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Bio-Efficacy of Post Emergent Herbicides on Weeds in Direct Seeded Rice (*Oryza sativa L.*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to study the bio-efficacy of post emergent herbicides on weeds in direct seeded rice in medium black clay soil at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka during *Kharif* 2022. The experiment was laid

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out in Randomized complete block design with three replications. There were eight treatments consisting of five post emergent herbicides sprayed at 25 DAS, hand weeding at 20 and 40 DAS, weed free check and weedy check in direct seeded rice and the variety RNR 15048 was used in this trial. Application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower weed density, weed dry weight, weed index and higher weed control efficiency compared to all the other treatments. It also produced higher number of productive tillers (409.4 m^{-2}), panicle weight (3.89 g), filled grains per panicle (243.1), lower number of unfilled grains per panicle (8.4), higher grain yield (6058 kg ha^{-1}) and straw yield (6935 kg ha^{-1}) in direct seeded rice. So it can be concluded that application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} at 25 DAS (weeds at 2-3 leaf stage) was most effective in managing the weeds with higher weed control efficiency. It also resulted in higher growth and yield components of direct seeded rice leading to higher grain yield.

Keywords: Direct seeded rice; post emergent herbicides; cyhalofop butyl + penoxsulam; weed management.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is the most important cereal crop and a staple food for one third of the world population. It is necessary to increase its production and productivity in order to meet the growing demand of increasing population. In the world, rice is being grown in an area of 165.25 m ha with a production of 787 m t and the productivity of 4762 kg ha^{-1}" [1]. "The total area of rice in India is 46.27 m ha, with a production and productivity of 129.5 m t and 2789 kg ha^{-1}, respectively" [2].

"Weed infestation in direct seeded rice remains the largest constraint limiting its productivity. Weeds in direct seeded rice germinate along with rice seeds and compete from initial stage itself. They compete for resources and not only cause huge reductions in crop yields but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect-pests and diseases, affect aesthetic look of the ecosystem, affect native biodiversity, as well as affect human and cattle health. In India, presence of weeds in general reduces crop yields by 31.5 per cent in winter season and 36.5 per cent in *summer* and *kharif* seasons and in some cases can cause complete devastation of the crop" [3].

Nearly 1800 species of plants reported as weeds in rice, out of these Cyperaceae and Poaceae weeds are predominant. The adoption of direct-seeding has resulted in a change in relative abundance of weed species in rice crops. The major associated weeds reported are *Echinochloa colona* and *Echinochloa crus-galli* and these are the most serious weeds affecting rice in all methods of rice establishment. Other weeds of major concern in rice includes *Cyperus iria*, *Cyperus difformis*, *Eclipta alba*, *Fimbristylis miliacea*, *Ischaemum rugosum*, *Leptochloa chinensis*, *Monochoria vaginalis*, *Paspalum distichum* and *Spaenoclea zeylanica*. *E. colona* requires less moisture than *E. crus-galli* resulting in the predominance of *E. colona* in dry-seeded rice. *Cyperus rotundus* and *Cynodon dactylon* are other major problems in upland conditions, particularly in poorly managed fields.

Various pre emergence and post emergence herbicides are presently accessible in the market to control weeds in paddy. The efficacy of these herbicides is to be worked out as an effect of herbicides depends on the type of crop, soil, season, weed flora type and intensity of rainfall and so forth. Pre emergent herbicides are ineffective in controlling the late emerged weeds. Due to rain during the sowing of kharif paddy the application of pre emergent herbicide becomes difficult. The lately emerging weeds offer severe competition to the crop and infest the land with weed seeds making it less productive in successive seasons. Hence, post emergent herbicide become a possible alternative for wide range of weed control. Applications made after emergence of crops and weeds, allow for identification of the weed species present, as well as the severity of infestation. So, herbicide selection can be tailored to a particular field.

In recent years many new molecules have been synthesized which exhibit high level of activity at low dose with shorter half-life, low mammalian toxicity and higher weed control efficiency. These herbicides are characterised by broad spectrum weed control with broad window of application, with an environmental advantage deriving from

their very low application rates in grams rather than kilogram per hectare which markedly reduce the chemical load in the environment. Keeping the above facts in view, an investigation was undertaken to study the bio-efficacy of post emergent herbicides on weeds in direct seeded rice.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2022 at Agricultural Research Station, Dhadesugur, on *Vertisol* having pH 8.05 and EC 0.45 dS m^{-1}. The soil was low in organic carbon content (0.43 %), low in available N (279.8 kg ha^{-1}), high in available P_2O_5 (28.2 kg ha^{-1}) and high in available K_2O content (377.4 kg ha^{-1}). The experimental site was located at a latitude of 15˚ 6´ North, longitude of 76˚ 8´ East and an altitude of 358 meters above mean sea level in North Eastern Dry Zone of Karnataka (Zone 2).

During the cropping period of 2022-23, a total rainfall of 599 mm was received from July 2022 to November 2022 as against the normal rain of 544.2 mm. The average maximum air temperature of 31 ^oC was recorded in the months of July, August and September during the experimental period. The average minimum temperature of 19 ^oC was recorded in the months of October and November during crop growth period. The average maximum relative humidity of 88 per cent was recorded in the months of August, September and October and minimum relative humidity of 43 per cent was recorded in the month of November during crop growth period as given in Fig. 1.

The research was arranged in Randomized complete block design, there were eight treatments consisting of five different post emergent herbicides sprayed at 25 DAS, hand weeding at 20 and 40 DAS, weed free check and weedy check. After the previous crop was harvested, the field was ploughed twice before sowing the crop and the experiment was laid out as per the treatments. The plots were levelled and furrows were opened at 20 cm row spacing. The seeds of paddy cultivar RNR 15048 were sown by adopting line sowing method on 19th July 2022 @ 25 kg ha^{-1} using manual labours. Paddy seeds were sown to a depth of less than 3 cm in the inter row spacing of 20 cm. An irrigation was given immediately after sowing to get uniform germination. The basal application of fertilizers in the form of urea, diammonium phosphate and muriate of potash were applied with recommended dose of 150:75:75 kg $N:P_2O_5:K_2O$ ha^{-1}. Herbicides were applied as per the treatments. Required amount of herbicides were worked out and dissolved in water and applied as foliar spray at 2-4 leaf stage (25 DAS) of weeds as per the treatments with a spray volume of 500 litres per hectare using Knapsack sprayer with flat pan nozzle (Table 1). Subsequently, two hand weeding were carried out at 20 and 40 DAS to control the weeds in experimental plot. The observations on weed density (no.m^{-2}), weed dry weight (g m^{-2}) and weed control efficiency (%) at 15, 30 and 45 DAS were recorded. Weeds were counted using a quadrant of 1.00 square meter (1.0 m x 1.0 m). The weed control efficiency was worked out based on the data from weed dry weight in the field using the formula as suggested by Mani et al. [4].

$$WCE\ (\%) = (X-Y) / X * 100$$

Where,

WCE = Weed control efficiency expressed in percentage
X = Total weed dry weight in unweeded control plot (g)
Y = Total weed dry weight in the treated plot (g)

Weed index was calculated by using the formula as given by Gill and Kumar [5].

$$WI\ (\%) = (X-Y) / X * 100$$

Where,

WI = Weed index expressed in percentage
X = Yield of hand weeding plot (kg $plot^{-1}$)
Y = Yield from treatment for which weed index is to be worked out (kg $plot^{-1}$)

2.1 Statistical Analysis of Data

2.1.1 Transformation of data

"Since the data on weed density (No. m^{-2}) and weed dry weight (g m^{-2}) were not normally distributed, the data were transformed by using square root (x+1) as suggested" by Gomez and Gomez [6]. The transformed data were analyzed statistically.

Table 1. Details of the treatments

Treatment No.	Treatment details (Commercial names)
T_1	Bispyribac sodium 10 % SC @ 250 ml ha^{-1} (Nominee gold)
T_2	Chlorimuron ethyl 10 % WP + Metsulfuron methyl 20 % WP @ 20 g ha^{-1} (Almix)
T_3	Cyhalofop butyl 5.1 % + Penoxsulam 1.02 % OD @ 2000 ml ha^{-1} (Vivaya)
T_4	Triafamone 20 % + Ethoxysulfuron 10 % WG @ 100 g ha^{-1} (Council activ)
T_5	Bispyribac sodium 20 % + Pyrazosulfuron ethyl 15 % WDG @1.5 kg ha^{-1} (Officer)
T_6	Hand weeding at 20 and 40 DAS
T_7	Weed free check
T_8	Weedy check

SC- Soluble Concentrate;WP- Wettable Powder;OD- Oil Dispersion; WG- Water Dispersible granules;WDG- Water Dispersible Granules;DAS: Days After Sowing

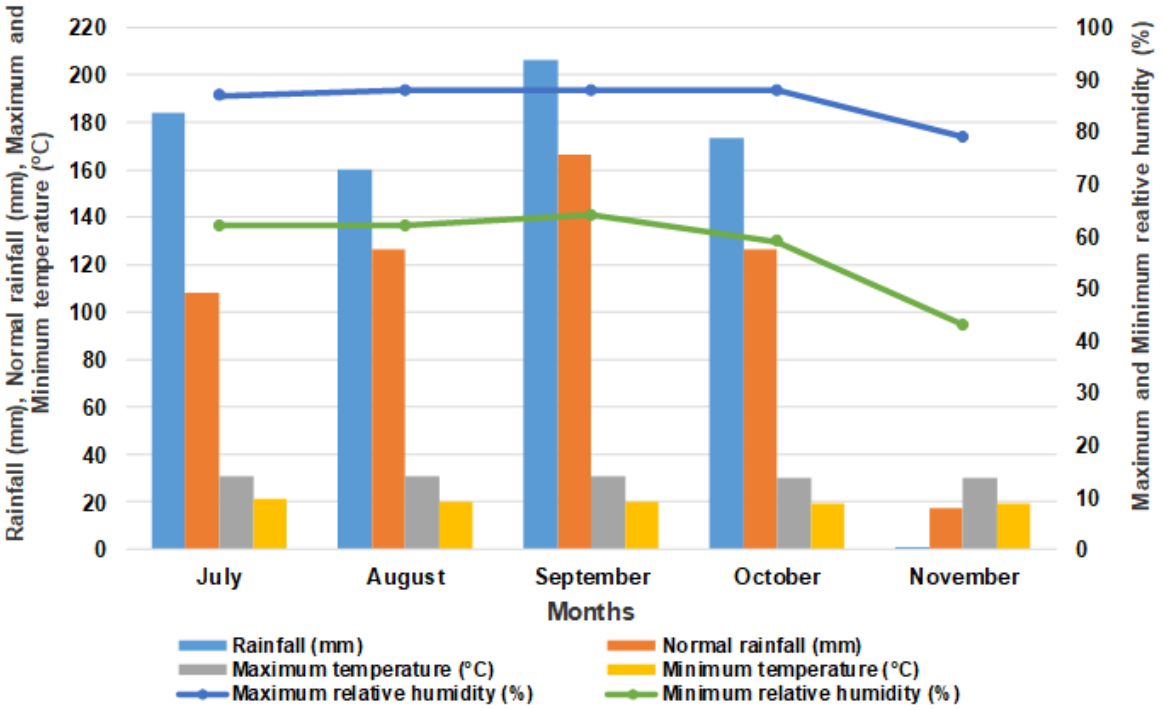

Fig. 1. Mean monthly meteorological data for the experimental period (2022) at agricultural research station, Dhadesugur

2.1.2 Statistical analysis and interpretation of data

The experimental data collected on plant growth parameters, yield components and weed parameters were subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme [7].

3. RESULTS AND DISCUSSION

3.1 Weed Flora of the Experimental Field

The dominant weed species noticed in direct seeded rice were *Echinochloa* spp. *Panicum repens, Cynodon dactylon, Leptochloa chinensis, Brachiaria mutica, Digitaria sanguinalis* among grasses, *Eclipta alba*, *Ludwigia parviflora* and *Commelina communis* as broad leaved weeds and *Cyperus* spp. as sedge. Ramesha *et al*. [8] observed similar weed flora in direct seeded rice. The emergence of different weed species is mainly attributed to initial soil weed seed bank, difference in tillage intensity during land preparation, earlier cropping system, weather parameters during crop growth, favourable soil environment *etc*. All the weed management practices significantly affected the weed density and weed dry weight at 15, 30 and 45 DAS in comparison to weedy check (Table 2).

Table 2. Effect of weed management practices on weed parameters, weed control efficiency and weed index in direct seeded rice

Treatment	Weed density (m^{-2})			Weed dry weight (g m^{-2})			Weed control efficiency (%)			Weed index (%)
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS	
T_1	6.03 (35.41)	4.97 (23.71)	6.42 (40.20)	2.77 (6.71)	2.76 (6.59)	5.44 (28.57)	47.2	72.6	70.5	25.15
T_2	5.81 (32.83)	4.43 (18.63)	5.88 (33.55)	2.62 (5.86)	2.55 (5.50)	3.97 (14.79)	53.9	77.2	84.7	18.40
T_3	5.75 (32.11)	2.75 (6.57)	3.25 (9.54)	2.38 (4.68)	2.03 (3.10)	2.50 (5.27)	63.2	87.1	94.6	1.69
T_4	5.79 (32.63)	4.24 (16.95)	5.63 (30.71)	2.53 (5.39)	2.42 (4.84)	3.33 (10.11)	57.6	79.9	89.6	13.65
T_5	5.86 (33.42)	4.55 (19.67)	6.08 (35.93)	2.70 (6.29)	2.68 (6.20)	4.50 (19.29)	50.6	74.3	80.1	20.50
T_6	5.79 (32.53)	3.65 (12.31)	4.16 (16.31)	2.46 (5.05)	2.34 (4.47)	3.30 (9.87)	60.3	81.4	89.8	8.65
T_7	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100.0	100.0	100.0	0.00
T_8	6.19 (37.36)	8.07 (64.14)	9.88 (96.57)	3.70 (12.72)	5.01 (24.08)	9.89 (96.78)	0.0	0.0	0.0	54.74
S. Em. ±	1.14	0.04	0.06	0.47	0.02	0.05	16.7	1.4	1.5	1.36
C.D. at 5 %	NS	0.13	0.17	NS	0.07	0.14	NS	4.2	4.5	3.11

SC- Soluble concentrate; WP- Wettable powder; OD- Oil dispersion; WG- Water Dispersible Granules; WDG- Water Dispersible Granules; NS- Non significant; DAS: Days After Sowing;

Original weed density (x) data were transformed to √(x+1); Figures in parentheses indicates original values

3.2 Weed Density (No. m^{-2})

Different weed management practices had no significant effect on the total density of weeds at 15 DAS. At 30 DAS, the total weed density was significantly lower (1.00 m^{-2}) in weed free check compared to other weed management practices. Among different herbicide treatments, application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower total weed density (2.75 m^{-2}). Among weed management practices at 45 DAS, significantly lower total weed density (1.00 m^{-2}) was observed in weed free check. Among various herbicide treatments, application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly least total weed density (3.25 m^{-2}).

Among different weed management practices, application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded lower total weed density. This might be due to the prevention of biosynthesis of branched chain amino acids *viz*., valine, leucine and isoleucine in chloroplast of susceptible weeds. These herbicides are broad spectrum in activity and are absorbed by foliage and translocated through both xylem and phloem. The susceptible weeds stop growing after herbicide application and exhibits stunting, interveinal chlorosis, red venation, purpling and gradual death of the weed. The results of this study confirmed the earlier findings of Singh et al. [9]. Hand weeding at 20 and subsequently at 40 DAS resulted in lower weed density. These results were further supported by the findings of Vinay [10]. Significantly higher weed density was noticed in weedy check which was attributed to initial deposition of weed seeds in the soil from the previous seasons which has led to increased weed seed bank in the soil which is undisturbed for any activity after sowing. These findings are in accordance with the findings of Dhanapal et al. [11].

3.3 Weed Dry Weight (g m^{-2})

The total dry weight of weeds differed significantly among the different weed management practices. At all the stages of the crop growth, significantly lower total dry weight of weeds was recorded in weed free check over all the weed management practices. Different weed management practices had no significant effect on the total dry weight of weeds at 15 DAS. At 30 DAS, among weed management practices, significantly higher total dry weight (5.01 g m^{-2}) was recorded in weedy check and significantly lower total dry weight (1.00 g m^{-2}) was recorded in weed free check. Among herbicide treatments, application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower total dry weight (2.03 g m^{-2}). Among different weed management practices at 45 DAS, significantly lower total dry weight of weeds (1.00 g m^{-2}) was observed in weed free check. Application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower total dry weight of weeds (2.50 g m^{-2}) among all the herbicide treatments.The weed dry weight in direct seeded rice has followed the similar trend as that of weed density at different crop growth stages. Lower weed density and lesser dry weight in hand weeded plot might be due to the removal of germinated weeds from the fields through hand weeding. These findings agree with the findings of Teja et al*.* [12] who reported significantly lower density and dry weight of weeds due to hand weeding in direct seeded rice. Among the different herbicides, cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower density and dry weight of weeds. This might be due to broad spectrum effect of this post emergent herbicide which is highly effective in suppressing the major weed flora. Thus, resulted in lower weed dry weight and the findings agree with the findings of Sah *et al.* [13]. Significantly higher weed dry weight was observed in weedy check which was attributed to higher weed density compared to other weed management treatments. These results are in accordance with the findings of with Dhanapal *et al*. [14].

3.4 Weed Control Efficiency (%)

Weed control efficiency at 15 DAS did not vary significantly by different weed management practices. At 30 DAS, significantly higher weed control efficiency (100.0 %) was observed in weed free check which was followed by application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} (87.1 %). At 45 DAS, significantly higher weed control efficiency (100.0 %) was recorded with weed free check followed by application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} (94.6 %) (Table 2).

Higher weed control efficiency under these treatments at all the crop growth stages was attributed to significantly lower total weed dry

Table 3. Effect of weed management practices on yield attributes and yields of direct seeded rice

Treatment	Number of productive tillers per square meter	Panicle weight (g)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	371.5	2.95	203.1	19.8	4612	5636
T_2	374.6	3.41	210.3	14.5	5019	6134
T_3	409.4	3.89	243.1	8.4	6058	6935
T_4	384.6	3.52	222.5	12.0	5321	6503
T_5	370.2	3.30	207.2	15.8	4899	5977
T_6	387.0	3.63	228.3	10.6	5629	6529
T_7	415.7	3.96	246.5	8.0	6162	6949
T_8	279.3	2.83	190.9	21.3	2789	3542
S.Em ±	6.4	0.06	3.7	0.3	88	105
C.D. at 5 %	19.4	0.18	11.1	0.8	266	319

SC- Soluble Concentrate; WP- Wettable Powder; WG- Water dispersible granules; WDG- Water Dispersible Granules; DAS: Days After Sowing; OD- Oil Dispersion

weight. Because of effective suppression of weeds by both hand weeding and herbicides which suppress the population of weed, leads to higher weed control efficiency. These results are supported by the findings of Singh et al. [15].

3.5 Weed Index (%)

The weed index is a measure of the crop yield loss occurred across treatments in comparison to weed free check. Weed index differed significantly among different weed management practices.

The results revealed that weedy check recorded significantly higher weed index (54.74 %). Among different weed management practices, application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} recorded significantly lower weed index (1.69 %) (Table 2). Lower weed index was attributed to lower weed density and weed dry weight in herbicide treated plots which resulted in luxuriant crop growth leading to increase in yield. These findings were similar with the findings of Pal et al. [16].

3.6 Effect on Yield and Yield Attributes

Among weed management practices, weed free check recorded significantly higher number of

productive tillers (415.7 m^{-2}), panicle weight (3.96 g), number of filled grains per panicle (246.5), lower number of unfilled grains per panicle (8.0), higher grain yield (6162 kg ha^{-1}) and straw yield (6949 kg ha^{-1}) and it was found on par with the application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} (409.4 m^{-2}, 3.89 g, 243.1, 8.4, 6058 and 6935 kg ha^{-1}, respectively). Significantly lower number of productive tillers (279.3 m^{-2}), panicle weight (2.83 g), number of filled grains per panicle (190.9), higher number of unfilled grains per panicle (21.3), lower grain yield (2789 kg ha^{-1}) and straw yield (3542 kg ha^{-1}) was recorded with weedy check (Table 3).

The increased yields under these treatments were due to the elimination of weeds, which enhanced the availability of nutrients, space, sunlight and water, resulting in better growth and development of crop plants. This resulted in improved yield attributing characters. These results of yield parameters are consistent with the findings of Sah et al. [13].

4. CONCLUSION

Application of cyhalofop butyl 5.1 % + penoxsulam 1.02 % OD @ 2000 ml ha^{-1} at 25 DAS (weeds at 2-3 leaf stage) was most effective in managing the weeds with higher weed control efficiency. It also resulted in higher growth and yield components of direct seeded rice leading to higher grain yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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