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Leaching of Rice Herbicide, Cyhalofop-Butyl in Vertisols Following an Application in Lysimeters under Tropical Rainfall Conditions

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Leaching can significantly contribute to pesticide contamination of surface and ground water. Therefore, leaching of a rice herbicide, cyhalofop-butyl, *i.e.*, (butyl(R)-2-[4-cyano-2-fluorophenoxy)phenoxy])propanoate was examined in sandy loam soil in field lysimeters at two levels of applications. A quantitative evaluation of soil samples taken at 0-225 cm depths indicated that rainfall events in initial days caused leaching of cyhalofop-butyl and an amount of 0.48 and 0.104 μg L^{-1} cyhalofop-butyl were detected in the leachates in corresponding to two application levels. After receiving 253.2 mm of rainfall average concentration of cyhalofop-butyl at 0-100 cm soil depths at two levels of application was found 78.7 to 19.16 % which was decreased to 5.58, 5.37 % after receiving 91.9 and 15.2 mm rainfall at 5 and 10th day, respectively. Rapid degradation of cyhalofop-butyl occurred in the soil at various depths though the chemical hydrolysis process and three degradation products of cyhalofop-butyl were detected from soil and leachates. The study showed that measured concentration of cyhalofop-butyl did not exceed EPA guidelines values of no observed effect level (NOEL) on aquatic system in the water.

Keywords: Degradation, Leaching, Cyhalofop-butyl, Rainfall, Vertisols, Sandy loam soil.

INTRODUCTION

Increasing use of highly mobile herbicides may pose serious environmental problems through leaching and runoff. Leaching and transport limits weed control efficacy of herbicides [1-3] and enhance risk of groundwater contamination [4-7]. Risk of contamination of water bodies is high in rice cultivated area [2,7-14]. In has been reported that pesticide leaching and subsequent groundwater contamination are affected by herbicide formulation, mode of application, chemical and physical properties of soil, interaction between soil and pesticides and rainfall [7,15,16]. Few studies that are directly concerned with effect of rainfall on herbicide mobility in soils, demonstrated that rainfall may affect behaviour and quantity of a herbicide that may be leached down into the soil profile [17].

Cyhalofop-butyl, (butyl(R)-2-[4-cyano-2-fluorophenoxy)-phenoxy])propanoate (Fig. 1) is a post emergence herbicide emergence herbicide for controlling a wide range of grassy weeds [18-20]. Cyhalofop-butyl is a fatty acid synthesis inhibitor and usually applied at 100 g ha^{-1} in tropical rice [21,22]. Herbicides that are applied to the paddy fields are a matter of concern for potential leaching and persistence in soil and water due to subsequent rain events during crop growth period [7,12,14,23]. In flooded soils of rice growing area, high volume of paddy water increases amount of agrochemicals in solution and this reduced their adsorption into the paddy-field sediment [24]. As many herbicides residues were found in ground water [2,7,9,11], it is apparent that there is significant transport of these chemicals through the soil profile. Heavy rains or large amount of irrigation water may cause herbicide leaching from surface soil to the lower soil profile. Thus leaching is very useful to understand herbicide behaviour under varied rainfall conditions and to predict risk of ground water contamination. Rice fields are generally located on clay and sandy soil found in central region known as vertisols. The main objective of this study was to quantify leaching of cyhalofop-butyl and variation in physico-chemical properties of the soil in a lysimeter as a result of naturally occurring rainfall.

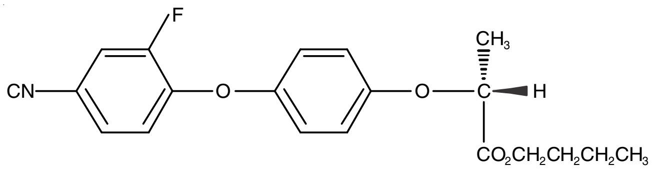


Fig. 1. Chemical structure of cyhalofop-butyl ((butyl(R)-2-[4-cyano-2-fluorophenoxy)phenoxy])propanoate

EXPERIMENTAL

Leaching experiment: Experimental lysimeters (12 numbers) were set up at research field. Lysimeters were oriented lengthwise having 3 m depths and 0.5 m diameters. The disturbed soil of the lysimeters falls under vertisol and belongs to Kheri-series of fine montmorillonite, Hyperthermic family of Typic Haplusterts. The textural class of soil was sandy clay loam, non-saline (EC-270 µS cm^{-1}), non-calcareous (2.70 %) having sand 67.32 -66.31 %, silt 9.2-10.00 %, clay 22.68-21.88 % and organic carbon 0.369-0.280 % at 0-225 cm depths. The experiment was conducted in a randomized complete block design with three replications.

Cyhalofop-butyl [emulsifying concentrate (EC) 10 %, Table-1] was applied at 90 and 180 g a.i. ha^{-1} to lysimeters using a hand sprayer. Soil samples were taken from 0-25, 50-75, 75-100, 100-125, 125 150, 150-175, 175-200 and 200-225 cm depths at 3, 5, 10, 20, 30, 60 and 90 days after cyhalofop-butyl applications from each lysemeter that received varying rains. Leachates were collected in acrylic plastic canes of 25 L capacity attached to the drain of each lysemeter. At the end of the rainfall season (September), experiment was terminated. Physico-chemical properties of cyhalofop-butyl is given in Table-1. A total of 1633 mm of precipitation was received during the experiment. Maximum and minimum temperature and humidity were 30.8-20.8 °C and 96-61 %, respectively.

TABLE-1
IMPORTANT PHYSICO-CHEMICAL
PROPERTIES OF CYHALOFOP-BUTYL

m.w.	357.14
m.f.	$C_{20}H_{20}NO_4F$
Formulation	EC 10 %
Solubility	0.07, 0.44 mg L^{-1} (20 °C)
Vapour pressure	1×10^{-7} Pa at 25 °C
Hennery constant	9.51×10^{-4} Pa m^3 mol^{-1}
pKa	3.8
Partition coefficient log P_{ow}	3.32

Chemical assay: Cyhalofop-butyl reference analytical standard of purity 99 % was obtained from AccuStandard Inc, USA. Chemicals and solvents were of analytical grade were supplied by Merck, Germany. Validation of the method was also performed in terms of recovery studies before analysis of sample at each sampling occasion [22]. Recovery of cyhalofop-butyl was found to be 96 and 94 % for the fortification level at 0.01 and 0.5 µg mL^{-1}, respectively. Shimadzu high performance liquid chromatography consisting of an LC-10 Atvp pump and PDA detector was used to determine extractable cyhalofop-butyl residues in the soil and leachates. Separation of cyhalofop-butyl was performed by using a Phenomenex C18 (ODS) column of 25 cm length × 4.6 mm i.d. using mobile phase acetonitrile: water (70:30) at a flow rate of 1 mL min^{-1}. Wavelengths were set at 220 and 205 nm for detection of cyhalofop-butyl and its degradation products. 20 µL volumes of sample and standard were injected separately using fixed loop Rheodyne injector. At the limit of detection (0.001 µg mL^{-1}) signal to noise ratio was 3:1.

Identification of degradation products of cyhalofop-butyl in soil and leachates was done by an ABI 3200 Q-Trap mass spectrometer. Mass spectrometric analysis was performed with turbo spray ionization (TSI) in positive and negative (5500 eV) mode for each sample. LC/MS total ion current (TIC) chromatograms were recorded between m/z 50 and 550 at a rate of 2 scans per second. The turbo spray source parameters were optimized by infusion of analyte standard solutions. The curtain gas, source gas and exhaust gas were adjusted at 65, 105 and 55 psi, respectively. The ion temperature was set at 500 °C. Each sample was injected by flow injection technique at rate of 3 µL min^{-1}.

Statistical analysis: Leaching data was analyzed using variance of analysis technique (ANOVA). Probability of 0.05 or less was considered as significant. Significant interaction among application rate of cyhalofop-butyl, rainfall and soil physico-chemical properties at various depths were calculated using two ways ANOVA table. All statistical analyses were done with GENSTAT. In the case of significance in ANOVAs, means were compared by the least significant difference (LSD) multiple comparison procedure at $P < 0.05$.

RESULTS AND DISCUSSION

Effect of precipitation on cyhalofop-butyl leaching in the soil: Soil samples were taken at various depths from lysimeters after cyhalofop-butyl application and subsequent rain. Sporadic distribution of cyhalofop-butyl concentration was found in soil at various depths after its application at two rates on the surface of lysemeter that received varying rains. After 3 and 5 days of experiment, approximately 253.2 and 91.3 mm of rainfall that resulted in leaching and 0.0480 to 0.0021 µg g^{-1} of cyhalofop-butyl residues were found at 0-200 cm depths. Cyhalofop-butyl residues did not found at 200-225 cm soil depths in initial days of sampling in both the application rates. After 10 days, 15.2 mm of rain was received in the experimental field and an amount of 0.0034 and 0.0031 µg g^{-1} cyhalofop-butyl residues were found at upper (0-25) and 50-75 cm depths at two levels of application. After 20 days, cyhalofop-butyl residues were not detected at various depths (Table-2).

Higher concentration of cyhalofop residues were detected up to 5 days after application in the soil samples taken at 0-150 cm depths (Table-2). After 5 days subsequent concentration of cyhalofop-butyl was decreased at 10 days in the soil at various depths. This relatively fast decline of cyhalofop-butyl concentration in soil at various depths showed faster degradations and also demonstrated that leaching was rainfall event driven. This finding further support the general conclusion, that, solute concentration may be largely determined by Kordel *et al.* [25].

The amount of cyhalofop-butyl residues at two doses of applications varied between 0.0488 to 0.025 µg g^{-1} and 0.0580 to 0.0025 µg g^{-1} after 3 and 10 days at upper depth, respectively. Residues were detected in less quantity in lower soil depths in both the application rates (Fig. 2). In general, after herbicide application on soil surface, it undergoes several processes including degradation and transport [26]. Herbicides with high persistence and a strong sorption rates are likely to remain near the soil surface, increasing chances of being carried to a stream or lake *via* surface runoff. In contrast, herbicides with

TABLE-2
RESIDUE OF CYHALOFOP-BUTYL AT VARIOUS DEPTHS IN SOIL

	Residue (µg g^{-1})						
	Precipitation (mm)						
	253.2	91.3	15.2	16.4	429.1	435.1	463.2
Treatment	3 day	5 day	10 day	20 day	30 day	60 day	90 day
T_1	0.0105	0.0018	0.0016	< 0.001	< 0.001	< 0.001	< 0.001
T_2	0.0129	0.0016	0.0033	< 0.001	< 0.001	< 0.001	< 0.001
T_3	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
LSD (T×T)	0.009	0.0005	0.0008				
Depth (cm)							
Upper	0.0480	0.0061	0.0034	< 0.001	< 0.001	< 0.001	< 0.001
50-75	0.0014	0.001	0.0031	< 0.001	< 0.001	< 0.001	< 0.001
75-100	0.0032	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
100-125	0.0019	0.0027	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
125-150	0.0022	0.0023	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
150-175	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
175-200	0.0021	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
200-225	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	
LSD (D×D)	0.0015	0.0011	0.0019			–	
LSD (T×D) at 5 %	0.022	0.0013	0.0022				

(D- Depth; T- Treatment; T_1- 90 g ha^{-1}; T_2- 180 g ha^{-1}; T_3- 0.0 g ha^{-1})

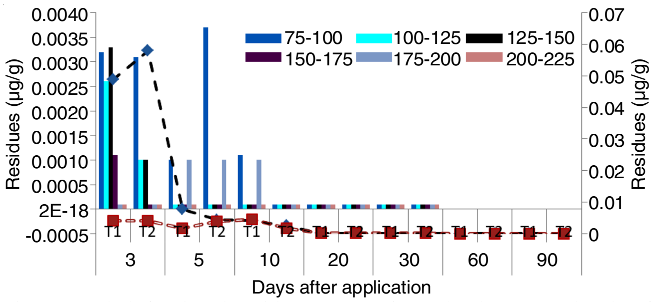


Fig. 2. Cyhalofop-butyl residues at 0-225 cm depths at two levels of application

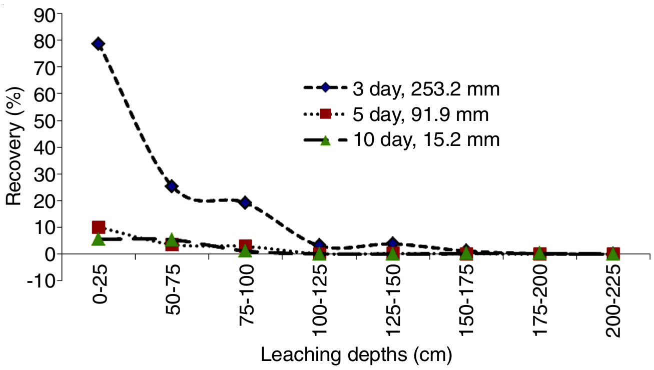


Fig. 3. Average recovery of cyhalofop-butyl at 0-225 cm depths after naturally occurring rain event at various days

high persistence and weak sorption rate may be readily leached through the soil and are more likely to contaminate groundwater [22,27].

After 5 days of application approximately 91.3 mm rains was received that resulted in leaching and a total of 0.0061, 0.0027, 0.0023 µg g^{-1} of cyhalofop-butyl were found at upper, 50-75, 100-125, 125-150 cm depths, respectively. After 10 days, 15.2 mm of rain was received in the experimental field and 0.0034 and 0.0031 µg g^{-1} cyhalofop-butyl residues were found at upper (0-25) and 100-125 cm depths. After 20 days cyhalofop-butyl residues were not detected at various depths (Table-2).

Despite high KOC and K_d values (5247 and 57, respectively) of cyhalofop, less concentration was detected up to 175-200 cm depths in the sandy clay soil this may be due to slow kinetics and thus the herbicide might not have been in equilibrium with the soil solid materials [28]. After receiving 253.2 mm of rainfall average concentration of cyhalofop-butyl at 0-25, 50-75, 75-100 cm depths at two level of applications was found 78.7, 25.31 and 19.16 % and at lower depths < 3.5 % concentration was detected. Subsequent concentration of cyhalofop-butyl was decreased to 5.58, 5.37, 1.151 % after receiving 91.9 and 15.2 mm rainfall at 5 and 10th day (Fig. 3).

On comparing effect of rains on leaching between two levels of herbicide application by two ways ANOVA table, significant difference ($P < 0.05$) was observed between cyhalofop-butyl application at two level and subsequent rainfall (Table-2). Sampling depth also showed significant differences in the study with all interactions being significant up to 10 days (Table-2). Higher concentrations of cyhalofop-butyl were found in the surface soil, followed by successively lower quantity at the lower depths. Overall results suggested that there was a positive correlation between two levels of cyhalofop-butyl application and amount of rainfall with depth of leaching of cyhalofop-*p*-butyl.

Cyhalofop-butyl concentration in leachates: Amount of chemicals received from leachates reveal the leaching potential and risk of ground water contamination. Thus after each rainfall leachates were collected and analyzed for cyhalofop-butyl residues. After receiving 376 mm rains, a total of 0.48 and 0.104 µg L^{-1} of cyhalofop-butyl residues were found in the leachates treated with 90 and 180 g ha^{-1} of cyhalofop-*p*-butyl, respectively. This showed leaching of cyhalofop-butyl through the soil profile. However cyhalofop-butyl concentration was found below the no observed effect level (NOEL) set by EPA (3 mg kg^{-1}) and not likely to affect aquatic life. In this study cyhalofop-butyl leaching losses in the leachates were < 0.1 % at two level of applications. This indicated that due to fast degradation of cyhalofop-butyl less leaching losses occurred and therefore less concentration was found in the leachates.

Similar findings were reported by Carabias *et al.* [29]. They monitored concentration of fifteen herbicides owing to their frequency and amounts used, toxicity and persistence in river basins in the provinces of Zamora and Salamanca (Spain). After 6 months, presence of six out of the fifteen herbicides monitored was detected at levels ranging from the detection limit to 1.2 $\mu g\ L^{-1}$ as a result of agricultural activities as well as kind of crop and treatment period.

Effect of precipitation on cyhalofop-butyl leaching: Prediction of leaching and fate of herbicides in soils represent an important strategy in limiting their environmental impact. Cyhalofop-butyl application at two rates and amount of rainfall had a significant impact on the depth of leaching. Leaching was observed with both level of cyhalofop-butyl applications or amount of rainfall ($p < 0.005$) (Table-1). Weber and Miller [30] and Bovey *et al.* [31] reported that leaching of herbicides in soils was governed largely by amount of rainfall especially first few days after an application of herbicide and soil type. Similar results were observed in this study. Soil contained more than 67 % of sand and low organic matter content (0.369-0.280 %) might have provided more chances for leaching. Results at two application levels also suggested that there was a positive correlation between cyhalofop-butyl application rates and rain which has been reflected in more leaching of cyhalofop-butyl at high application rate and *vice-e-versa*. This showed moderate leaching of cyhalofop-butyl in sandy clay loam soil [32-34]. Similar finding was also reported by Jhala *et al.* [35]. Low soil adsorption capacity, high rates of application and high rainfall increased total runoff and contamination of local waterways [31].

Following cyhalofop-butyl, a total of 253.2 mm of rainfall on 3 days, which was followed by a 3 days period of dry weather. About 91.3 and 15.2 mm rainfall in the last week of June and first week of July. Approximately 46 mm of rainfall on the 12 days. In, second, third and fourth week of July rainfall was for 3, 6 and 3 days. A third period of rainfall was recorded between August first and second weeks for 5 and 6 days, giving rise to a further 435.1 mm of rain and subsequent 46.3 mm rains was received up to 90 days. Sharma and Singh [33] reported positive correlation between amount of rainfall and herbicide leaching. They showed that leaching depth of norflurazon increased from 19.6 to 105.4 cm with increasing amount of rainfall from 6.25 to 12.5 cm ha^{-1}.

Effect of cyhalofop-butyl on soil pH: Physico-chemical properties of herbicides affect their behaviour in the soil and regulate their interaction with organic and inorganic soil phases. To demonstrate effect of leaching on the soil physico-chemical properties (Table-3), two important parameters *viz.* pH and electrical conductivity were evaluated and interaction between doses *versus* herbicide movement at various depth at varying rainfall was observed. pH of soil solution directly influenced soil's physical and chemical processes by affecting charge sites and dissociation of herbicide molecule that could lead to either increased or decreased adsorption, depending upon the soil characteristics at that particular pH. Cyhalofop-butyl application at 90 and 180 g ha^{-1} levels and subsequent rains caused leaching which resulted in the significant difference in soil pH at various depths ($P < 0.05$) (Table-4). For ionizable herbicides leaching is also affected by soil pH, with weaker sorption at higher pH [36]. We did not found any effect of soil pH on cyhalofop-butyl leaching.

TABLE-3
EFFECT OF CYHALOFOP-BUTYL ON ELECTRICAL CONDUCTIVITY AND pH OF LEACHATES

Days	EC ($\mu S\ cm^{-1}$)		pH	
	T_1	T_2	T_1	T_2
5	1993	1642	7.52	7.70
7	1660	2011	7.48	7.70
9	1743	2000	7.34	7.81
24	1582	2019	8.64	7.42
31	1797	1745	7.35	7.70
33	1056	1754	8.90	9.00
45	1480	1415	8.01	7.60
55	1057	1276	7.20	7.50
72	523	748	8.14	7.71
82	727	684	8.70	7.80

EC = Electrical conductivity; T_1 = 90 g ha^{-1}; T_2 = 180 g ha^{-1}

TABLE-4
EFFECT OF CYHALOFOP-BUTYL LEACHING ON SOIL pH AT VARIOUS DEPTHS

	pH						
	Precipitation (mm)						
	253.2	91.3	15.2	16.4	429.1	435.1	463.2
Treatment	3 day	5 day	10 day	20 day	30 day	60 day	90 day
T_1	8.03	7.80	7.80	8.20	8.30	7.80	7.60
T_2	7.86	7.70	7.70	8.10	8.40	7.60	7.90
T_3	7.24	7.30	7.30	7.30	7.40	7.40	7.30
LSD (T×T)	0.20	0.25	0.26	0.18	0.17	0.25	0.22
Depth (cm)							
Upper	7.73	7.50	7.50	7.80	7.80	7.90	7.40
50-75	7.66	7.50	7.60	7.90	8.00	7.70	7.70
75-100	7.60	7.70	7.70	8.00	8.00	7.60	7.80
100-125	7.60	7.60	7.60	8.02	8.10	7.70	7.70
125-150	7.76	7.70	7.80	8.00	8.10	7.60	7.70
150-175	7.83	7.70	7.60	8.01	8.10	7.60	7.70
175-200	7.70	7.80	7.70	7.80	8.10	7.40	7.60
200-225	7.73	7.60	7.60	7.60	8.10	7.50	7.60
LSD (D×D)	NS	NS	0.42	0.30	0.28	0.40	0.37
LSD (T×D) at 5 %	NS	0.72	0.73	0.52	0.49	0.70	0.64

(D- Depth; T- Treatment; T_1- 90 g ha^{-1}; T_2- 180 g ha^{-1}; T_3- 0.0 g ha^{-1})

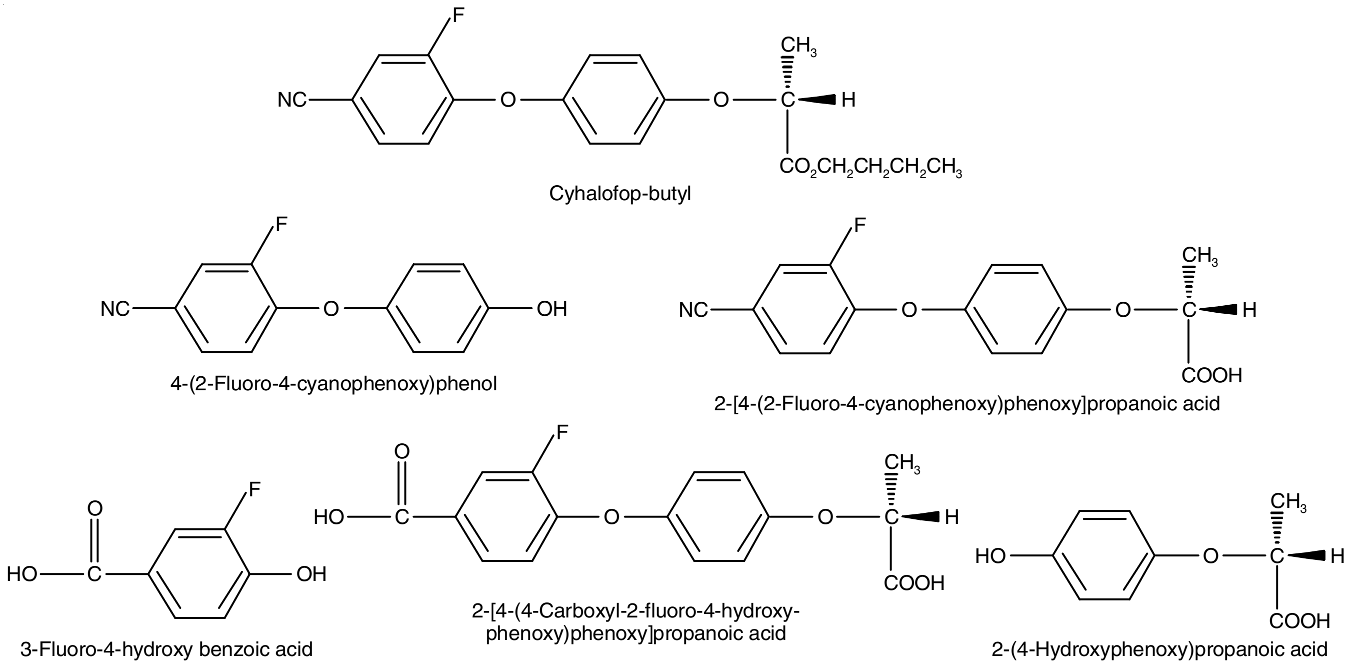
Effect of cyhalofop-butyl on soil electrical conductivity (EC): Electrical conductivity in the sampled soil at various depths were found to be between 160 to 309 µS cm^{-1} with the greatest amount and variation in upper soil (0-25 cm). Rainfall caused significant difference in the soil electrical conductivity at various depths and it was found higher where considerable amount of cyhalofop-butyl was leached due to subsequent rainfall after receiving cyhalofop-butyl applications ($P = 0.05$ level) (Table-5). These values are within the range typical for vertisol [37]. Electrical conductivity associated with a particular soil is a function of clay and organic matter types, as well as quantity of herbicide present. Because electrical conductivity of a soil was closely related to the organic matter and clay content, it might be expected that a high electrical conductivity would give rise to an increased adsorption. Blasioli *et al.* [38] reported that organic matter have no effects on cyhalofop leaching, while they observed that the presence of potassium ions reduced the leaching of cyhalofop-butyl due to increased soil adsorption of the inner sphere complex, with a potassium ions formed at the carboxyl group by cation bridge. Dissolved organic matter influences mobility of herbicides by complex interactions that can facilitate or reduce movement of chemicals along soil profile [12].

Cyhalofop-butyl degraded to cyhalofop acid through cleavage of ester linkage. Cyhalofop acid is further degraded by sequential oxidation of cyano group to cyhalofop diacid and amide [39]. Diacid degraded to form 3-fluro-4-(4-hydroxyphenoxy) benzoic acid or by cleavage of the ether bridge

TABLE-5
EFFECT OF CYHALOFOP-BUTYL LEACHING ON ELECTRICAL CONDUCTIVITY OF SOIL AT VARIOUS DEPTHS AT 3 TO 90 DAYS

	Electrical conductivity (µS cm^{-1})						
	Precipitation (mm)						
	253.2	91.3	15.2	16.4	429.1	435.1	463.2
Treatment	1 day	5 day	10 day	20 day	30 day	60 day	90 day
T_1	274.41	291.37	244.78	222.55	210.73	141.65	144.35
T_2	294.62	284.37	272.70	166.96	231.32	273.32	123.85
T_3	236.58	241.16	237.00	242.62	228.83	241.79	241.50
LSD (T×T)	11.61	14.67	12.38	40.80	25.12	14.14	24.67
Depth (cm)							
Upper	160.63	164.66	206.30	208.30	171.23	205.53	208.46
50-75	265.00	294.00	231.00	191.63	236.00	249.93	153.73
75-100	275.00	272.00	264.00	207.30	259.33	216.86	176.86
100-125	281.80	287.66	256.00	194.80	250.66	204.73	146.83
125-150	275.88	267.44	261.44	217.88	241.88	212.14	161.10
150-175	287.00	287.33	230.33	203.94	233.66	204.76	166.96
175-200	309.33	299.00	270.00	236.73	203.26	208.93	171.00
200-225	293.66	306.33	292.33	225.10	193.00	248.46	169.16
LSD (D×D)	18.97	23.97	20.21	66.63	41.02	23.09	40.29
LSD (T×D) at 5 %	32.86	41.52	35.02	115.42	71.05	40	69.78

(D- Depth; T- Treatment; T_1- 90 g ha^{-1}; T_2- 180 g ha^{-1}; T_3- 0.0 g ha^{-1})



Cyhalofop-butyl

4-(2-Fluoro-4-cyanophenoxy)phenol

2-[4-(2-Fluoro-4-cyanophenoxy)phenoxy]propanoic acid

3-Fluoro-4-hydroxy benzoic acid

2-[4-(4-Carboxyl-2-fluoro-4-hydroxy-phenoxy)phenoxy]propanoic acid

2-(4-Hydroxyphenoxy)propanoic acid

Fig. 4. Detection of cyhalofop-butyl degradation product in soil at various depths and leachates

between the two phenyl rings to form 2-(4-hydroxyphenoxy) propionic acid, while 3-fluro-4-(4-hydroxyphenoxy) benzoic acid and 2-(4-hydroxyphenoxy) propionic acids are minor products in the metabolic pathway. These were further degraded to CO_2 and non-extractable residues. Strong adsorption of cyhalofop-butyl to the soil together with the rapid degradation resulted in low potential for parent ester to move into lower depths. Hence after 20 days, cyhalofop-butyl was not found in the soil in all the depths after its application. However its three degradation products, namely 2-[4-(2-fluoro-4-cyanophenoxy) phenol (*m/z* 230, (M+1), 2-[4-(2-fluoro-4-cyanophenoxy)-phenoxypropanoic acid (Acid)(*m/z* 302 (M+1) and [R-(+)-2-(4-(4-carboxyl-2-fluoro-4-hydroxy-phenoxy)phenoxy)-propanoic acid] (Diacid) (*m/z* 335 (M+1) were detected at various depths from soil (Fig. 4). Braschi *et al.* [12] reported that cyhalofop-butyl degradation is slow in the paddy-field sediment and leads to the cyhalofop-acid formation in the forest soil.

Conclusion

Movement of cyhalofop-butyl was determined largely by the amount of water moving through the soil with soil characteristics altering this movement. Since ionic solutions affect many chemical reactions, they might also be expected to affect herbicide movement. Therefore, this study was conducted to observe any trends in leaching behaviour of cyhalofop-butyl as influenced by rainfall and two application rates. High rains in the initial days of experiments caused leaching of cyhalofop-butyl between 3 to 10 days; afterwards cyhalofop-butyl concentration was not detected. Measured concentration of cyhalofop-butyl did not exceed EPA guidelines values of no observed effect level (NOEL) on aquatic system in the water. This study demonstrated that preferential transport was the major transport process in the lysimeters. It can be concluded that at higher rainfall events and saturated soil moisture conditions, cyhalofop-butyl can leach to subsurface soil and pose moderate leaching risk. The possibility that rainfall and drying cycles influence the movement and adsorption of cyhalofop-butyl in the soil may also be investigated further.

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