of different herbicides and aqueous allelochemical extracts on the weed dynamics and performance of direct-seeded rice.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi*, 2020 and summer 2021 at Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra, University of

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Agricultural Sciences, Bengaluru, Karnataka, India (12º 58' N, 77º 33' E). The soil of the experimental site was red sandy loam with 0.41% organic carbon and pH of 6.2. Available N, P and K content in the soil was 261.7, 34.62 and 268.3 kg/ha, respectively. Rice *cv 'MAS 946-1'* (130 days duration) was line sown with a spacing of 30 cm between rows and fertilizer level of 100 kg N, 50 kg P and 50 kg K/ha.

The treatments tested were: pre-emergence application (PE) of bensulfuron-methyl + pretilachlor 660 g/ha, pyrazosulfuron-ethyl 40 g/ha PE, oxadiargyl 100 g/ha PE, post-emergence application (PoE) of bispyribac-sodium 40 g/ha, quizalofop-p-ethyl 37.5 g/ha PoE, cyhalofop-p-butyl 100 g/ha PoE, metamifop 100 g/ha PoE, *Leucas aspera* plant extract, *Eucalyptus* leaves extract, *Hyptis suaveolens* plant extract, hand weeding twice at 20 and 40 days after seeding (DAS) and unweeded control. The herbicides were applied using spray volume of 500 L/ha for pre-emergence (0-3 DAS) and 375 L/ha for post-emergence (15-20 DAS) spray with knapsack sprayer having flood jet nozzle.

For preparing allelochemical extracts, the plant samples during their flowering stage were collected and taken to the laboratory where they were washed thoroughly with tap water to remove the dirt. A 10 g of plant sample was weighed and blended by slowly adding 100 ml of distilled water. The blended solution was first filtered through a double layered muslin cloth and then through Whatman No. 1 filter paper. The obtained 10% (w/v) aqueous allelochemical extract was used for spraying as post-emergence application during 15-20 DAS (Javaid *et al.* 2006).

During sampling time (45 DAS and at harvest), a quadrat of 25 × 25 cm was placed, randomly, at two places in each plot to determine the weed density. The weeds present in one quadrat were removed for estimating weed dry weight (biomass). Weed biomass was recorded after drying the weed samples at 70°C for 48 hours until obtaining a constant weight. Weed control efficiency was calculated based on the formula given by Mani *et al.* (1973).

$$\text{Weed control efficiency} = \frac{X - Y}{X} \times 100$$

Where,

X = Weed biomass in unweeded check plot

Y = Weed biomass in the treated plot

Crop growth parameters like plant height (cm), tillers per m row length, total dry matter accumulation (g/hill) were recorded at the time of harvest. Grain and straw yield (t/ha) were recorded after threshing and sun drying. Weed index was calculated by using the formula given by Gill and Kumar (1969).

$$\text{Weed Index} = \frac{(X\text{-}Y)}{X} \times 100$$

Where, X = Yield from hand weeding plot

Y = Yield from treated plot

In addition, the economics of weed management practices were also calculated based on the prevalent market prices of the inputs used.

The data of weed density and biomass were subjected to transformation before analysis and then subjected to Fisher's ANOVA as outlined by Panse and Sukhatme (1954). However, original values are provided in parenthesis for easier comprehension. All the data were analyzed and the results were presented and discussed at a probability level of five per cent.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora of the experimental plots comprised of grasses such as: *Cynodon dactylon, Digitaria sanguinalis, Echinochloa colona, Eleusine indica, Dactyloctenium aegyptium* and *Panicum repens;* broad-leaved weeds: *Alternanthera sessilis, Amaranthus viridis, Borreria hispida, Cassia* sp., *Euphorbia geniculata, Ipomoea alba, Mollugo disticha, Ageratum conyzoides, Portulaca oleracea* and *Phyllanthus niruri* and the sedge: *Cyperus rotundus.*

Bensulfuron-methyl + pretilachlor 660 g/ha PE and bispyribac-sodium 40 g/ha PoE effectively controlled the sedge (**Table 1** and **2**). The lower grass density and biomass during both the years was recorded with metamifop 100 g/ha PoE and was statistically at par with quizalofop-p-ethyl 37.5 g/ha, cyhalofop-p-butyl 100 g/ha and bispyribac-sodium 40 g/ha PoE. Significantly lower broad- leaved weed density and biomass were recorded with bispyribac-sodium 40 g/ha PoE. Among all the herbicidal treatments, bispyribac-sodium 40 g/ha PoE was statistically superior in reducing weed density and biomass followed by bensulfuron-methyl + pretilachlor 660 g/ha PE.

Bispyribac-sodium and bensulfuron-methyl + pretilachlor are broad spectrum herbicides and hence, they reduced the density and biomass of sedges, grasses and broad-leaved weeds which aided in recording lower total weed density and biomass. Between the years, the total weed density and biomass were considerably higher in 2020 than 2021. All the herbicide treatments including allelochemical treatments significantly lowered the weed density and biomass when compared to unweeded control. The results were in conformity with the findings of Chandra *et al.* (2013), Suresh *et al.* (2013) and Prakash *et al.* (2017).

The weed control efficiency (WCE) was largely dependent on weed biomass. The highest weed control efficiency was obtained with hand weeding at 20 and 40 DAS (99.67% in 2020 and 99.66% in 2021) at 45 DAS (**Table 2**). Whereas, among the herbicidal treatments, bispyribac sodium 40 g/ha PoE recoded higher weed control efficiency of 94.99% in 2020 and 95.01% in 2021, followed by bensulfuron-methyl + pretilachlor 660 g/ha PE (93.24% in 2020 and 93.09% in 2021, respectively) confirming findings of Rawat *et al.* (2012) and Teja *et al.* (2015). The herbicides use has resulted in better weed control efficiency compared than with allelochemical plant extracts which might be due to their lesser efficiency, lower residual nature when compared to herbicides.

Effect on the crop

All the crop growth parameters, *viz.* plant height, number of tillers per meter row length, total dry matter accumulation per hill, grain and straw yield were maximum with hand weeding at 20 and 40 DAS followed by bispyribac-sodium 40 g/ha PoE and bensulfuron-methyl + pretilachlor 660 g/ha PE during 2020 and 2021 (**Table 3**). Reduced weed competition and increased availability of growth factors like nutrients, soil moisture, light and space has paved the way for higher crop growth parameters in these treatments which is demonstrated by taller plants and a greater number of tillers, which in turn increased the crop's biomass. The results are in parity with Teja *et al.* (2015) and Prakash *et al.* (2017). Among the allelochemical treatments, application of *Eucalyptus* leaves extract recorded higher grain and straw yield over *Leucas aspera* and *Hyptis suaveolens* plant extracts.

There is an inverse relationship between crop yield and weed index in any crop. The lowest weed index was noticed in bispyribac-sodium 40 g/ha PoE (1.64 and 4.22% in 2020 and 2021, respectively) *fb* bensulfuron-methyl + pretilachlor 660 g/ha PE (5.36 and 5.25% in 2020 and 2021, respectively). The highest weed index was noticed in unweeded control (86.69 and 86.53% in 2020 and 2021, respectively) due to severe yield reduction due to adverse effect of weed competition.

B:C Ratio

The highest B:C was obtained with bispyribac-sodium 40 g/ha PoE (2.65 and 2.57 in 2020 and 2021, respectively) closely followed by bensulfuron-methyl + pretilachlor 660 g/ha PE (2.58 and 2.56 in 2020 and 2021, respectively) due to improved yield and

Table 1. Effect of weed management treatments on sedges, grasses, broad-leaved weeds and total weed density (no./m^2) at 45 days after seeding (DAS) in direct-seeded rice

Treatment	Sedges		Grasses			Broad-leaved weeds		Total weeds
	2020+	2021+	2020#	2021#	2020+	2021+	2020#	2021#
Bensulfuron-methyl + pretilachlor 660 g/ha PE	1.73(2.0)	1.52(1.3)	1.08(10.0)	1.03(8.6)	3.13(8.7)	3.00(8.0)	1.36(20.7)	1.30(17.9)
Pyrazosulfuron ethyl 40 g/ha PE	2.65(6.0)	2.07(3.3)	1.13(11.4)	1.05(9.3)	3.22(9.3)	3.11(8.7)	1.46(26.7)	1.37(21.3)
Oxadiargyl 100 g/ha PE	2.77(6.7)	2.24(4.0)	1.17(12.7)	1.12(11.3)	3.34(10.1)	3.22(9.4)	1.50(29.5)	1.43(24.7)
Bispyribac-sodium 40 g/ha PoE	2.24(4.0)	2.07(3.3)	0.93(6.6)	0.90(6.0)	3.02(8.0)	2.77(6.7)	1.31(18.6)	1.26(16.0)
Quizalofop-p-ethyl 37.5 g/ha PoE	3.70(12.7)	3.61(12.0)	0.90(5.9)	0.83(4.7)	5.23(26.6)	5.26(26.7)	1.67(45.2)	1.66(43.4)
Cyhalofop-p-butyl 100 g/ha PoE	3.70(12.7)	3.42(10.7)	0.94(6.7)	0.82(4.6)	4.70(21.2)	4.65(20.6)	1.63(40.6)	1.58(35.9)
Metamifop 100 g/ha PoE	3.61(12.0)	3.42(10.7)	0.86(5.3)	0.72(3.3)	4.64(20.6)	3.14(21.9)	1.60(37.9)	1.58(35.9)
Leucas aspera plant extract	3.51(11.3)	3.21(9.3)	1.51(30.7)	1.47(27.3)	4.71(21.3)	4.64(20.5)	1.81(63.3)	1.77(57.1)
Eucalyptus leaf extract	3.21(9.3)	2.88(7.3)	1.47(27.3)	1.41(24.0)	4.27(17.3)	4.35(17.9)	1.75(53.9)	1.71(49.2)
Hyptis suaveolens plant extract	3.21(9.3)	3.11(8.7)	1.48(28.0)	1.44(25.3)	4.57(20.0)	4.49(19.2)	1.77(57.3)	1.74(53.2)
Hand weeding twice at 20 and 40 DAS	1.30(0.7)	1.30(0.7)	0.53(1.4)	0.43(0.7)	1.05(0.0)	1.00(0.0)	0.61(2.1)	0.53(1.4)
Unweeded control	3.96(14.7)	3.61(12.0)	1.72(50.0)	1.69(46.7)	6.15(37.2)	6.02(35.3)	2.02(101.9)	1.98(94.0)
LSD (p=0.05)	0.52	0.58	0.16	0.20	0.69	1.43	0.13	0.10

Table 2. Effect of weed management treatments on sedges, grasses, broad-leaved weeds, total weed biomass (g/m^2) and weed control efficiency (WCE) (%) at 45 days after seeding (DAS) and weed index (%) in direct-seeded rice

Treatment	Sedges		Grasses		Broad-leaved weeds		Total weeds		WCE		Weed index	
	2020+	2021+	2020#	2021#	2020+	2021+	2020#	2021#	2020	2021	2020	2021
Bensulfuron-methyl + pretilachlor 660 g/ha PE	1.15(0.3)	1.13(0.3)	0.78(4.0)	0.76(3.8)	0.68(2.8)	0.67(2.6)	0.96(7.2)	0.94(6.7)	93.24	93.09	5.36	5.25
Pyrazosulfuron ethyl 40 g/ha PE	1.24(0.5)	1.22(0.5)	0.85(5.0)	0.82(4.6)	0.77(3.8)	0.74(3.5)	1.06(9.4)	1.03(8.6)	91.15	91.1	8.13	6.96
Oxadiargyl 100 g/ha PE	1.33(0.8)	1.25(0.6)	0.97(7.3)	0.86(5.3)	0.85(5.1)	0.75(3.6)	1.18(13.1)	1.06(9.4)	87.66	90.24	12.56	11.29
Bispyribac-sodium 40 g/ha PoE	1.21(0.5)	1.17(0.4)	0.65(2.4)	0.63(2.2)	0.65(2.4)	0.63(2.2)	0.87(5.3)	0.83(4.8)	94.99	95.01	1.64	4.22
Quizalofop-p-ethyl 37.5 g/ha PoE	4.17(16.4)	3.70(12.7)	0.55(1.5)	0.50(1.2)	1.39(22.6)	1.28(17.1)	1.63(40.6)	1.52(30.9)	61.88	68.05	25.81	25.64
Cyhalofop-p-butyl 100 g/ha PoE	3.62(12.1)	3.47(11.0)	0.56(1.6)	0.53(1.4)	1.30(18.0)	1.25(16.0)	1.53(31.7)	1.48(28.4)	70.21	70.62	24.34	24.98
Metamifop 100 g/ha PoE	3.28(9.8)	3.15(8.9)	0.49(1.1)	0.47(1.0)	1.34(20.1)	1.31(18.4)	1.52(31.0)	1.48(28.3)	70.92	70.77	18.11	17.81
Leucas aspera plant extract	1.53(1.3)	1.50(1.2)	1.40(23.2)	1.36(21.2)	1.31(18.5)	1.20(13.8)	1.65(43.1)	1.58(36.2)	59.55	62.61	59.18	57.52
Eucalyptus leaf extract	1.35(0.8)	1.27(0.6)	1.38(21.8)	1.26(16.2)	1.25(15.9)	1.14(11.7)	1.61(38.5)	1.48(28.5)	63.88	70.51	34.89	29.57
Hyptis suaveolens plant extract	1.43(1.0)	1.33(0.8)	1.38(22.2)	1.26(16.4)	1.26(16.3)	1.24(15.2)	1.62(39.6)	1.54(32.4)	62.84	66.58	48.13	41.73
Hand weeding twice at 20&40 DAS	1.07(0.1)	1.06(0.1)	0.35(0.2)	0.34(0.2)	0.30(0.0)	0.30(0.0)	0.37(0.4)	0.37(0.3)	99.67	99.66	0	0
Unweeded control	4.52(19.4)	4.33(17.7)	1.66(43.2)	1.63(40.5)	1.66(43.9)	1.61(38.6)	2.04(106.5)	1.99(96.8)	0	0	86.69	86.53
LSD (p=0.05)	0.18	0.14	0.28	0.17	0.17	0.13	0.16	0.18	-	-	-	-

Data within the parentheses are original values; Transformed values - # = log (x+2), + = square root of (x+1). PE: pre-emergence application; PoE: post-emergence application; DAS: days after seeding

Table 3. Effect of weed management practices on crop growth parameters at harvest in direct-seeded rice

Treatment	Plant height (cm)		Tillers per meter row length		Total dry matter (g/hill)		Grain yield (t/ha)		Straw yield (t/ha)		B:C	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Bensulfuron-methyl + pretilachlor 660 g/ha PE	58.00	60.32	176.85	186.69	19.03	20.83	4.8	4.9	6.6	6.8	2.58	2.56
Pyrazosulfuron ethyl 40 g/ha PE	56.74	58.17	174.09	184.48	18.33	20.69	4.7	4.9	6.5	6.7	2.52	2.53
Oxadiargyl 100 g/ha PE	55.83	57.31	170.50	179.91	17.94	18.88	4.4	4.6	6.3	6.7	2.41	2.42
Bispyribac-sodium 40 g/ha PoE	59.60	61.95	179.30	192.91	19.38	21.32	5.0	5.0	6.8	6.9	2.65	2.57
Quizalofop-p-ethyl 37.5 g/ha PoE	51.10	53.67	148.34	161.56	14.32	16.84	3.8	3.9	5.9	5.9	2.05	2.03
Cyhalofop-p-butyl 100 g/ha PoE	53.83	54.27	157.84	168.04	15.01	18.05	3.8	3.9	5.7	6.0	2.18	2.15
Metamifop 100 g/ha PoE	54.37	56.62	161.99	174.20	17.26	18.62	4.1	4.3	6.0	6.0	2.26	2.24
Leucas aspera plant extract	48.62	49.57	131.07	144.15	12.51	13.35	2.1	2.2	4.0	4.2	1.24	1.27
Eucalyptus leaf extract	50.66	52.06	146.37	154.41	14.06	16.31	3.3	3.7	5.2	5.5	1.89	2.01
Hyptis suaveolens plant extract	49.65	51.19	135.61	147.74	13.46	16.47	2.6	3.0	4.2	4.7	1.51	1.67
Hand weeding twice at 20 and 40 DAS	60.97	63.17	185.18	196.00	19.90	21.94	5.1	5.2	6.9	7.0	2.36	2.35
Unweeded control	42.97	44.25	83.53	89.21	6.06	7.53	0.7	0.7	1.5	1.5	0.45	0.46
LSD (p=0.05)	4.19	4.76	10.74	11.36	1.40	2.17	0.4	0.3	0.3	0.4	-	-

PE: pre-emergence application; PoE: post-emergence application; das: days after seeding

reduced cost of weed management with herbicides use. The hand weeding twice at 20 and 40 DAS recoded slightly lower B:C (2.36 in 2020 and 2.35 in 2021) due to increased cost of cultivation. The lowest B:C was recorded in the unweeded control.

Conclusion

Bispyribac-sodium 40 g/ha PoE or bensulfuron-methyl + pretilachlor 660 g/ha PE were found to be best in controlling weeds, recording higher weed control efficiency, rice yield and economic returns in direct-seeded rice.

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