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Agronomy

Bio efficacy and Persistence of Oxyfluorfen in Aerobic Rice

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Abstract

A field study was conducted at ZARS, V.C. Farm Mandya to determine bio efficacy and persistence of oxyfluorfen residue in soil and aerobic rice crop. Oxyfluorfen (23.5% EC) was applied (100 g a.i ha^{-1} and 200 g a.i ha^{-1}) to crop (Var MAS 946^{-1}). Soil samples were collected at 0, 5, 10, 20, 30, 45, 60, 90 days after sowing and at harvest. Plant samples were collected at 60, 90 days after sowing and at harvest. Both the samples were analyzed for oxyfluorfen residues by a validated high-performance liquid chromatography method with an accepted recovery of 82.6% for soil and 92.6% for plant samples at the minimum detectable concentration of 0.05 µg g^{-1}. Higher persistence of oxyfluorfen was noticed in treatment which received oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1} ranging between 0.61 µg g^{-1} and 0.08 µg g^{-1} at 0 and 60 days after treatment whereas oxyfluorfen did not persist in rice at any growth stages. A higher half life of 7.0 days and lower rate constant of 9.8 × 10-3 day^{-1} were also recorded in the same treatment.

Highlights

- Application of oxyfluorfen @ 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1} recorded higher persistence of oxyfluorfen 0.61 µg g^{-1} and 0.08 µg g^{-1} at 0 and 60 days after treatment .
- Higher half life of 7.0 days and lower rate constant of 9.8×10^{-3} day^{-1} was recorded in the treatment receiving oxyfluorfen @ 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}.

Keywords: *Aerobic rice, bio efficacy, Oxyfluorfen, Persistence, Weed flora*

Rice is one of the most important food crops globally. One third of the global population depends on rice for their daily sustenance. In India, rice is the most important food crop in terms of production and consumption. The yield losses due to weed infestation in rice may be as high as16 – 90 per cent (Zoschke, 1990). Aerobic rice is one of the methods of cultivation of rice, in which the seeds are seeded directly in non-puddled, non-flooded fields. Aerobic rice requires less water and labour than flooded rice established through transplanting, but is usually subject to much higher weed pressure (Balasubramanian and Hill, 2002), because direct seeded rice weeds and crop seeds germinates simultaneously. Weeds are the greatest yield limiting constraint to aerobic rice, contributing about 50 per cent to yield gaps. Hand weeding is complicated due to morphological similarity of rice and grassy weed seedlings. Moreover, timely hand weeding is not possible due to scarce availability of human labour and increased labour cost, which thus necessitates the use of herbicides. Hence, chemical weed control with appropriate herbicides has become a useful, economical and effective option. Oxyfluorfen is a diphenyl ether group contact and pre-emergence herbicide used for control of many annual broadleaf and grassy weeds in a variety of field crops. Herbicides have been proven effective in many cases, but intensive herbicide use can cause environmental contamination and the development of herbicide resistance. Nowadays, there is an increasing concern about the persistence of pesticide residues in soils, crop produce and subsequent contamination of soil and water. In this concern it is necessary that, contamination of agricultural products, soil and water by pesticides needs to be prevented to protect public health, soil and aquatic life. Oxyfluorfen is a highly toxic and persistent herbicide, which persists in soil and accumulates in terrestrial plants and certain aquatic environments through runoff (USEPA 1992). Thus, herbicide concentration in the environment may increase every year after its application. There are several reports on the efficacy of oxyfluorfen against various weeds in rice; few reports on the methods of chemical analysis and environmental fate in rice agro-ecosystems are available. Field studies on persistence of oxyfluorfen residues in aerobic rice are limited. Thus, actual field monitoring of oxyfluorfen residues is necessary to accurately evaluate the persistence. Hence, a study was conducted to assess the bio efficacy and persistence oxyfluorfen of in aerobic rice.

Materials and Methods

A field experiment was conducted at Zonal Agricultural Research Station, VC Farm, Mandya. The study area is situated between 11 ° 30ʿ to 13° 05ʿ North latitude and 76 °05ʿ and 77° 45ʿ East longitude and an altitude of 695 meters above mean sea level. It comes under the Region-III and the agro climatic zone VI (Southern Dry Zone) of Karnataka. The soil was Sandy clay loam in texture (sand, 65%, clay, 22.9%; silt, 12.1%);and with Available N 260.4 kg ha^{-1}, available $P_2O_5$18.7 kg ha^{-1}, and Available K_2O 140.6 kg ha^{-1} with Organic matter 12.9 g kg^{-1}, EC 0.23 m mhos cm^{-1}, and pH 6.9. The crop was sown (var MAS 946-1) on 24 August 2009 and the experiment was laid out in RCBD with three replications and the treatment details are given below.

T_1 : Oxyfluorfen at 100 g a.i ha^{-1}

T_2 : Oxyfluorfen at 100 g a.i ha^{-1}+ FYM @ 10 t ha^{-1}

T_3 : Oxyfluorfen at 100 g a.i ha^{-1}+ FYM @ 10 t ha^{-1}+ One hand weeding at30 DAS

T_4 : Oxyfluorfen at 200 g a.i ha^{-1}

T_5 : Oxyfluorfen at 200 g a.i ha^{-1}+ FYM @ 10 t ha^{-1}

T_6 : Hand weeding @ 30 & 45 days after sowing

T_7 : Un weeded Control.

The quantity of Oxyfluorfen (23.5%) needed for each treatment was calculated as per treatment. The herbicide was applied three days after sowing with spray solution of 750 litres ha^{-1} . Periodical biometric observations on growth and yield parameters were recorded. To know the bio efficacy of oxyfluorfen observations on Weed population was recorded by placing 100 cm X 100 cm quadrate randomly in each plot. After counting weed numbers, weed sample from the quadrate was collected and dried in oven at 60°C and weighed. Weed dry matter was expressed as weed dry weight g m^{-2}. The weed control efficiency of different treatments compared to control is calculated by using the formula

$$WCE = \frac{DWC - DWT}{DWC}$$

DWC = Dry weight of weeds in weedy check plot.

DWT = Dry weight of weeds in treated plots.

Persistence of oxyfluorfen was studied by collecting soils from each treatment at 0, 10, 20, 30, 45, 60, 90 days after sowing and at harvest and brought to the laboratory. The residue of oxyfluorfen in soil and plant was done as per the methodology given by Gennari *et al,* (1990) using High Performance Liquid Chromatography (HPLC). Oxyfluorfen was separated on HPLC and identified at the particular retention time of 2.7 minute. The linearity of oxyfluorfen in HPLC was observed up to 10 ppm. The amount of oxyfluorfen residues was calculated by comparing the sample response with the response of the standards by using the following formula.

Table 1. Effect of oxyfluorfen on Plant height, number of tillers hill $^{-1}$, panicle length, number of panicles hill^{-1}, Grain yield and Straw yield at harvest in aerobic rice.

Treatments	Plant height (cm)	No of tillers hill^{-1}	Panicle length (cm)	Number of panicles hill^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Oxyfluorfen 100 g a.i ha^{-1}	63.5	28.9	15.5	8.1	1630.5	2571.4
T_2: Oxyfluorfen 100 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	67.6	31.1	16.9	9.2	1828.6	3428.5
T_3: Oxyfluorfen100 g a.i ha^{-1} + FYM @ 10 t ha^{-1} + hand weeding	71.4	33.4	17.2	11.4	2468.6	4394.1
T_4: Oxyfluorfen 200 g a.i ha^{-1}	70.1	32.2	17.2	9.5	2902.9	4857.15
T_5: Oxyfluorfen 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	72.8	34.1	17.4	12.5	3315.2	5142.9
T_6: Hand weeding 30 & 45 DAS	66.7	29.6	15.9	8.8	3169.5	5100.5
T_7:Unweeded control	62.7	28.1	11.7	7.8	1379.0	2013.25
S.Em ±	0.77	0.32	0.37	0.38	242.1	233.3
C.D. (P=0.05)	2.38	0.98	1.15	1.15	745.9	718.9

Table 2. Weed population (no. m^{-2}) as influenced by weed control treatments in aerobic rice.

Treatment	30 DAS				60 DAS				At harvest			
	Monocot weeds	Sedge	Dicot weeds	Total	Monocot weeds	Sedge	Dicot weeds	Total	Monocot weeds	Sedge	Dicot weeds	Total
T1: Oxyfluorfen 100 g a.i ha-1	12.0 (3.50)	19.5 (4.47)	18.5 (4.40)	50.0 (7.10)	25.5 (5.19)	21.0 (4.63)	19.5 (4.47)	66.0 (8.15)	26.5 (5.19)	25.0 (5.04)	24.4 (4.98)	75.9 (8.74)
T2: Oxyfluorfen 100 g a.i ha-1 + FYM @ 10 t ha-1	14.5 (3.87)	21.5 (4.69)	16.5 (4.12)	52.5 (7.28)	26.5 (5.19)	19.5 (4.47)	16.5 (4.12)	62.5 (7.94)	28.5 (5.38)	23.5 (4.89)	22.5 (4.79)	74.5 (8.66)
T3: Oxyfluorfen100 g a.i ha-1 + FYM @ 10 t ha-1 + hand weeding	13.0 (3.67)	19.5 (4.47)	17.0 (4.18)	49.5 (7.07)	21.5 (4.69)	17.8 (4.27)	17.5 (4.24)	56.8 (7.57)	22.5 (4.79)	21.0 (4.63)	21.5 (4.69)	65 (8.09)
T4: Oxyfluorfen 200 g a.i ha-1	9.5 (3.16)	16.5 (4.12)	14.5 (3.87)	40.5 (6.40)	16.0 (4.06)	12.5 (3.60)	13.6 (3.75)	42.1 (6.53)	21.5 (4.69)	16.0 (4.06)	19.5 (4.47)	57 (7.58)
T5: Oxyfluorfen 200 g a.i ha-1 + FYM @ 10 t ha-1	7.5 (2.82)	18.5 (4.35)	11.5 (3.46)	37.5 (6.16)	15.5 (4.0)	10.5 (3.32)	15.0 (3.94)	41.0 (6.44)	17.5 (4.24)	18.5 (4.36)	22.5 (4.79)	58.5 (7.68)
T6: Hand weeding 30 & 45 DAS	8.5 (3.0)	20.0 (4.53)	15.0 (3.94)	43.5 (6.63)	17.5 (4.24)	11.0 (3.39)	12.5 (3.60)	41.0 (6.44)	20.5 (4.58)	21.5 (4.69)	22.5 (4.79)	64.5 (8.06)
T7:Unweeded control	25.0 (5.04)	46.5 (6.85)	51.5 (7.21)	123.0 (11.11)	32.0 (5.7)	44.5 (6.71)	49.0 (7.03)	125.5 (11.22)	13.5 (3.74)	45.0 (6.74)	50.5 (7.14)	109 (10.46)
S.Em ±	0.19	1.06	1.31	0.19	0.84	1.15	0.89	0.44	0.71	0.91	1.29	0.43
C.D. (P=0.05)	0.96	1.25	4.04	0.96	2.59	1.75	2.76	1.36	2.18	2.81	3.97	1.34

Figures in the parenthesis indicated the transformed values ($\sqrt{X + 0.5}$).

DAS= Days After Sowing

Table 3. Weed dry weight (WDW) and weed control efficiency (WCE) as influenced by weed control treatments.

Treatments	30 DAS		60 DAS		At harvest	
	WDW (g m^{-2})	WCE (%)	WDW (g m^{-2})	WCE (%)	WDW (g m^{-2})	WCE (%)
T_1: Oxyfluorfen 100 g a.i ha^{-1}	5.27 (2.35)	74.5	36.33 (6.08)	59.5	71.0 (8.45)	29.6
T_2: Oxyfluorfen 100 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	5.8 (2.46)	72.0	38.25 (6.23)	57.3	71.5 (8.48)	29.1
T_3: Oxyfluorfen100 g a.i ha^{-1} + FYM @ 10 t ha^{-1} + hand weeding	5.68 (2.43)	72.5	28.66 (5.40)	68.0	64.6 (8.07)	35.9
T_4: Oxyfluorfen 200 g a.i ha^{-1}	2.13 (1.51)	89.7	21.22 (4.66)	76.3	52.0 (7.24)	48.4
T_5: Oxyfluorfen 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	3.12 (1.82)	84.9	23.21 (4.87)	74.1	48.6 (7.01)	51.8
T_6: Hand weeding 30 & 45 DAS	18.66 (4.37)	9.8	19.25 (4.44)	78.5	45.1 (6.75)	55.3
T_7:Unweeded control	20.69 (4.60)	0.0	89.66 (9.52)	0.0	100.8 (10.06)	0.00
S.Em ±	0.68	--	1.2	--	0.94	--
C.D. (P=0.05)	2.05	--	3.5	--	2.91	--

Figures in the parenthesis indicated the transformed values ($\sqrt{X + 0.5}$).
DAS= Days After Sowing

Table 4. Persistence of Oxyfluorfen residues (µg g^{-1}) in soil in aerobic rice.

Treatments	Days after treatment							
	0	10	20	30	45	60	90	At harvest
T_1: Oxyfluorfen at 100 g a.i ha^{-1}	0.14	0.12	0.11	0.01	0.007	0.005	BDL	BDL
T_2: Oxyfluorfen at 100 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	0.18	0.14	0.12	0.02	0.014	0.006	BDL	BDL
T_3: Oxyfluorfen at 100 g a.i ha^{-1} +FYM @ 10 t ha^{-1} + handweeding	0.18	0.13	0.12	0.04	0.011	0.007	BDL	BDL
T_4: Oxyfluorfen at 200 g a.i ha^{-1}	0.60	0.48	0.38	0.21	0.13	0.06	BDL	BDL
T_5: Oxyfluorfen at 200 g a.i ha^{-1} +FYM @ 10 t ha^{-1}	0.61	0.41	0.40	0.26	0.21	0.08	BDL	BDL
T_6: Hand weeding @ 30 & 45 days after sowing	ND	ND	ND	ND	ND	ND	ND	ND
T_7: Unweeded control	ND	ND	ND	ND	ND	ND	ND	ND

BDL: Below Detection Limit.
ND: Not Detected.

Table 5. Degradation kinetics of oxyfluorfen residues in soil in aerobic rice

Treatments	K_{deg} (× 10^{-3} day^{-1})	Half life (days) $t_{1/2}$	R^2
T_1: Oxyfluorfen at 100 g a.i ha^{-1}	12.00	5.8	0.803
T_2: Oxyfluorfen at 100 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	11.80	5.9	0.839
T_3: Oxyfluorfen at 100 g a.i ha^{-1} +FYM @ 10 t ha^{-1} + handweeding	10.00	6.9	0.882
T_4: Oxyfluorfen at 200 g a.i ha^{-1}	9.90	6.9	0.889
T_5: Oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}	9.80	7.0	0.896

$$\text{Oxyfluorfen (mg kg}^{-1}) = \frac{(A_s)(V_{Std})(df) \times C \times F}{(A_{Std})(V_s)(W_s)}$$

Where, A_s = Peak area of the sample
V_{Std} = Volume (ml) of the standard injected
A_{Std} = peak area of the standard
V_s = Volume (ml) of the sample injected
df = Dilution factor
W_s = Weight (g) of the sample
C = Concentration of the standard (mg kg^{-1})
F = Recovery factor

$$F = \text{Recovery factor} = \frac{100}{\text{Percent Mean recovery}}$$

Results and Discussion

Grain and straw yield of aerobic rice was significantly influenced by application of oxyfluorfen. Application of oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1} recorded significantly higher grain yield and straw yield (3315.9 & 5142.9 Kg ha^{-1} respectively) which was on par with treatment receiving two hand weeding @ 30 & 45 days after sowing(DAS) and oxyfluorfen at 200 g a.i ha^{-1}. Whereas unweeded control recorded the lower grain yield and straw yield (1379.0 & 2013.25 Kg ha^{-1} respectively) (Table 1). Grain yield is governed by number of factors, which has direct or indirect impact. The main factors, responsible for high grain yield are the number of tillers hill $^{-1}$, panicle length and number of panicles $hill^{-1}$. At harvest, highest plant height (72.8 cm), number of tillers $hill^{-1}$ (34.1), panicle length (17.4 cm) and number of panicles $hill^{-1}$ (12.5) were recorded by treatment receiving oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}. The better growth and yield performance of T_5 (Oxyfluorfen @ 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}) over other treatments is due to higher dose of oxyfluorfen and its higher persistence due to external supplementation of organic manure, which resulted in significant control of weeds. Higher crop yield was realised due to better suppression of weed growth at critical growth stages of crop due to application of herbicide. This in turn resulted in reducing competition between crop and weed, thereby better utilization of available and applied resources by the crop was attained (Reddy *et al*., 2000).

The major weed flora observed in the experimental field were *Fimbristylis milliacea* L. (Link), *Cyperus difformis* L. and *C. iria* L. (among sedges); *Echinochloa glabrascens* L. and *Echinochloa colona* L. (among grasses); *Ludwigia parviflora* L., *Rotala verticillaris* L., *Eclipta alba* L., *Spilanthus acmella* L., *Lindernia veronicaefolia* (L.) F. Mull and *Glinus oppositifolius* L. *Alternanthera sessilis* L., (among broad leaf weeds). The data on weed flora showed that monocot weeds and sedges were predominant in aerobic rice over dicot weeds. At 30 and 60 DAS and at harvest treatments receiving oxyfluorfen at 200 g a.i ha^{-1} (T_4 and T_5) and treatment with two hand weeding on 30 and 45 DAS had recorded lowest weed population as compared to unweeded control (Table 2). However all the weed control treatments significantly reduced the growth of monocot, sedges and dicot weeds at 30, 60 days after sowing and at harvest when compared with unweeded control. Total weed dry weight (g m^{-2}) recorded at different growth stages of the crop differed significantly in all weed control treatments when compared with control. Among the treatments hand weeding @ 30 & 45 DAS recorded significantly lower weed dry weight at 60 DAS and at harvest (19.25 & 45.1 g m^{-2} respectively) followed by treatments receiving oxyfluorfen at 200 g a.i ha^{-1} (Table.3) (Renu *et a.,l* 2000). Better weed control efficiency was observed due to application of oxyfluorfen @ 200 g a.i ha^{-1} and the treatment receiving two hands weeding @ 30 and 45 DAS (T_6) as compared to unweeded control at different growth stages of aerobic rice (Table 3).

Results on persistence of oxyfluorfen in aerobic rice reveals that, T_5 (Oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}) recorded higher residues of oxyfluorfen ranging between 0.61 µg g^{-1} and 0.08 µg g^{-1} at all the intervals of sampling whereas T_4 (Oxyfluorfen at 200 g a.i ha^{-1}) recorded a slightly less residues of herbicide ranging between 0.60 µg g^{-1} and 0.06 µg g^{-1} (Table 4). The higher half life of 7 days indicated the elevated persistence of oxyfluorfen in T_5 (Oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}) which received higher dose of herbicide with FYM whereas lower half life of 5.8 days in T_1 (Oxyfluorfen at 100 g a.i ha^{-1}) indicated the less persistence of oxyfluorfen. This applied organic matter through farm yard manure might have bound the herbicide and made it resistant to get degraded fast. Accordingly the lower rate constant of 9.8×10^{-3} day^{-1} (T_5 Oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}) supported the higher persistence of oxyfluorfen because of slow rate of degradation. The higher rate constant of 12.0×10^{-3} day^{-1} in T_1 (Oxyfluorfen at 100 g a.i ha^{-1}) indicated a faster dissipation of oxyfluorfen and therefore its less persistence (Table 5). The elevated persistence of oxyfluorfen residues in T_5 (Oxyfluorfen at 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1}) may be due to higher dose of oxyfluorfen coupled with presence of organic matter resulted in high adsorption of oxyfluorfen in soil (Gennari *et al*, 1994). Durovic *et al*, (2009) obtained lower recoveries of pendimethalin and oxyfluorfen whose sorption to soil was mainly determined by organic matter content in the soil. In addition to organic matter the clay content can also play an important role in degradation rate of pesticides .results of the current study are in agreement with the earlier findings of Rao *et al.,* (2010). The most likely route of dissipation for oxyfluorfen is soil binding but few investigators suggested that a combination of chemical, biological, physical and environmental factors may operate at different levels in influencing the degradation of herbicides (Sondhia and Singhai, 2008). The plant samples analysed for oxyfluorfen at 60, 90 days after treatment and at harvest did not show any residues persisted in them.

Application of oxyfluorfen @ 200 g a i ha^{-1} + FYM @ 10 t ha^{-1} recorded higher grain and straw yield coupled with better control of weed flora in aerobic rice system. On the contrary even though persistence of oxyfluorfen residues in soil was higher with application of Oxyfluorfen @ 200 g a.i ha^{-1} + FYM @ 10 t ha^{-1} (0.61 and 0.08 µg g^{-1} at 0 and 60 days after treatment). After 90 days no residues were determined in soil in any of the treatments. Similarly plant samples analysed for oxyfluorfen at 60, 90 days after treatment and at harvest did not show any residues persisted in them.

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