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Entrapped pre-emergence oxadiargyl on growth and yield of rice under various agro-ecosystems

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ABSTRACT

Field experiments were carried out in two locations, *viz*. Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai and ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands during *Kharif*, 2016 and 2017 respectively to study the effect of entrapped pre-emergence oxadiargyl herbicide on the growth and yield of rice under various agro ecosystems. Weed control measures significantly reduced the density and dry weight of weeds in both the ecosystems. In mainland ecosystem, at 20 DAT, the highest reduction in weed density (61.8%) was noticed with the application of oxadiargyl encapsulated with starch which was comparable with the application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT (60.8%). Whereas, under island ecosystem, the lowest total weed density (78.2%) was observed with the application of oxadiargyl loaded in zeolite which entrapped herbicides have increased sorption and decreased the dissipation of herbicide in soil which helps to release herbicide slowly through entire season for effective weed control. Application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT recorded significantly higher number of productive tillers/m^2 followed by the application of oxadiargyl loading with zeolite on 3 DAT. Weed free check has recorded significantly higher grain and straw yield in both ecosystems. The increase in grain yield with weed control treatment was ranged from 1.22 to 2.97 t/ha and 1.07 to 3.15 t/ha in main and island ecosystem, respectively compared to weedy check. The highest straw yield of 59.3 and 72.4% was recorded under weed free check as compared to weedy check in main and island ecosystem, respectively.

INTRODUCTION

Rice is the stable food crop and extensively grown cereal in more than hundred countries in the world. Asian countries produced and consumed 90 per cent of rice and it supplies 50 to 80% calories of energy. In India, rice occupies an area of 43.99 mha with production and productivity of 106.69 mt and 2.43 t/ha, respectively. In Tamil Nadu and Andaman Nicobar Islands the rice production is 6.40 and 0.013 m t from an area of 1.85 mha and 6400 ha with productivity of 3.47 and 2.05 t/ha, respectively (Indiastat 2018). Intensification of agriculture has provoked the complications of biotic stresses including insects, diseases and weeds on crops including rice. The world population is estimated to increase by 9 to11 billion by the year 2025 out of which 4.3 billion will be dependent on rice for their basic food. Agronomists are having great challenges to meet the food demands of the growing population and to achieve food security in the country, the present production levels need to be increased by two million tonnes every year.

Weeds are intense competition with rice crop for natural resources during the entire growth period, causing significant yield losses. Manual hand weeding is quite effective, but laborious and at earlier stages not easy due to morphologically weeds are similar to rice seedling (Rahman *et al.* 2012) which resulted time consuming and high cost. Shortage of agricultural labourers and increased wages rate, declining interest among farmers on agriculture-based occupation and raise of input cost caused rice farming less remunerative. In general, farmers are applying premergence herbicide which fails to control late emerging and diverse weed flora in rice. Encapsulated herbicides are expected to control the targeted weed species without affecting non-targeted plants and retained in soil throughout growing season which reduce late emerging weeds and not leaving herbicide residues at end of the cropping season (Bommayasamy *et al.* 2018). Therefore, the present study was carried out with the entrapped pre-emergence oxadiargyl herbicide on weed control and growth and yield of rice crop under various agro ecosystems.

MATERIALS AND METHODS

Field experiments were conducted in two locations, *viz*. Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai and ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands during *Kharif*, 2016 and 2017 respectively to study the effect of entrapped pre-emergence oxadiargyl on growth and yield of rice under various agro ecosystems. The experimental sites were geographically located in the Western agro-climatic zone of Tamil Nadu and Islands agro climatic zones of India at $9^0$54'and $11^0$38' N latitude and $78^0$54' and $92^0$39' East longitude at an altitude of 147 m and 15 m above MSL, respectively. The soils of the experimental plots were sandy clay loam and clay loam with a pH of 6.9 to 7.3 and EC of 0.30 to 0.34, dS/m in texture with medium organic carbon (0.30 to 0.38%) status, low available nitrogen (246 to 263 kg/ha), medium in available phosphorus (16.1 to 19.5 kg/ha) and medium to high in available potassium (249 to 284 kg/ha), respectively.

The experiment was laid out in randomized block design with eight treatments and replicated thrice. Weed control treatments, *viz*. oxadiargyl (100 g/ha) loaded with 1:1 ratio of biochar or zeolite (100 g of zeolite/biochar was taken and added 1000 ml of 10% oxadiargyl and stirred it for 15 min in magnetic stirrer and suspension was allowed to dry for overnight which enables oxadiargyl to adsorb on the zeolite/biochar surface) applied at 3 days after transplanting (DAT), encapsulated oxadiargyl (100 g/ha) with starch or water soluble polymer (water soluble polymers like poly allylamine hydrochloride (PAH) and sodium poly styrene sulfonate (PSS) weighed each 20 mg was added to 20 ml 03-05 NaCl solution in separate beakers and dissolved it completely and pH was adjusted to neutral level. PAH solution was added to oxadiargyl and suspension was gently stirred in magnetic stirrer for 15 min followed by centrifuged at 1000 rpm for 15 min then rinsed three times with NaCl to remove the unbounded particles. The same procedure was repeated with oppositely charged polyelectrolyte (PSS). Then the suspension was centrifuged and allowed to dry for overnight), oxadiargyl alone at the rate of 100 g/ha, butachlor at the rate of 1.25 kg/ha applied on 3 DAT *fb* hand weeding on 40 DAT, weed free check and weedy check. The recommended dose of fertilizer (150: 50: 50 kg N: P_2O_5: K_2O /ha) was applied through urea, single super phosphate and muriate of potash. Nitrogen was applied in four splits at 10 DAT, active tiller, panicle initiation and flowering stages while 100% phosphorus and 50% potassium were applied as basal. Remaining 50% potassium was applied at panicle initiation stage. The paddy variety ***TKM-13*** with 130 days duration was used for the study. Seedling with age of 30 days old were transplanted on August, 2016 and July 30, 2017 with a spacing of 20 x 10 cm. The plots were irrigated to 2.5 cm depth of water upto establishment, thereafter cyclic submergence of 5 cm was continued thought the crop period. Need based plant protection measures were given whenever the incidences (leaf folder) more than economic threshold level. All other recommended package of practices was adopted as per the schedule. The data was statistically analyzed by following the method of Gomez and Gomez (1984). The data pertaining to weeds were transformed to square root of $\sqrt{x+2}$ and analysed as suggested by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Effect on weeds

The dominant occurrence of weed species in rice could probably be due to the ecological adaptation of main and island ecosystems. Among the weeds *Echinochloa colonum*, *Leptochloa chinensis, Panicum flavidum* and *Cynodon dectylon* under grass, *Cyperus rotundus, Fimbristylis miliacea* and *Cyperus difformis* under sedges and *Eclipta alba, Ammannia baccifera, Convolvulus arvensis, Aeschynomene indica* and *Bergia capensis* under broad-leaved weeds were observed thought the period of experiment under mainland ecosystem. Whereas in Island ecosystem, the weeds, *viz*. *Echinochloa colonum, Cynodon dectylon* and *Setaria glauca* among grasses, *Cyperus haspan, Cyperus iria, Cyperus eragrostis, Cyperus difformis*, and *Fimbristylis miliacea* among sedges and *Sphenoclea zeylanica, Ammannia baccifera,* and *Bergia capensis* among BLW were observed during the entire crop growth season.

Weed control measures significantly reduced the density and dry weight of weeds in both the ecosystems (**Table 1**). In mainland ecosystem, at 20

Table 1. Effect of oxadiargyl encapsulated/loaded herbicide formulations on total weed density and total weed dry weight of rice under different ecosystem

Treatment	Mainland ecosystem				Island ecosystem			
	Total weed density (no./m^2)		Total weed dry weight (g/m^2)		Total weed density (no./m^2)		Total weed dry weight (g/m^2)	
	20 DAT	40 DAT	20 DAT	40 DAT	20 DAT	40 DAT	20 DAT	40 DAT
Oxadiargyl loaded with biochar on 3 DAT	7.43(53.3)	9.63(91.3)	3.45(9.92)	4.92(22.2)	5.86(32.3)	8.16(64.7)	2.95(6.7)	5.42(27.4)
Oxadiargyl loaded with zeolite on 3 DAT	7.02(47.3)	8.96(78.3)	3.41(9.62)	4.64(19.6)	5.48(28.0)	7.59(55.7)	2.30(3.3)	5.27(25.8)
Oxadiargyl encapsulated with starch on 3 DAT	6.29(37.7)	10.1(100.7)	3.60(11.0)	4.94(22.6)	6.43(39.3)	7.95(61.3)	2.98(6.9)	5.51(28.5)
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	8.21(65.3)	10.3(105.3)	3.79(12.3)	4.77(21.3)	6.19(36.3)	8.24(66.3)	2.90(6.4)	5.81(31.8)
Oxadiargyl at 100 g/ha on 3 DAT	8.81(75.7)	11.1(120.7)	3.84(12.8)	5.28(25.8)	6.85(45.0)	9.47(88.0)	3.35(9.3)	5.93(33.2)
Butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT	6.36(38.7)	7.83(59.3)	3.66(11.4)	4.47(18.0)	9.48(88.0)	7.87(60.0)	4.22(15.8)	5.17(24.8)
Weed free check	1.41(0)	1.41(0)	1.41(0)	1.41(0)	1.41(0)	1.41(0)	1.41(0)	1.41(0)
Weedy check	10.0(98.7)	13.1(170.7)	5.89(32.8)	7.49(54.2)	11.4(128.3)	13.4(178.3)	6.79(44.2)	8.91(77.8)
LSD (p=0.05)	0.70	0.82	0.32	0.60	0.72	0.94	0.33	0.66

Original figures in parentheses were subjected to square root $\sqrt{x+2}$ transformation before statistical analysis, DAT: Days after transplanting

DAT, the highest reduction in weed density (61.8%) was noticed with application of oxadiargyl encapsulated with starch which was comparable with application of application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT (60.8%), application of oxadiargyl loaded in zeolite on 3 DAT (52.0%) and application of oxadiargyl loaded in biochar on 3 DAT (45.9%). Whereas, under island ecosystem, the lowest total weed density of 78.2% was observed with the application of oxadiargyl loaded in zeolite. It was on par with the application of oxadiargyl loaded in biochar. This might be due to higher adsorption of herbicide molecules in zeolite and biochar which released the active ingredients slowly and reduced leaching loss of herbicide and affects nutrient uptake by weeds under island ecosystem. Similar findings were reported by Bommayasamy *et al.* (2018). At 40 DAT, in mainland ecosystem, the highest reduction in weed density of 54.1, 46.6 % and weed dry weight of 63.7, 66.8% were observed with application of oxadiargyl loaded in zeolite and application of oxadiargyl loaded in biochar, respectively. Whereas, under island ecosystem, the lowest total weed density was recorded with the application of oxadiargyl loaded in zeolite followed by oxadiargyl encapsulated with starch and these treatments were on par with each other. Chinnamuthu *et al.* (2007) reported that smart delivery of herbicide will be more useful to exhaust the weed seed bank which is responsible for the weeds causing one hundred percentage crops loss, is a great accomplishment for the farming community.

Effect on crop growth

Weed control treatment significantly influenced plant height at harvest stage of the crop (**Table 2**). Plant height at harvest stage ranged from 5.1 to 18.1% and 2.8 to 21.8% higher than weedy check in

Table 2. Effect of oxadiargyl encapsulated/loaded herbicide formulations on plant height, leaf area index (LAI), crop growth rate of rice under different ecosystem

Treatment	Mainland ecosystem				Island ecosystem			
	Plant height (cm)	LAI at flowering	CGR (g/m^2/d)		Plant height (cm)	LAI at flowering	CGR (g/m^2/d)	
			Tillering - flowering	Flowering - harvest			Tillering - flowering	Flowering - harvest
Oxadiargyl loaded with biochar on 3 DAT	90.2	5.50	14.8	13.6	106.1	5.78	18.8	12.5
Oxadiargyl loaded with zeolite on 3 DAT	92.1	5.80	16.0	13.6	112.2	6.09	18.6	12.0
Oxadiargyl encapsulated with starch on 3 DAT	89.8	5.44	14.7	15.5	105.1	5.72	17.0	11.0
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	89.1	5.37	15.4	12.1	102.5	5.64	18.0	13.0
Oxadiargyl at 100 g/ha on 3 DAT	86.9	5.22	14.2	12.5	101.5	5.48	14.9	11.2
Butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT	93.9	5.86	15.2	14.3	114.7	6.15	19.3	15.4
Weed free check	97.7	5.95	17.5	16.6	119.9	6.25	21.1	18.0
Weedy check	82.7	5.02	13.6	11.6	98.7	5.20	10.4	9.2
LSD (p=0.05)	8.1	0.56	1.7	1.6	12.3	0.59	2.8	1.2

DAT: Days after transplanting; CGR: crop growth rate; LAI: leaf area index main and island ecosystem, respectively. During this stage, among the weed control treatments, the highest plant height was recorded with the application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT under both the ecosystems. Whereas, other weed control treatments were on par with one another. The lowest plant height was observed with weedy check under both the ecosystems. Severe weed competition for natural resources results in suppression of crop growth at all stages of competition. This finding was in line with observations of Payman and Singh (2008). In mainland ecosystem, weed control treatment showed significant effect on LAI at flowering stage (**Table 2**). Weed free check recorded significantly higher LAI. Application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT significantly recorded higher LAI and was on par with application of oxadiargyl loaded in zeolite on 3 DAT and application of oxadiargyl loaded in biochar on 3 DAT. The least LAI was registered with the weedy check treatment. Whereas, similar trend was observed under island ecosystem with varied LAI, except application of oxadiargyl loaded with biochar on 3 DAT. This might be due to higher leaf area at flowering stage enabled the increased source-sink relationship through higher photosynthetic area of rice crop. This is in conformity with the findings of Rajput *et al.* (2017).

In mainland ecosystem, at tillering to flowering stage, weed free check recorded the highest crop growth rate (CGR) value (28.1%) and it was on par with application of oxadiargyl loaded with zeolite on 3 DAT. From flowering to harvest stage, higher CGR value (33.6, 23.3, 17.4, 17.4%) was recorded with the application of oxadiargyl encapsulated with starch, butachlor at 1.25 kg/ha applied on 3 DAT *fb* hand weeding on 40 DAT, oxadiargyl loaded in zeolite and oxadiargyl loaded in biochar, respectively. In island ecosystem, weed free check registered high CGR of 55.1% than weedy check at tillering to flowering stage and this was closely on par with application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT, application of oxadiargyl loaded in biochar and application of oxadiargyl loaded in zeolite. Whereas, at flowering to harvest stage, application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT recorded significantly higher CGR. The next best treatment was application of oxadiargyl encapsulated with water soluble polymer on 3 DAT, oxadiargyl loaded in biochar on 3 DAT and application of oxadiargyl loaded in zeolite on 3 DAT. Similar findings were reported by Sopena *et al.* (2009) who have revealed that alachlor encapsulated in EC is more effective in comparison to the commercial formulation.

Effect on yield components and yield

Number of productive tillers exhibited significant variation owing to weed control treatments. A significant increase in productive tillers formation resulted with weed free check in both ecosystems. In mainland ecosystem, the number of productive tillers/m^2 due to weed control treatment ranged from 238 to 363 productive tillers/m^2. Application of butachlor at 1.25 kg/ ha on 3 DAT *fb* hand weeding on 40 DAT recorded significantly higher number of productive tillers/m^2 followed by application of oxadiargyl loaded in zeolite on 3 DAT and application of oxadiargyl loaded in biochar on 3 DAT and were comparable with each other. In island ecosystem, similar trend was observed in the number of productive tiller/m^2 except application of oxadiargyl loaded in biochar on 3 DAT. The lowest number of productive tillers/m^2 was registered with weedy check in both ecosystems. Effective control of weeds during early stages of crop might have resulted in better tiller production. This finding is in conformity with the results of Bhimwal and Pandey (2014). Weed control treatment manifested favourable influence on the number of filled grains/ panicle (**Table 3**). In mainland ecosystem, among the weed control treatments, application of oxadiargyl loaded in zeolite on 3 DAT and oxadiargyl loaded in biochar on 3 DAT registered 30.9 and 21.8% more number of filled grains/panicle respectively. In island ecosystem, similar trend was noticed in the number of filled grains/panicle except oxadiargyl loaded in biochar on 3 DAT. The lowest number of filled grains/ panicle was registered in the weedy check treatment. This might be due effective control of weed dry matter accumulation favoured higher nutrient uptake by crop results in the production of more of filled grains/panicle. Similar lines of findings on the productive tillers, filled grains/panicle were obtained by Ganie *et al.* (2014). The difference in 1000 grain weight was not significant due to weed control treatments in both the ecosystems.

The grain and straw yield were significantly influenced by various weed control treatments (**Table 3**). Weed free check recorded significantly higher grain and straw yield in both ecosystems. Increased grain yield with weed control treatment was ranged from 1.22 to 2.97 t/ha and 1.07 to 3.15 t/ha in main and island ecosystem, respectively compared to weedy check. Application of butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT significantly recorded higher grain yield and was on par with the application of oxadiargyl loaded in zeolite on 3 DAT. The next best treatment was application of oxadiargyl

Table 3. Effect of oxadiargyl encapsulated/loaded herbicide formulations on yield attributes and yield of rice under different ecosystem

Treatment	Mainland ecosystem					Island ecosystem				
	Productive tillers/m^2	Filled grains/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Productive tillers/m^2	Filled grains/ panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Oxadiargyl loaded with biochar on 3 DAT	308	184.8	14.2	4.83	7.51	343	170.3	14.8	5.46	7.83
Oxadiargyl loaded with zeolite on 3 DAT	312	195.3	14.3	5.06	7.64	347	181.3	14.9	5.65	7.63
Oxadiargyl encapsulated with starch on 3 DAT	307	176.4	14.0	4.74	7.47	328	168.5	14.8	4.90	7.39
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	279	172.3	14.1	4.28	7.39	322	163.6	14.7	4.70	8.36
Oxadiargyl at 100 g/ha on 3 DAT	278	164.8	14.0	4.07	7.18	302	154.3	14.3	4.34	7.13
Butachlor at 1.25 kg/ha on 3 DAT *fb* hand weeding on 40 DAT	321	187.2	14.2	5.34	7.75	372	187.0	14.9	5.93	8.70
Weed free check	363	227.6	14.6	5.83	8.84	380	213.3	15.2	6.42	9.57
Weedy check	238	149.2	13.5	2.86	5.55	284	146.5	13.9	3.27	6.15
LSD (p=0.05)	40	30.4	NS	0.44	1.12	31	16.7	NS	0.60	0.73

DAT: Days after transplanting

loaded in biochar on 3 DAT and oxadiargyl encapsulated with starch on 3 DAT. However, these two treatments were comparable with each other. The weed free check recorded 59.3 and 72.4% higher straw yield as compared to weedy check in main and island ecosystem respectively.

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