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Pre-emergence herbicide of oxy fluorfen on Weed control in transplanted rice

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Abstract
A field experiment were conducted for two years at Agricultural Research Station, Bhavanisagar of Tamil Nadu Agricultural University, during *rabi* season of 2010 and 2011 to evaluate the new formulation of oxyfluorfen (23.5% EC) on weed control in transplanted rice. Oxyfluorfen is a diphenyl-ether herbicide as a pre or post-emergence herbicide used for control of annual and perennial broad leaved weeds in a variety of field crops. Many of the field experiments revealed the bio-efficacy of this herbicide; however, no information is available on the phytotoxicity symptoms in different crops and bioassay study of this herbicide in succeeding crops under Indian tropical conditions. Based on two years field experimentation, it was found that pre-emergence (PE) application of oxyfluorfen at 400 g ha^{-1} gave significantly lower total weed density, weed dry weight and higher weed control efficiency at all the intervals. Oxyfluorfen at 200 g ha^{-1} as PE herbicide can keep the weed density and dry weight below the economic threshold level and increase the grain yield (5709 and 6645 kg ha^{-1}) and straw yield (7102 and 7327 kg ha^{-1}) in transplanted rice. Unweeded control accounted for lower grain yield (3382 and 4136 kg ha^{-1}) which sequentially reflected through higher weed density and dry weight, respectively during both the years, due to heavy competition of weeds for nutrients, space and light. Even though some phytotoxicity effect was noticed in rice seedlings in higher doses immediately after application of oxyfluorfen, then the seedlings recovered and resulted in higher grain.

Keywords: oxyfluorfen, transplanted rice, weed density, weed dry weight, grain yield.

1. Introduction
Rice (*Oryza sativa* L.) is a staple food for more than 60% of the world population. It is the most important cereal crop and is extensively grown in tropical and subtropical regions of the world. In India, rice is cultivated in an area of 44.07 million hectares annually with a production of 103.4 million tonnes, with an average productivity of 2.3 t ha^{-1} (FAO, 2012) [3]. Weeds constitute one of the biggest problems in agriculture that also reduce the yield and also utilize essential nutrients. Most of the improved crop management practices in rice cultivation failed due to poor and improper practices for containing weeds. There are several reasons for low productivity and the one due to weeds is the most important. Weeds compete with rice for moisture, nutrients, light, temperature and space. Pillai and Rao (1974) [10] estimated the extent of yield reduction due to weeds to be over 50% in direct seeded upland rice, 30-35% in direct seeded rice under puddled condition and around 15-20% in transplanted rice. Uncontrolled weeds have caused yield reduction of 28-45% in transplanted rice (Singh *et al*., 2007; Manhas *et al*., 2012) [12, 7]. Furthermore, any delay in weeding will lead to increased weed biomass which has a negative correlation with yield. Hand weeding is the traditional weed control measure in rice cultivation practices. However, due to high labour cost, non-availability of labour and time taken for manual removal, farmers are forced to decide for cheaper alternative of chemical weed control. Many herbicides are being used successfully for weed control in rice both as pre-emergence and post-emergence application. Pre-emergence herbicides in common use are butachlor, pretilachlor, thiobencarb *etc*. New herbicides are now coming in the market and the use of herbicides of different chemical composition is desirable to reduce the problem of residue buildup, shift in weed flora and development of herbicide resistance in weeds. At present, no single approach of either use of herbicides or manual or mechanical weeding is effective in containing weed menace. Therefore, there is a necessity that these herbicides are supplemented with hand weeding to widen weed control spectrum. Hence, the present investigation was to study the influence of herbicide weed management on weed control efficiency and productivity of transplanted rice. The present study was undertaken to

study efficacy of oxyfluorfen (23.5% EC) in pre- emergence, it control of major wetland weeds in transplanted rice and also to arrive at an optimum dosage that can be recommended in rice tracts of Tamil Nadu in India.

2. Materials and Methods

Field experiments were laid out during *Rabi* seasons of 2010 and 2011 in North Block Farm of Agricultural Research Station (ARS) Bhavanisagar, located at Western Zone of Tamil Nadu, India. The geographical location of the experimental site is 11º29”N latitude and 77º08”E longitude with an altitude of 256 m above MSL and the farm receives the normal total annual rainfall of 696 mm in 42 rainy days. The soil was red sandy loam in texture with low in available nitrogen (240 kg ha^{-1}), medium in available phosphorus (21 kg ha^{-1}) and high in available potassium (258 kg ha^{-1}) with pH of 6.8. The experiment was laid out in randomized block design with nine treatments and replicated thrice. Treatments consisted of pre-emergence application of already registered oxyfluorfen (goal) at 200 g ha^{-1}, new formulation of oxyfluorfen (23.5% EC) at 150, 200, 250, 300 and 400 g ha^{-1}, butachlor 50% EC at 0.75 kg ha^{-1} + HW on 45 DAT, hand weeding twice on 25 and 45 DAT and unweeded control. The herbicides as per the treatment schedule were applied as pre-emergence at third day after sowing followed by a hand weeding on 45 DAT. Hand operated knapsack sprayer fitted with a flat fan type nozzle (WFN 40) was used for spraying the herbicides adopting a spray volume of 500 litres ha^{-1}. After transplanting, immediately a light irrigation was given to the crop for uniform germination. Recommended dose of 150:50:50 kg ha^{-1} of nitrogen, phosphorus and potassium in the form of urea (46% N), single super phosphate (16% P_2O_5) and murate of potash (60% K_2O) were applied. Fifty per cent of nitrogen (75 kg) and full dose of phosphorus (50 kg) and potassium (50 kg) were applied basally before sowing. The balance fifty per cent of nitrogen (75 kg) was top dressed thrice at active tillering, panicle initiation and heading stages of rice crop. Weed species present in the experimental plot were identified from unweeded control plot and grouped as grasses, sedges and broad leaved weeds. Weeds were sampled in each plot at 7, 15 and 30 days after transplanting (DAT) of the crop from an area of 1.0 m^2, counted and dried to constant weights at 80°C in hot air oven. Weed density and dry weight of each group of weeds were expressed as number m^{-2} and g m^{-2}, respectively. During the course of experiment, the data were recorded on predominant weed flora, weed density, weed dry weight and grain yield of rice. The data pertaining to weeds was transformed to square root scale of $\sqrt{(X+2)}$ and analysed as suggested by Snedecor and Cochran (1967) [13]. Whenever significant difference existed, critical difference was constructed at five per cent probability level.

3. Results and Discussion

3.1. Weed flora of the experimental field

The observation made on the common weeds of the experimental field.
The experimental field consisted of grasses, sedges and broad leaved weeds (BLW) from unweeded check plot at flowering stage of the crop. The major grass weed was *Echinochloa colona* (*L.*), *Echinochloa crusgulli* (L.), *Panicum repens* (L.) and the major sedge weed was *Cyperus rotundus* (L.). Among the broad leaved weeds *Eclipta alba* (L.), *Ammania baccifera* (L.) and *Ludwigia parviflora* (L.) were the dominant species.

3.2. Weed infestation in transplanted rice

3.2.1. Weed density

Pre-emergence application of new formulation of oxyfluorfen at 250, 300 and 400 g ha^{-1} followed by one hand weeding on 45 DAT resulted in effective control of broad leaved weeds, grasses and to some extent sedge due to its broad spectrum action **(Table 1).** Thus, broad leaved weeds were effectively controlled with the herbicide. Pre-emergence application of oxyfluorfen at higher doses of 300 and 400 g ha^{-1} followed by oxyfluorfen at 250 g ha^{-1} gave more impressive control of grasses and broad leaved weeds like *Echinochloa crusgulli, Panicum repens*, *Eclipta alba*, *Ammania baccifera* and *Ludwigia parviflora* due to the herbicidal effect over cell membrane causing disruption of the cells, ionic balance and ultimately death of weeds. Vargsaraj and Prince (1987) [14]. reported that 0.20 kg ha^{-1} controlled most weeds in rice except *Monochoria vaginalis*. The pre-emergence application of oxyfluorfen at 200 g ha^{-1} reduced the density of broad leaved weeds (70 to 90%) in onion compared with non treated plots was given by Sathya Priya *et al*. (2013) [11]. Application of oxyfluorfen at 400 g ha^{-1} resulted in the weed control of more than 90% of weeds, but the herbicide inhibited the crop growth. Kumar and Gautam (1986) [6] reported that application of oxyfluorfen at 0.15 kg ha^{-1} gave efficient weed control in direct seeded rice in puddle soil. However, Verma *et al.* (1987) [15] observed that application of oxyfluorfen at 0.20 kg ha^{-1} provided good control of weeds than its lower dose in transplanted rice.

3.2.2. Weed dry weight

Weed dry weight is the most important parameter to assess the weed competitiveness for the crop growth and productivity. Sparse weeds with high biomass might be more competitive for crops than dense weeds with lesser dry matter. Considerable reduction in weed dry weight was recorded with the application of oxyfluorfen at 300 and 400 g ha^{-1} at all the stages of observation and it was followed by pre-emergence application of oxyfluorfen at 250 g ha^{-1} and butachlor at 0.75 kg ha^{-1} + HW on 45 DAT (Table 2). This herbicide kills weed seedlings through contact action and membrane disruption, since light is required for herbicidal activity, diphenyl ether phytotoxicity is related to the process of photosynthesis and inhibition of both electron transport and ATP synthesis (Janaki *et al*, 2013) [4]. Minimum dry weed biomass was recorded in plots sprayed with oxyfluorfen at 200 g ha^{-1} while, maximum dry weed biomass was noticed in weedy check, where weeds were not controlled. Weed control efficiency which indicates the comparative magnitude of reduction in weed dry matter and also highly influenced by different weed control treatments. Throughout the experimental period, weed control efficiency was higher with pre-emergence application of oxyfluorfen at 400 g ha^{-1} followed by oxyfluorfen spray at 300 and 250 g ha^{-1} owing to the fact that it registered lesser weed density and weed dry weight.

3.3. Phytotoxic symptom scoring and rating on crop

The phytotoxicity symptom of pre-emergence application of oxyfluorfen (23.5% EC) was observed at higher doses of 300 and 400 g ha^{-1}. Moorthy and Menna (1988) [8] reported that oxyfluorfen at 0.1 kg ha^{-1} caused phytotoxicity to rice. Pillai *et al*. (1983) also reported slight toxicity to rice when oxyfluorfen was applied at 0.2 kg ha^{-1} six days after transplanting. Visual scoring for phytotoxic symptoms (crop discolouration / chlorosis / stunting / wilting/ deformation / vein clearing) in rice was done on 7, 15 and 30 days after pre-emergence oxyfluorfen application (Table 3 & 4). Singh *et al*. (1990) [12] reported that oxyfluorfen at above 0.5 kg ha^{-1} resulted in slight phytotoxicity to the crop during the initial growth period but afterwards the crop recovered. Mukopadhyay and Mandal (1982) [9] also found that rice seedlings recovered from the phytotoxicity effect of oxyfluorfen within 10 days of application. Even though some phytotoxicity effect was noticed in rice seedlings immediately after application of oxyfluorfen, the seedlings recovered and resulted in higher grain and straw yields.

3.4. Effect on crop

During both the years of study, among the weed control treatments, pre-emergence application of oxyfluorfen at 250 g ha^{-1} recorded higher grain yield of 6645 and 7102 kg ha^{-1} due to better control of weeds at critical stages thus providing favourable environment for better growth and development leading to enhanced yield and yield attributes in transplanted rice (Table 5). This treatment was comparable with oxyfluorfen at 200 g ha^{-1} with a grain yield of 6421 and 6854 kg ha^{-1} during *rabi* 2010 and 2011, respectively. Azad *et al*., (1990) [2] reported that in transplanted rice, oxyfluorfen granules applied at 0.2 kg ha^{-1} controlled all types of weeds from germination stage, gave the lower dry weight of weeds, higher number of panicles per square meter and the higher grain yield. Rice productivity is mainly decided by the weed control efficiency of weed management methods as earlier observed by Abraham *et al*. (2010) [1]. The pre-emergence herbicides offer the most practical, effective and economical method of weed control for increasing grain yield of transplanted rice. Hand weeding twice on 25 and 45 DAT and application of butachlor at 0.75 kg ha^{-1} + HW on 45 DAT was the next best treatment compared to application of oxyfluorfen at 200 and 250 g ha^{-1} during both the years. Higher grain yield attributes was recorded with the PE application of butachlor at 0.75 kg ha^{-1} + HW on 45 DAT over already registered oxyfluorfen (goal) at 200 g ha^{-1} applied plots and this might due to weed free environment and effective utilization of all above and below ground available resources. Kumar and Gautam (1986) [6] reported that application of oxyfluorfen at 0.15 kg ha^{-1} gave higher grain yield of 3960 kg ha^{-1} in direct seeded rice in puddle soil whereas, Jiang *et al*. (1989) [5] observed that higher grain yield in rice when oxyfluorfen was applied at 0.1 kg ha^{-1}. Even if, the weed control efficiency was higher under application of oxyfluorfen at 300 and 400 g ha^{-1} the grain yield were lower and the reason might be due to initial phytotoxicity symptoms on rice, which resulted in lesser plant height, dry matter production and to end with lower grain yield. PE application of oxyfluorfen at lower doses of 150 g ha^{-1} and oxyfluorfen (goal) at 200 g ha^{-1} registered lower grain yield when compared to other herbicidal treatments due to poor control of problematic weeds like *Echinochloa colona*, *Echinochloa crusgulli* and *Panicum repens* which showed higher weed density, dry weight and lower weed control efficiency. Under such conditions the crop may not be able to put forth optimum growth due to lack of resources resulting in reduced leaf area, dry matter production and to end with recorded lower grain yield of transplanted rice.

4. Conclusion

The study revealed that application of oxyfluorfen (23.5% EC) at 250 g ha^{-1} as pre-emergence herbicide can keep the weed density and dry weight below the economic threshold level and increase the grain yield in transplanted rice. Even though some phytotoxicity effect was noticed in rice seedling immediately after application of oxyfluorfen, the seedlings recovered within days and resulted in higher grain and straw yields at par with hand weeding twice.

5. Acknowledgments

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Table 1: Effect of different weed management practices on total weed density in transplanted rice

Treatments	Total weed density (No. m^{-2})					
	***Rabi*, 2010**			***Rabi*, 2011**		
	7 DAHS	**15 DAHS**	**30 DAHS**	**7 DAHS**	**15 DAHS**	**30 DAHS**
T_1 - PE oxyfluorfen (Goal) at 200 g a.i ha^{-1}	2.98 (5.67)	3.75 (10.04)	3.89 (10.97)	2.54 (3.52)	3.30 (7.38)	4.18 (12.94)
T_2 - PE oxyfluorfen at 150 g a.i ha^{-1}	3.12 (6.33)	3.90 (11.22)	4.77 (17.40)	3.12 (6.38)	4.19 (13.03)	5.53 (24.15)
T_3 - PE oxyfluorfen at 200 g a.i ha^{-1}	2.84 (4.96)	3.72 (9.87)	4.53 (15.55)	2.78 (4.63)	3.80 (10.37)	4.90 (18.52)
T_4 - PE oxyfluorfen at 250 g a.i ha^{-1}	2.11 (1.84)	3.47 (8.34)	3.75 (10.04)	2.51 (3.49)	3.57 (8.94)	4.33 (14.07)
T_5 - PE oxyfluorfen at 300 g a.i ha^{-1}	1.97 (1.38)	3.26 (7.16)	3.47 (8.35)	2.37 (2.87)	3.30 (7.37)	4.09 (12.34)
T_6 - PE oxyfluorfen at 400 g a.i ha^{-1}	1.78 (0.72)	2.94 (5.42)	3.25 (7.06)	2.11 (1.85)	2.96 (5.54)	3.81 (10.49)
T_7 - Butachlor at 0.75 kg ha^{-1} + HW on 45 DAT	2.82 (4.85)	4.49 (8.46)	4.80 (17.70)	2.78 (4.96)	5.54 (23.32)	5.53 (29.13)
T_8 - HW twice on 25 and 45 DAT	6.50 (34.12)	10.32 (89.58)	3.51 (8.54)	4.57 (15.83)	11.04 (102.13)	3.81 (10.45)
T_9 - Unweeded control	6.93 (39.42)	10.53 (92.62)	10.87 (98.96)	4.78 (17.58)	10.84 (98.47)	11.07 (102.72)
SEd	0.13	0.21	0.17	0.07	0.22	0.17
CD (P=0.05)	0.29	0.44	0.35	0.15	0.84	0.35

Figures in parenthesis are original values; PE - Pre emergence; HW - Hand weeding

Table 2: Total weed dry weight and weed control efficiency as influenced by different weed management practices in transplanted rice

Treatments	*Rabi,* 2010				*Rabi,* 2011			
	Total weed dry weight (kg ha^{-1})		WCE (%)		Total weed dry weight (kg ha^{-1})		WCE (%)	
	15 DAHS	30 DAHS	15 DAHS	30 DAHS	15 DAHS	30 DAHS	15 DAHS	30 DAHS
T_1 - PE oxyfluorfen (Goal) at 200 g a.i ha^{-1}	3.66 (9.43)	6.89 (38.52)	82.63	76.75	2.86 (5.0)	7.04 (40.37)	91.76	77.05
T_2 - PE oxyfluorfen at 150 g a.i ha^{-1}	3.99 (11.58)	8.04 (53.20)	78.68	67.87	4.37 (14.32)	8.41 (58.46)	76.36	66.77
T_3 - PE oxyfluorfen at 200 g a.i ha^{-1}	3.66 (9.46)	8.01 (52.80)	82.55	68.12	3.70 (9.7)	7.83 (50.33)	84.07	71.32
T_4 - PE oxyfluorfen at 250 g a.i ha^{-1}	3.01 (5.73)	7.25 (42.91)	89.48	74.09	3.28 (7.2)	6.72 (36.57)	88.18	79.285
T_5 - PE oxyfluorfen at 300 g a.i ha^{-1}	2.88 (5.07)	6.84 (37.97)	90.63	77.11	2.84 (4.9)	6.35 (32.57)	91.99	81.53
T_6 - PE oxyfluorfen at 400 g a.i ha^{-1}	2.59 (3.74)	6.35 (32.43)	93.10	80.43	2.63 (3.9)	5.97 (28.55)	93.62	83.87
T_7 - Butachlor at 0.75 kg ha^{-1} + HW on 45 DAT	3.40 (7.86)	7.46 (45.52)	85.82	72.52	3.78 (10.2)	7.77 (49.53)	83.15	71.73
T_8 - HW twice on 25 and 45 DAT	7.98 (52.43)	6.02 (11.85)	48.66	92.87	8.68 (62.4)	3.58 (8.96)	42.44	94.98
T_9 - Unweeded control	8.11 (54.18)	14.01 (165.60)	-	-	8.56 (60.5)	14.41 (175.24)	-	-
SEd	**0.15**	**0.21**	**-**	**-**	**0.16**	**0.22**	**-**	**-**
CD (P=0.05)	**0.31**	**0.45**	**-**	**-**	**0.34**	**0.47**	**-**	**-**

Figures in parenthesis are original values; PE - Pre emergence; HW - Hand weeding

Table 3: Visual scoring for phytotoxic symptoms in transplanted rice during both the years

Treatments	7 DAHA	15 DAHA	30 DAHA	45 DAHA
T_1 - Oxyfluorfen (goal) at 200g ha^{-1}	0	0	0	0
T_2 - Oxyfluorfen at 150g ha^{-1}	0	0	0	0
T_3 - Oxyfluorfen at 200g ha^{-1}	0	0	0	0
T_4 - Oxyfluorfen at 250g ha^{-1}	2	0	0	0
T_5 - Oxyfluorfen at 300g ha^{-1}	3	2	0	0
T_6 - Oxyfluorfen at 400g ha^{-1}	4	4	3	0

DAHA - Days After Herbicide Application

Table 4: Phytotoxic symptom scoring and rating on weeds and crop

Weed control rating	Crop injury symptom	Rating	Effect
No control	No injury, Normal	0	None
Very poor control	Slight stunting, injury or discoloration	1	Slight
Poor control	Some stand loss, stunting / discoloration	2	Slight
Poor to deficient control	Injury more pronounced but not persistent	3	Slight
Deficient control	Moderate injury, recovery possible	4	Moderate

Table 5: Effect of weed management methods on grain and straw yield of transplanted rice

Treatments	*Rabi,* 2010			*Rabi,* 2011		
	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1 - PE oxyfluorfen (Goal) at 200 g a.i ha^{-1}	18.7	4836	6578	18.2	5552	7336
T_2 - PE oxyfluorfen at 150 g a.i ha^{-1}	18.8	4341	6158	18.2	5967	6867
T_3 - PE oxyfluorfen at 200 g a.i ha^{-1}	19.2	5495	6854	19.1	6421	7148
T_4 - PE oxyfluorfen at 250 g a.i ha^{-1}	19.4	5709	7102	19.3	6645	7327
T_5 - PE oxyfluorfen at 300 g a.i ha^{-1}	19.1	5007	6349	19.0	5435	6707
T_6 - PE oxyfluorfen at 400 g a.i ha^{-1}	18.9	4477	5850	18.9	5276	4892
T_7 - Butachlor at 0.75 kg ha^{-1} + HW on 45 DAT	19.0	4737	6019	19.0	5744	6591
T_8 - HW twice on 25 and 45 DAT	19.1	4944	6368	19.4	5813	6984
T_9 - Unweeded control	18.5	3382	4780	18.4	4356	4736
SEd	0.04	220	407	0.05	206	386
CD (P=0.05)	NS	463	855	NS	433	787

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