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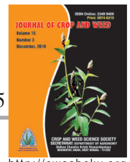

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The effect of herbicide carriers on weed characteristics and the yield of rice under transplanted condition

*A. CHANDRAN AND R. KRISHNAN

Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu-641 003, India

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ABSTRACT

The field experiment was executed to assess the effect of herbicide carriers on weed characteristics and the yield of transplanted rice during 2016-2017. The experiment was designed to evaluate two herbicides (Butachlor at the rate of 1 kg ha^{-1} on 3 days after transplanting (DAT) and Pyrazosulfuron-ethyl at the rate of 30 g ha^{-1} on 3 DAT) and seven different herbicide carriers (dry sand, prilled urea, sawdust, charcoal powder, fly ash, talc powder and water). As per the obtained results, higher weed control and yield were found in the use of Butachlor @ 1 kg ha^{-1} on 3 DAT together with carrier material talc powder. Lower weed control and yield were recorded in the usage of Pyrazosulfuron-ethyl on 3 DAT at the rate of 30 g ha^{-1} along with the carrier material water.

Keywords**:** Butachlor, herbicide carriers, pyrazosulfuron-ethyl, transplanted rice, weed flora

Rice is one of India's extensively cultivated food crops and its production ensures food security apart from the contribution to the growth of the national economy. Rice has been cultivated in India throughout the year in different regions of the country, in varied ecologies spread over an area of 43.8 M ha yielding 85.3 M t of rice and the productivity average accounting to 2960 kg ha^{-1} (Jagtap *et al*., 2012). Despite that, low average rice productivity of 1.710 t ha^{-1} is recorded in India (Prakash *et al*., 2008). Weed competition may bring in a serious reduction in rice yield when occurred during the critical growth period of rice. Rice under transplanted condition is susceptible to a wide range of weeds which include grasses, sedges and broad-leaved weeds. In the transplanted rice ecosystem, *Echinochloa crusgalli*, *Echinochloa colona,* and *Cyperus difformis* are the most prevalent weed species found. Pre-emergence herbicides like Butachlor and Pyrazosulfuron-ethyl effectively control weeds which emerges at an earlier growth stage of rice. Indiscriminate application of herbicides at improper doses and improper stages of application has resulted in increasing residue levels of these chemicals in soil, water and plant produce. Apart from that, the high rate of application of herbicides increases the cost of cultivation on account of the higher amount of herbicides being used.

Application of herbicides along with suitable carriers reduces the release rate of herbicides. The use of suitable carrier materials reduces the concentration of the effective principles in the environment through the slow and restrained release of herbicides. This sustained release and reduction in the leaching of herbicides is expected for enhancing their efficacy and reduction of pollution. Apart from these, it also aids in reducing the cost of cultivation. Hence, the current study examines the impact of herbicide carriers on weed characteristics and the yield of rice cultivated under transplanted conditions.

The investigation was carried out at Tamil Nadu Agricultural University, Coimbatore to assess the efficiency of herbicide carriers for transplanted lowland rice during 2016-17. The experiment site is located at 11º North latitude, 76º East longitude, and is 426.7 meters above Mean Sea Level. The soil in the investigation field was clay loam having a pH of 8.2 and electrical conductivity of 0.45 dS m^{-1}. The field soil had low available nitrogen content (254 kg ha^{-1}), high available potassium content (564 kg ha^{-1}), medium available phosphorus content (22.4 kg ha^{-1}), and medium carbon content (0.6%). The experimental field was laid out in a factorial randomized block design (RBD), which consisted of two factors: herbicides and herbicide carriers with 14 treatments duplicated thrice. The treatment comprised of a combination of the pre-emergence application of two herbicides 3 days after transplanting (DAT) *viz.* Butachlor used at the rate of 1 kg ha^{-1}, Pyrazosulfuron-ethyl used at the rate of 30 g ha^{-1}, and seven herbicide carriers *viz.* dry sand, prilled urea, sawdust, charcoal powder, fly ash, talc powder, and water. Herbicides were mixed with different carrier materials at a rate of 25 kg ha^{-1} for all carrier materials except water, whereas water was used at the rate of 500 L ha^{-1}. A Weedy check was maintained outside the experimental plot.

Short Communication

Email: ambika27077@gmail.com

CO (R) 50, a rice variety of medium duration, was used for the experiment, and twenty-two days old seedlings of which were transplanted at 20 x 10 cm spacing. The crop was fertilized with the recommended nitrogen, phosphorus and potassium doses of 150:50:50 kg ha^{-1} in the form of urea, single super phosphate and muriate of potash. Before transplanting 50% nitrogen and an entire dose of phosphorus and potassium were used initially and nitrogen was equally top-dressed at active tillering, panicle initiation, and heading stages of rice. Water was maintained as a thin film during the herbicide use and a common hand weeding was given on the 45 DAT.

Periodical weed samples were drawn from four random sampling areas of 0.25 m^2 each in every plot. In each experimental plot, weeds were sampled at 30 DAT, 60 DAT, and harvest of the crop. Details of predominant weed flora and weed density were recorded as per standard norms. The formula proposed by Sankaran and Mani (1974) was used for calculating weed control efficiency (WCE).

$$\text{WCE (\%)} = \frac{\text{DWC-DWT}}{\text{DWC}} \times 100$$

where, DWC: Weed density in the weedy check (Number m^{-2})

DWT: Weed density in the control treatments (Number m^{-2})

For calculating the grain yield, mature grains obtained from each plot (net) were cleaned, dried under the sun, and weighed at moisture of 14 per cent and the rice yield was indicated in t ha^{-1}. At harvest information on productive tillers per m^2 and the number of filled grains per panicle were also collected.

The data were statistically interpreted as per procedures given by Gomez and Gomez (1984). As the information on weed density recorded increased deviation, they were undergone square root transformation $\sqrt{(x+2)}$ (Bartlett,1936) and was statistically interpreted. The Least Significant Difference (LSD) at 0.05 per cent probability was calculated for comparison wherever statistical significance was found. The non-significant difference was mentioned as NS.

Weed flora

Weed flora consisted of grasses such as *Echinochloa colona, Panicum repens*, *Echinochloa crusgalli*, sedges such as *Fimbristylis miliacea, Cyperus iria*, *Cyperus difformis*, *and* broad-leaved weeds such as *Ammannia baccifera, Marsilea quadrifolia*, *Eclipta alba*.

Weed density and weed dry weight

The usage of different herbicides significantly altered the weed density and dry weight. During all stages of observation, the use of Butachlor at the rate of 1 kg ha^{-1} on 3 DAT had declined the total weed density (Table 1) and total weed dry weight (Table 2). Chandra *et al.* (1998) found that the application of Butachlor provided 35.10% weed control in rice. While the use of Pyrazosulfuron-ethyl recorded increased weed density and dry weight at all stages of observation. Sunil and Shankaralingappa (2014) observed that Pyrazosulfuron-ethyl @ 25 g ha^{-1} alone was ineffective in controlling weeds.

Among the herbicide carriers used, the application of talc powder @ 25 kg ha^{-1} on 3 DAT recorded lesser weed density and dry weight during the entire stages of observation. The efficiency in controlling weeds by the application of talc powder was seen up to the maturity of the crop. Jebakumar and Satheeja (2007) reported that the use of carriers has increased the adsorption rate, escalated the holding ability of Butachlor, and resulted in the slow discharge of the herbicide. The application of talc power obtained better weed control and was followed by the usage of charcoal powder and sawdust as carrier materials. Superior weed density and weed dry weight was reported at 60 DAT in comparison with the earlier stage of observation. This might have been due to the dissipation of the active ingredient of herbicides applied as the days progressed. At all stages of application, use of water @ 500 L ha^{-1} on 3 DAT registered significantly higher total weed density and total weed dry weight. The non-significant interaction effect was seen between applied herbicides and the carrier materials used during the entire stages of observation which includes on 30, 60 DAT and at the harvest of rice.

Weed control efficiency

The use of Butachlor at the rate of 1 kg ha^{-1} on 3 DAT reported increased weed control efficiency (Table 3) than the application of Pyrazosulfuron-ethyl. This is due to a higher reduction of grasses, sedges, and BLW during the early stage of rice. The usage of Butachlor at the rate of 1.5 kg ha^{-1} followed by hand weeding resulted in the highest weed control efficiency (Singh *et al*., 1994 and Srinivasan *et al*., 2008).

Out of the herbicide carriers used, the superior WCE was seen in the application of talc powder @ 25 kg ha^{-1} on 3 DAT at 30 DAT, 60 DAT, and at the harvest stage of the crop. This could be attributed to the reason that the combination of herbicides with inert materials like talc powder diminishes the effect of herbicides through the physicochemical dissolution forces. This is consistent with the findings of Jebakumar and Satheeja (2007). Whereas, weed control efficiency was lowest in the use of water as carrier @ 500 L ha^{-1} on 3 DAT.

Table 1: Effect of weed management practices on the total weed density (No. m^{-2}) in rice

Treatment	30 DAT			60 DAT			Harvest		
	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean
Dry sand (25 kg ha^{-1}) on 3 DAT	8.17 (66.26)	8.67 (74.59)	8.42 (70.42)	9.41 (88.14)	9.94 (98.27)	9.68 (93.20)	7.61 (57.35)	8.22 (67.08)	7.91 (67.08)
Prilled urea (25 kg ha^{-1}) on 3 DAT	8.36 (69.46)	8.75 (76.06)	8.56 (72.76)	9.68 (93.12)	10.32 (105.91)	10.00 (99.51)	7.86 (61.25)	8.53 (72.32)	8.20 (72.32)
Sawdust (25 kg ha^{-1}) on 3 DAT	7.44 (54.83)	7.80 (60.38)	7.62 (57.61)	8.37 (69.56)	9.06 (81.53)	8.71 (75.54)	6.83 (46.19)	7.12 (50.15)	6.98 (50.15)
Charcoal powder (25 kg ha^{-1}) on 3 DAT	7.26 (52.15)	7.65 (58.03)	7.45 (55.09)	8.18 (66.44)	8.66 (74.43)	8.42 (70.43)	6.41 (40.60)	6.89 (47.04)	6.65 (47.04)
Fly ash (25 kg ha^{-1}) on 3 DAT	8.69 (75.06)	9.08 (81.91)	8.89 (78.48)	10.05 (100.50)	10.62 (112.38)	10.34 (106.44)	8.18 (66.40)	8.87 (78.20)	8.53 (78.20)
Talc powder (25 kg ha^{-1}) on 3 DAT	6.22 (38.16)	6.79 (45.60)	6.50 (41.88)	7.17 (50.97)	7.77 (59.95)	7.47 (55.46)	5.43 (29.00)	5.91 (34.41)	5.67 (34.41)
Water (500 L ha^{-1}) on 3 DAT	9.42 (88.27)	9.80 (95.63)	9.61 (91.95)	11.00 (120.50)	11.54 (132.56)	11.27 (126.53)	9.14 (83.08)	9.74 (94.36)	9.44 (88.72)
Mean	7.94 (63.46)	8.28 (70.31)		9.12 (84.18)	9.60 (95.00)		7.35 (54.84)	7.89 (61.67)	
	H	T	H x T	H	T	H x T	H	T	H x T
SEm(±)	**0.17**	**0.31**	**0.44**	**0.20**	**0.37**	**0.53**	**0.19**	**0.35**	**0.50**
LSD (0.05)	**0.34**	**0.64**	**NS**	**0.41**	**0.77**	**NS**	**0.39**	**0.73**	NS
Weedy check		15.37 (236.42)			17.57 (308.40)			14.80 (218.78)	

Notes: H_1 - Butachlor 1 kg ha^{-1} on 3 DAT; $H_{2:}$ Pyrazosulfuron-ethyl 30 g ha^{-1} on 3 DAT; figures mentioned in the parenthesis are original values; Data has been subjected to square root transformation

Table 2: Effect of weed management practices on the total weed dry weight (kg ha^{-1}) in rice

Treatment	30 DAT			60 DAT			Harvest		
	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean
Dry sand (25 kg ha^{-1}) on 3 DAT	13.16 (172.69)	13.80 (189.94)	13.48 (181.31)	16.40 (268.57)	17.26 (297.41)	16.83 (282.99)	8.29 (68.28)	8.66 (74.50)	8.48 (71.39)
Prilled urea (25 kg ha^{-1}) on 3 DAT	13.48 (181.30)	14.13 (199.06)	13.81 (190.18)	16.78 (281.00)	17.97 (322.54)	17.38 (301.77)	8.31 (68.60)	8.71 (75.31)	8.51 (71.95)
Sawdust (25 kg ha^{-1}) on 3 DAT	11.88 (140.71)	12.53 (156.68)	12.21 (148.65)	14.30 (204.00)	15.70 (245.99)	15.00 (225.00)	7.53 (56.20)	7.99 (63.29)	7.76 (59.74)
Charcoal powder (25 kg ha^{-1}) on 3 DAT	11.59 (133.75)	12.28 (150.22)	11.93 (141.98)	14.03 (196.25)	14.87 (220.62)	14.45 (208.43)	7.38 (54.00)	7.83 (60.76)	7.60 (57.38)
Fly ash (25 kg ha^{-1}) on 3 DAT	13.71 (187.56)	14.29 (203.80)	14.00 (195.68)	17.19 (295.00)	18.12 (327.83)	17.66 (311.42)	8.43 (70.62)	8.80 (76.88)	8.62 (73.75)
Talc powder (25 kg ha^{-1}) on 3 DAT	10.20 (103.50)	10.86 (117.51)	10.53 (110.51)	12.43 (154.05)	12.75 (162.08)	12.59 (158.00)	6.33 (39.60)	6.78 (45.51)	6.56 (42.56)
Water (500 L ha^{-1}) on 3 DAT	14.96 (223.40)	15.66 (244.63)	15.31 (234.02)	18.96 (359.13)	20.31 (412.14)	19.64 (385.50)	9.14 (83.00)	9.55 (90.64)	9.34 (86.22)
Mean	12.71 (163.27)	13.36 (180.25)		15.73 (251.10)	16.71 (284.13)		7.91 (62.90)	8.32 (69.55)	
	H	T	H x T	H	T	H x T	H	T	H x T
SEm(±)	**0.25**	**0.46**	**0.65**	**0.38**	**0.71**	**0.98**	**0.16**	**0.30**	**0.46**
LSD (0.05)	**0.50**	**0.94**	**NS**	**0.78**	**1.47**	**NS**	**0.33**	**0.62**	**NS**
Weedy check		**20.13 (405.03)**			**27.80 (772.30)**			**14.33 (204.50)**	

Notes: H_1 - Butachlor 1 kg ha^{-1} on 3 DAT; $H_{2:}$ Pyrazosulfuron-ethyl 30 g ha^{-1} on 3 DAT; figures mentioned in the parenthesis are original values; Data has been subjected to square root transformation

Table 3: Effect of weed management practices on weed control efficiency, productive tillers/m², number of filled grains/panicle and grain yield in rice

Treatment	WCE (%)									Productive tillers / m²			Filled grains/ panicle			Grain yield (t ha⁻¹)		
	30 DAT			60 DAT			Harvest											
	H1	H2	Mean	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean	H_1	H_2	Mean
Dry sand (25 kg ha^{-1}) on 3 DAT	77.61	74.80	76.21	72.80	69.67	71.23	71.75	66.96	69.35	361	345	353	92.8	89.7	91.2	6.4	6.0	6.2
Prilled urea (25 kg ha^{-1}) on 3 DAT	76.54	74.31	75.42	71.26	67.31	69.29	69.83	64.37	67.10	356	340	348	91.2	87.7	89.5	6.3	6.0	6.1
Sawdust (25 kg ha^{-1}) on 3 DAT	81.48	79.60	80.54	78.53	74.84	76.68	77.25	75.29	76.27	385	370	377	94.6	91.0	92.8	7.1	6.8	6.9
Charcoal powder (25 kg ha^{-1}) on 3 DAT	82.38	80.39	81.39	79.49	77.03	78.26	80.00	76.83	78.41	388	372	380	96.3	92.9	94.6	7.5	7.2	7.3
Fly ash (25 kg ha^{-1}) on 3 DAT	74.64	72.33	73.49	68.98	65.31	67.15	67.29	61.48	64.39	352	336	344	88.7	85.8	87.2	6.1	5.8	5.9
Talc powder (25 kg ha^{-1}) on 3 DAT	87.11	84.59	85.85	84.27	81.50	82.88	85.71	83.05	84.38	414	400	407	101.8	98.7	100.2	7.9	7.6	7.7
Water (500 L ha^{-1}) on 3 DAT	70.18	67.69	68.94	62.81	59.09	60.95	59.08	52.46	55.77	325	310	317	83.1	79.6	81.3	5.7	5.4	5.5
Mean	78.56	76.25		74.02	70.67		72.99	68.63		369	353		92.6	89.3		6.7	6.4	
										H	T	H x T	H	T	H x T	H	T	H x T
SEm(±)	-	-	-	-	-	-	-	-	-	**6.70**	**12.52**	**17.71**	**1.4**	**2.6**	**3.7**	**1.12**	**2.11**	**2.98**
LSD (0.05)	-	-	-	-	-	-	-	-	-	**13.76**	**25.74**	**NS**	**2.9**	**5.4**	**NS**	**2.31**	**4.33**	**NS**
Weedy check		-			-			-			**280**			**51.6**			-	

Notes: H_1 - Butachlor 1 kg ha^{-1} on 3 DAT; H_{2-} Pyrazosulfuron-ethyl 30 g ha^{-1} on 3 DAT; Data on WCE statistically not analysed

Yield attributes and yield of grains

Components contributing to yield like productive tillers present per square meter, the number of grains that are filled present per panicle constitute the most important factors determining the grain yield. When compared to Pyrazosulfuron-ethyl, the use of Butachlor @ 1 kg ha^{-1} on 3 DAT has enhanced yield components which include productive tillers present per square meter and grains which are filled present per panicle (Table 3). Regarding the herbicide carriers used, these attributes were higher with the use of talc powder @ 25 kg ha^{-1} on 3 DAT followed by the use of charcoal powder as the carrier @ 25 kg ha^{-1} and was comparable with sawdust when used @ 25 kg ha^{-1}. Gogoi *et al*. (2000) reported that reduced removal of nutrients by weeds and declined weed competition provided a competition-free environment for rice. This in turn enhanced the capacity for N, P, and K uptake and augmented source (LAI) and sink size and in turn increased the count of productive tillers present per square meter and the number of filled grains per panicle. Whereas the application of water as a carrier at 500 L ha^{-1} reported lower attributes contributing to yield on account of lesser weed control and increased competition between the crop and weeds.

The weed-free crop will always yield better compared to weed-infested crop. Butachlor when applied @ 1 kg ha^{-1} on 3 DAT registered significantly superior grain yield (6.7 t ha^{-1}) compared to Pyrazosulfuron-ethyl (6.4 t ha^{-1}) (Table 3). Among the application of herbicide carriers, talc powder @ 25 kg ha^{-1} retained its supremacy by recording a higher grain yield (7.7 t ha^{-1}) which was comparatively greater than the application of charcoal powder and sawdust @ 25 kg ha^{-1} as carrier materials. The efficacy of these carriers can be attributed to their increased surface area and finer particle size, which in turn results in an efficient release pattern of herbicides. This leads to a comparatively weed-free environment, which is established from the early stage till the harvest, resulting in less weed competition. Grain yield was lower (5.5 t ha^{-1}) in the application of water as the herbicide carrier at 500 L ha^{-1} on 3 DAT with herbicides. It could be associated with the severe competition between the crop and weed for resource pools.

According to the experimental results, the use of Butachlor @1 kg ha^{-1} along with the herbicide carrier talc powder @ 25 kg ha^{-1} records the lowest weed density and dry weight, highest WCE, and superior yield under lowland conditions.

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