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RESEARCH ARTICLE

Residual Effect of Slow Release Herbicide Formulations on Weed and Bhendi in the Rice-Bhendi Crop Sequence

N. Bommayasamy* and C.R.Chinnamuthu[1]

*Department of Agronomy, AC & RI, Tamil Nadu Agricultural University, Madurai-625104

[1]Department of Agronomy, TNAU, Coimbatore-641 003

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ABSTRACT

A Field experiment was carried during *rabi*, 2016-17 at the Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai to find out the residual effect of slow release herbicide formulations on weed and bhendi in the rice-bhendi crop sequence. Among weed control treatments, the residual effect of butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT recorded significantly lower total weed density of 21.33/m^2 and 51.17/m^2 at 20 and 40 DAS respectively. It was on par with the residual effect of oxadiargyl loaded in zeolite applied at 3 DAT, whereas, at 60 DAS and at harvest stage, the residual effect of oxadiargyl encapsulated with water-soluble polymer and loaded in zeolite applied on 3 DAT recorded lower weed density. Significantly, lower weed dry weight was recorded in butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS which was on par with residual effect of oxadiargyl loaded in zeolite at 3 DAT and oxadiargyl loaded in biochar at 3 DAT compared to all other treatments at 20 DAS. The same pattern was observed in total weed dry weight at 40, 60 DAS and at harvest stage except oxadiargyl loaded in biochar at 3 DAT. Slow release formulation of oxadiargyl recorded higher germination percentage of bhendi as compared to commercial formulations and weedy check. Weed-free check, butachlor at 1.25 kg/ha *fb* HW on 40 DAT, oxadiargyl loaded in zeolite applied to previous rice crop on 3 DAT has recorded higher bhendi fruit yield of 6.40, 3.70, 1.53 times against weedy check.

Keywords: *Encapsulated, Loaded, Oxadiargyl, Weed, Fruit yield, Bhendi*

INTRODUCTION

Bhendi (*Abelmoschus esculentus* L. Moench) is an important and widely grown fruit vegetable in the world. India is the leading country in the world with a production of 6.15 million tonnes from over 0.53 million ha area with productivity of 11.6 tonnes per hectare (Indiastat, 2018). Increasing population pressure has forced to enhance vegetable productivity with limited resources. Crop intensification is an alternative way to meetthe daily demand of a growing population. Bhendi crop is more susceptible to weed because of its slow growth rate in the early stages and canopy coverage. Interference of weeds affects bhendi productivity by 40 to 80% and depending on diverse weed flora, their intensity and stage (Jalendhar *et al.,* 2016). Bhendi crop responds to weed interference varied with soil fertility status and climatic condition. Blanket rate of pre-emergence herbicide application creates an initial higher concentration in the soil which may results in toxicity to crops and soil microflora and fauna. Replacement of commercial herbicide with encapsulated/loaded herbicide formulations releases the active ingredients slowly and offers sustained control of weeds over a longer period crop growth besides ecological and economic advantages in the cropping sequence. Therefore, the study was carried out to find out the consistent effect of slow release herbicide formulations on weeds and bhendi in the rice-bhendi crop sequence.

MATERIAL AND METHODS

A field experiment was carried out during *rabi*, 2016-17 at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai to find out the residual effect of slow release herbicide formulations on weed and bhendi in the rice-bhendi crop sequence. The farm is geographically located at 9° 54' N latitude and 78° 80' E longitude at an altitude of 147 m above mean sea level. The soil of the experimental field was

*Corresponding author's e-mail: samygs81@yahoo.co.in

sandy clay loam in texture, with low (237.0 kg/ha), medium (19.0 kg/ha) and medium (195.0 kg/ha) in available N, P and K, respectively. The experimental crop bhendi was raised in the previous season rice experimental field without altering the layout to study residual of slow release herbicide formulation applied to the rice crop.

The details of eight weed control treatments imposed to previous rice crop were oxadiargyl loaded in biochar applied at 3 DAT, oxadiargyl loaded in zeolite applied at 3 DAT, encapsulated oxadiargyl with starch applied at 3 DAT, encapsulated oxadiargyl with water-soluble polymer applied at 3 DAT, oxadiargyl at 100 g/ha applied at 3 DAT, butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding (HW) on 40 DAT, weed-free check and weedy check.

Bhendi hybrid CO-4 with 110 days duration and 5 kg/ha seed rate was used. The crop was fertilized with the recommended dose of 200:100:100 kg NPK /ha as a source of urea, single super phosphate and muriate of potash. Nitrogen applied as three equal splits, one-third of nitrogen, a full dose of P_2O_5 and 50% of K_2O were applied as basal while remaining nitrogen was applied in two splits on 30 and 60 DAS. The balance 50% of K_2O was applied on 30 DAS. The seeds were dibbled at the rate of two seeds/ hill in the rice stubbles with a spacing of 45cm x 30 cm during the first week of January. Gap filling and thinning was done on 10 DAS and leaving a single healthy plant/hill. The crop was irrigated immediately after sowing and life irrigation was given on three days after sowing and subsequent irrigations were given as and when crop required. Need-based plant protection measures were given whenever pest incidences are more than economic threshold level. Crop growth rate (CGR) and Relative growth rate (RGR) were computed by using the standard procedure suggested by Watson (1958) and Williams (1946) respectively. The data was statistically analyzed by following the method of Gomez and Gomez (2010). The data pertaining to weeds were transformed to the square root of x+2 and analyzed as suggested by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Weed dynamics

Total of 16 weed species were observed in the experimental field. In which four kinds of grass, four sedges and eight broad-leaved weeds were the dominant weed flora. *Echinochloa colonum, Leptochloa chinensis, Panicum flavidum, Cynodon dectylon* are the major weed species in grasses, *Cyperus rotundus, Fimbristylis miliacea, Cyperus difformis, Cyperus iria* species in sedges, *Eclipta alba, Trianthema portulacastrum, Ammannia*

Table 1. Residual effect of slow release herbicide formulations on absolute density (No./m^2) and relative density (%) of weeds in bhendi

Weed species	20 DAS		40 DAS		60 DAS		Harvest	
	AD (No.m^{-2})	RD (%)	AD (No.m^{-2})	RD (%)	AD (No.m^{-2})	RD (%)	AD (No.m^{-2})	RD (%)
Grasses								
Echinochloa colonum	38.67	27.17	80.67	30.10	128.33	32.41	148.33	30.23
Leptochloa chinensis	10.33	7.26	15.67	5.85	27.67	6.99	32.67	6.66
Panicum flavidum	10.67	7.50	13.33	4.97	22.00	5.56	26.33	5.37
Cynodon dectylon	9.33	6.56	12.33	4.60	18.67	4.71	20.67	4.21
Total grasses	69.00	48.48	122.00	45.52	196.67	49.66	228.00	46.47
Sedges								
Cyperus rotundus	24.33	17.09	39.33	14.68	39.67	10.02	55.33	11.28
Fimbristylis miliacea	7.67	5.39	16.67	6.22	19.33	4.88	27.67	5.64
Cyperus difformis	7.00	4.92	11.00	4.10	13.33	3.37	20.00	4.08
Cyperus iria	6.33	4.45	13.67	5.10	15.00	3.79	16.00	3.26
Total sedges	45.33	31.85	80.67	30.10	87.33	22.05	119.00	24.25
Broad leaved weeds								
Eclipta alba	11.67	8.20	23.67	8.83	38.67	9.77	47.33	9.65
Trianthema portulacastrum	3.33	2.34	9.33	3.48	16.67	4.21	23.33	4.75
Ammannia baccifera	5.67	3.98	14.33	5.35	25.33	6.40	30.67	6.25
Convolvulus arvensis	3.33	2.34	4.33	1.62	8.67	2.19	12.67	2.58
P.maderaspatensis	4.00	2.81	5.33	1.99	7.33	1.85	9.67	1.97
Phyllanthus niruri	0.00	0.00	4.67	1.74	6.33	1.60	7.67	1.56
Boerhavia diffusa	0.00	0.00	3.67	1.37	5.67	1.43	7.33	1.49
Cleome viscosa	0.00	0.00		0.00	3.33	0.84	5.00	1.02
Total BLW	28.00	19.67	65.33	24.38	112.00	28.28	143.67	29.28
Total weed density	142.33	100.00	268.00	100.00	396.00	100.00	490.67	100.00

AD- Absolute density RD- Relative density Data statistically not analyzed *baccifera, Convolvulus arvensis, Phyllanthus maderaspatensis, Phyllanthus niruri, Boerhavia diffusa, Cleome viscosa* species in BLW were the predominant weed flora.

The absolute density (No./m^2) and relative density (%) of individual weed spices are presented in Table 1. Generally, grassy weeds were the dominant weed species followed by sedges and broad leaved weeds at 20 and 40 DAS, whereas at 60 DAS and at harvest, grasses were the dominant followed by BLW and sedges. The relative density of individual weed species showed that the grassy weed *Echinochloa colonum* was the predominant weed species registered an absolute density of 38.67, 80.67, 128.33, 148.33/ m^2 witha relative density of 27.17, 30.10, 32.41, 30.23% at 20, 40, 60 DAS and harvest stage. Whereas, in sedges, *Cyperus rotundus* was the prime sedge weed species found higher proportion in weed flora with a higher relative density of 17.09, 14.68, 10.02, 11.28% with an absolute density of 24.33, 39.33, 39.67, 55.33/m^2 observed at 20, 40, 60 DAS and harvest stage, respectively. The predominant occurrence of the weed species in bhendi might be due to the wider ecological adaptation of weeds and abundance of resources available during crop growth. This invariably resulted in higher uptake of nutrients and faster growth of the weeds compared to crop. Similarly, a wide spectrum of weeds in field crops was reported by many workers of Govindan and Chinnusamy (2014) and Bommayasamy *et al.* (2018).

Table 2. Residual effect of slow release herbicide formulations on total weed density (No./m^2) and total weed dry weight (g/m^2) in bhendi

Treatments	Total weed density (No./m^{-2})				Total weed dry weight (g/m^2)			
	20 DAS	40 DAS	60 DAS	Harvest	20 DAS	40 DAS	60 DAS	Harvest
T_1-Oxadiargyl loaded in biochar on 3 DAT	6.71 (42.33)	12.10 (144.67)	14.74 (215.33)	16.35 (265.33)	5.44 (27.61)	7.45 (53.65)	10.26 (103.29)	11.82 (137.70)
T_2-Oxadiargyl loaded in zeolite on 3 DAT	5.83 (31.00)	10.75 (113.67)	13.41 (179.33)	14.94 (221.33)	4.75 (20.57)	7.25 (50.56)	10.15 (101.12)	11.65 (133.66)
T_3-Oxadiargyl encapsulated with starch on 3 DAT	8.31 (68.00)	13.08 (169.33)	14.40 (205.67)	15.59 (241.33)	5.14 (24.55)	7.69 (57.29)	10.90 (117.08)	12.37 (151.14)
T_4-Oxadiargyl encapsulated with water soluble polymer on 3 DAT	6.93 (40.33)	11.16 (122.67)	12.97 (166.33)	14.73 (215.00)	5.12 (24.23)	6.89 (45.48)	10.44 (107.11)	11.79 (137.10)
T_5-Oxadiargyl at 100 g ha^{-1} on 3 DAT	10.10 (92.67)	13.10 (170.00)	14.93 (221.00)	17.34 (298.67)	6.47 (39.87)	8.17 (65.01)	11.31 (126.16)	12.64 (157.82)
T_6-Butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS	4.90 (21.33)	8.77 (75.67)	10.78 (114.67)	12.53 (155.33)	4.86 (21.73)	6.29 (37.61)	8.37 (68.03)	10.02 (98.60)
T_7 -Weed free check	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)
T_8 –Weedy check	11.66 (142.33)	16.41 (268.00)	19.77 (389.33)	22.16 (490.67)	10.05 (99.54)	11.70 (135.30)	15.12 (227.26)	16.71 (277.40)
SEd	0.33	0.56	0.57	0.61	0.36	0.44	0.50	0.55
CD (P=0.05)	0.70	1.20	1.21	1.30	0.78	0.95	1.08	1.17

Figures in parentheses are mean of original values Data subjected to square root $\sqrt{x+2}$ transformation

Effect on weed density and weed dry weight

Weed control treatments hada significant influence on the total weed density and dry weight at all stages. Weed-free check showed its supremacy in total weed density and weed dry weight at all stages (Table 2). Among weed control treatments, the residual effect of butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS recorded significantly lowered total weed density of 21.33/m^2 and 51.17/m^2 at 20 and 40 DAS respectively. It was on par with the residual effect of oxadiargyl loaded with zeolite at 3 DAT. Whereas, 60 DAS and harvest stage, the residual effect of oxadiargyl encapsulated with water-soluble polymer on 3 DAT recorded lower weed density which was on par with the oxadiargyl loaded in zeolite on 3 DAT. A similar line of findings was reported by Bahri and Taverdet (2007) who have revealed that herbicide release rate can be controlled by coated microsphere in optimum level over a longer period of time.

Significantly lower weed dry weight was recorded in butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS (21.73 g/m^2) which was on par with residual effect of oxadiargyl loaded in zeolite on 3 DAT and oxadiargyl loaded in biochar at 3 DAT compared to all other treatments at 20 DAS. The same pattern was observed in total weed dry weight at 40, 60 DAS and harvest stage except oxadiargyl loaded in biochar at 3 DAT. This is might be due to the controlled release of encapsulated/ loaded herbicide reduced movement of herbicide in soil and keeping the sizable portion of the active ingredient in the surface soil layer for longer period of time. Similar findings were reported by Shirvani *et al.* (2014) and Bommayasamy *et al.* (2018). The highest total weed density and weed dry weight were recorded in weedy check at all stages.

Effect on crop growth attributes

Preceding rice herbicide residue showeda significant difference in bhendi seed germination percentage (Table 3). Bhendi germination percentage ranged from 73.7 to 94.2%. Slow release formulation of oxadiargyl recorded higher germination percentage as compared tothe commercial formulation and weedy check. Among the residual effect of encapsulated/loaded materials, higher germination percentage of 85.2% was recorded with the residual effect of oxadiargyl loaded in biochar on 3 DAT. Lower germination of 75.3% was recorded in weedy check. It might be due to higher weed density and biomass in the preceding rice crop which depleted more resources.

Plant height of 92.7 cm recorded under butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW at 20 and 40 DAS and it was significantly superior to other treatments except for weed-free check. The next order best treatments were a residual effect of encapsulated oxadiargyl with water-soluble polymer on 3 DAT and it was comparable with oxadiargyl loaded with zeolite on 3 DAT. Preceding crop herbicide residue and hand weeding resulted in minimum crop-weed competition which leads to higher plant height. These results are in accordance with findings of Baraiya *et al.* (2017). LAI, at 60 DAS, butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS recorded significantly higher LAI (1.84) which was on par with all other treatments except weedy check.

Weed-free check recorded significantly higher CGR of 11.35 and 12.68 g/m^2/day at 30 to 60 DAS and 60 DAS to harvest stage respectively. At 30 to 60 DAS, the highest CGR value of 8.91 g/m^2/day was recorded with preceding crop residue of butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS. The next best treatment was a residual effect of oxadiargyl encapsulated with water-soluble polymer on 3 DAT. Whereas, at 60 DAS to harvest stage, butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS registered higher CGR. The next order best treatments were a residual effect of oxadiargyl loaded in zeolite on 3 DAT, oxadiargyl encapsulated with starch on 3 DAT, oxadiargyl encapsulated with water-soluble polymer on 3 DAT, oxadiargyl loaded with biochar on 3 DAT. RGR, at 30 to 60 DAS, butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS recorded higher RGR of 0.0228 g/g/day and it was on par with oxadiargyl encapsulated with water soluble polymer on 3 DAT. At 60 DAS to harvest stage, the lowest RGR of 0.0053 g/g/day was registered with weedy check as compared to oxadiargyl encapsulated/loaded materials. This might be due to higher weed density adversely affected favorable growth condition of crops. These results were in accordance with reports of Shivalingappa *et al.* (2014).

Table 3. Residual effect of slow release herbicide formulations on germination, plant height, LAI, CGR, RGR and fruit yield of bhendi

Treatments	Germination (%)	Plant height (cm)	LAI (60 DAS)	CGR (g/m^2/day) 30 - 60 DAS	CGR (g/m^2/day) 60 DAS - Harvest	RGR (g/g/day) 30 – 60 DAS	RGR (g/g/day) 60 DAS - Harvest	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield (t/ha)
T_1-Oxadiargyl loaded in biochar on 3 DAT	85.8	66.2	1.24	3.04	4.95	0.0139	0.0075	15.6	6.54	20.3	7.55
T_2-Oxadiargyl loaded in zeolite on 3 DAT	81.2	67.8	1.26	4.58	7.09	0.0176	0.0079	16.6	6.78	23.3	8.40
T_3-Oxadiargyl encapsulated with starch on 3 DAT	82.6	63.6	1.68	2.84	4.92	0.0132	0.0076	13.9	6.14	17.4	7.17
T_4-Oxadiargyl encapsulated with water soluble polymer on 3 DAT	81.2	69.9	1.13	7.33	3.24	0.0228	0.0036	16.1	6.72	22.7	7.59
T_5-Oxadiargyl at 100 g ha^{-1} on 3 DAT	78.4	56.4	1.34	4.59	3.07	0.0179	0.0046	12.8	5.67	16.3	5.97
T_6-Butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS	87.3	92.7	1.84	8.91	8.84	0.0241	0.0066	17.2	6.74	23.8	15.37
T_7 -Weed free check	94.2	106.2	2.33	11.35	12.68	0.0250	0.0071	19.0	7.38	28.9	24.19
T_8 –Weedy check	73.7	43.4	1.13	2.91	3.50	0.0137	0.0062	12.6	5.61	11.6	3.27
SE.d	4.04	4.9	0.10	3.30	8.80	0.0010	0.0005	0.9	0.33	0.86	0.56
CD (P=0.05)	8.65	10.6	0.22	7.10	18.80	0.0022	0.0011	2.0	0.71	1.84	1.20

Effect on yield attributes and yield

Bhendi fruit length, fruit girth, fruit weight and fruit yield were significantly influenced by weed control treatments in bhendi (Table 3). The higher fruit length, fruit girth, fruit weight were recorded under weed-free check. Among the weed control treatments, maximum fruit length and fruit girth of 17.2 and 6.93 cm was recorded with the residual effect of butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS. It was comparable with the residual effect of oxadiargyl loaded in zeolite on 3 DAT, oxadiargyl encapsulated with water-soluble polymer on 3 DAT and oxadiargyl loaded with biochar on 3 DAT. Whereas, the highest individual fruit weight was recorded in the residual effect of oxadiargyl loaded in zeolite on 3 DAT (23.3g) which was comparable with oxadiargyl encapsulated with water-soluble polymer on 3 DAT. Weed-free check, butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT + HW twice at 20 and 40 DAS, oxadiargyl loaded in zeolite on 3 DAT were recorded 6.40, 3.70, 1.53 times higher fruit yield against the weedy check. Similar findings was reported earlier by Bommayasamy *et al.* (2018) who has revealed that slow release formulations reduced the loss of herbicide and degraded by microbes which creates unfavorable condition for weed growth. The least fruit length, fruit girth, individual fruit weight, fruit yield registered with weedy check. Similar results were reported by Hamma *et al.* (2016). Severe competition exerted for natural resources in the weedy check results in poor growth and fruit yield.

Finally, it could be concluded that the higher growth and yield attributes and yield of bhendi crop were realized with residual effect of the slow release formulation of oxadiargyl loaded in zeolite applied to previous rice crop at 3 days after transplanting.

CONCLUSION

The results clearly indicated that the higher growth and yield attributes and yield of bhendi crop was realized with residual effect of the slow release formulation of oxadiargyl loaded in zeolite applied to previous rice crop at 3 days after transplanting.

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