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Evaluation of leaching behavior of pendimethalin in sandy loam soil

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Abstract The mobility of pendimethalin in sandy loam soil was studied in soil columns under laboratory conditions at two application rates, 1.0 and 2.0 kg a.i. ha^{-1}, with simulated rainfall of 300 mm. The maximum concentration of the herbicide was found in the top 10 cm layer, though it was found distributed in soil at all the depths at both the doses.

Keywords Pendimethalin · Sandy loam soil · Leaching · Column · Leachates

Introduction

The movement of pesticides through soil is an important process that determines their fate both in soil and aquatic environments. Large quantity of herbicides is being used in India thus creating the need to study the fate of these herbicides in the tropical soil of India. Although the main processes involved in herbicide transport in soils are sorption and solubility, the mobility of herbicides is regulated by the properties of the chemical and soil, hydrogeologic properties, application, and climatic conditions (Hartley and Graham Bryce 1980; Sawhney and Brown 1989). Pendimethalin [*N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine] is a nonionic dinitroaniline herbicide used for the selective control of grassy and broadleaf weeds in a variety of crops (Sinha et al. 1996; Tsiropoulos and Miliadis 1998; Bhowmick and Ghosh 2002). It is a low volatile and low mobile herbicide having low water solubility (Savage and Jordan 1980; Schleicher et al. 1995).

Herbicide leaching through soil is particularly important in a number of environmental and agronomic problems (Costa et al. 1994). Leaching is considered as the main cause of groundwater contamination by herbicides (Flury 1996), which is largely determined by physical and chemical properties of herbicides. Increasing use of herbicides with high potential mobility may pose serious environmental problems through offsite movement, which must be controlled to minimize harmful effects on nontargeted organism. Ultimately, leaching and transport of herbicides may not only result in low efficacy, but also possible groundwater contamination (Koterba et al. 1993; Wagner et al. 1994; Ritter et al. 1996).

The increasing use of pendimethalin in cropping system is widely reported but concern exists

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over the ultimate fate and concentration of pendimethalin in soil and potential risk groundwater contamination. The present study was, therefore, undertaken to know the rate of downward movement of the herbicide in soil columns under simulated rainfall thereby predicting the risk of groundwater pollution.

Material and methods

Sample processing

The leaching experiment was conducted under laboratory conditions. Soil collected from Research Farm, CCS Haryana Agricultural University, Hisar was used after drying and sieving through a 2-mm sieve for the experiment. Soil was sandy loam (EC 2dSm^{-1}; K 10.08, P_2O_5 15 kg ha^{-1}) with pH 7.6 and organic carbon 0.67%. Commercial pendimethalin formulation (Stomp 30 EC) was used for leaching experiment. Plexiglass columns (90 cm × 5 cm internal diameter) fitted with a perforated sieve covered with filter paper (Whatman No.1) were used. Each column was sequentially filled with soil up to the height of 60 cm to a bulk density of 1.5 g cm^{-1}± 0.1. Weighed amount of soil (147 g) was poured in the column each time with the help of a funnel by tapping gently and pressed uniformly by a wooden roller. The process was repeated till each column was uniformly filled to a height of 60 cm. The experiment was conducted with three replicates and a blank. Before packing, the filter paper was kept at the perforated distal end of the column to allow only the passage of leachates. Pendimethalin formulation was dissolved in deionized water and simultaneously applied to the last 5 cm of the soil in the column at the dose of 1.0 and 2.0 kg a.i. ha^{-1}. The initial concentrations of pendimethlin residues in soil were 4.5 μg ml^{-1}for single dose and 9.0 μg ml^{-1} for double dose. After application of herbicide, the columns were irrigated with 98 ml of water daily for 6 days (equivalent to 300 mm rain) at the time interval of 24 h. After 6 days when addition of water was completed, the soil columns were allowed to drain for 36 h. Columns were then cut into two equal halves, and the soil was sampled in 10 cm segments and was used for the analysis of residues.

Extraction and cleanup

Pendimethalin residues from soil and leachates were extracted as per method of Kumari et al. (2007). A representative subsoil of 20 g mixed with 0.5 g each of activated charcoal and Florisil was filled in a 60-cm long glass column having 22 mm i.d. between two layers of anhydrous sodium sulfate. The residues were eluted with 125 ml of hexane: acetone (9:1 *v*/*v*). The organic layer was concentrated on rotary vacuum evaporator, and final volume was made to 2 ml in *n*-hexane. Water samples (leachates) collected were subjected to liquid–liquid partitioning with dichloromethane:hexane (15:85 *v*/*v*) thrice after addition of 5% NaCl solution.

Pendimethalin was determined on Shimadzu 2010 gas chromatograph (GC) equipped with ^{63}Ni electron capture detector and HP-1 capillary column (30 m × 0.32 mm i.d. × 0.25 μm film thickness). The temperatures for oven, injection port, and detector temperature were: 190, 250, and 280°C, respectively. The carrier gas (nitrogen) was used at 60 ml^{-1} with split ratio of 1:10. The retention time of pendimethalin was observed to be 7.399 min. Recoveries of pendimethlin in soil and water at the fortification levels of 0.25 and 0.50 μg g^{-1} were 94% to 96% and 98% and 99%, respectively. Limit of detection (LOD) and limit of quantitation (LOQ) were 0.001 and 0.005 μg ml^{-1} for water, and for soil, LOD and LOQ were 0.01 and 0.05 μg g^{-1}.

Result and discussion

Pendimethalin residues at different soil depths are presented in Table 1. The results showed that the herbicide leached up to the depth of 60 cm at 300 mm rainfall condition. The highest concentration of pendimethalin was found at 0–10 cm depth at both the application rates, and it was higher at T_2 dose (2 kg a.i. ha^{-1}) compared to T_1, i.e., 1 kg a.i. ha^{-1}. Although pendimethalin has low water solubility, it has also been reported

Table 1 Pendimethalin residues at different soil depth at two application rates

Depth (cm)	Residues (μg g^{-1})*		
	T_1(1 kg a.i. ha^{-1}) Average ± SD	T_2(2 kg a.i. ha^{-1}) Average ± SD	Mean
0–10	3.717 ± 0.027	7.477 ± 0.355	5.597
10–20	1.877 ± 0.133	3.233 ± 0.174	2.555
20–30	0.765 ± 0.025	0.921 ± 0.029	0.843
30–40	0.349 ± 0.037	0.498 ± 0.007	0.423^{a}
40–50	0.212 ± 0.008	0.391 ± 0.022	0.301^{a,b}
50–60	0.141 ± 0.005	0.175 ± 0.005	0.158^{b}
Mean	1.175	2.115	

*Average of three replicates.

Values denoted by similar letters (a,b) are at par with each other. CD (0.05): Treatment—0.1029, Depth—0.1782 Treatment × Depth—0.252

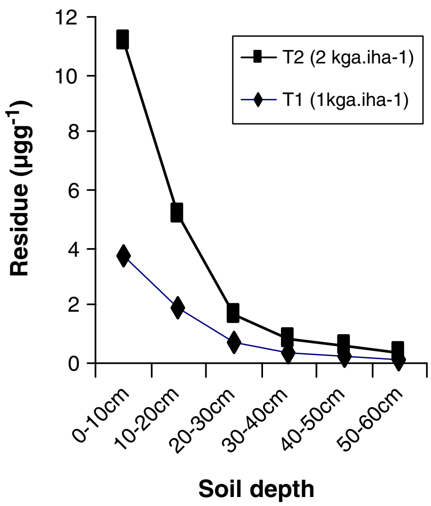

Fig. 1 Distribution of pendimethalin at 0–60 cm soil depths at two application rates

that the intrinsic mobility of a pesticide in soil is inversely related to its degree of sorption to soil surface (Gustafson 1995). These processes are mainly regulated by temperature and moisture in the substrate (James et al. 1995). Soil moisture, temperature, organic matter, pH, texture, and rains are the main factors that determine mobility of herbicide (James et al. 1995; Walker et al. 1989; Lazic et al. 1997).

Recovered amount of pendimethalin residues at various soil depths were analyzed statistically at probability 0.05 level. Significant differences on the recovered amount of pendimethalin residues at 0 to 30 cm depth were observed at both application rates. Irrespective of soil depth, residue levels were significantly low in single dose compared to double dose. From 30 cm depth onward, the residues were comparable at both the rates of application of pendimethalin at 0.05 level.

Pendimethalin content at 0–60 cm depth in sandy loam soil is presented in Fig. 1. The mean concentration of pendimethalin followed the decreasing pattern depth-wise. Maximum concentration of the herbicide was recovered from 0–10 cm depth with the value of 52.6% and 58.6% at T_1 and T_2 doses, respectively, followed by 10–20 cm depth (26.5% and 25.3%) in both application rates. Although soil moisture generally has an effect on the adsorption of herbicides to soil, it is unlikely to dominate herbicide transport unless this transport is very rapid. Theoretically, in the leaching studies in soil column, leaching could have been slow initially and gradually increased as water penetrated deeper (Vanwyk and Reinhardt 2001; Sondhia and Yaduraju 2005; Sondhia 2006; Sondhia and Dubey 2006). In this study, soil columns received continuous 300 mm irrigation that may be the reason that pendimethalin could leach even at 60 cm depth.

Sondhia (2007) reported leaching of pendimethalin up to 56 cm in clay loam soil in 200 mm continuous rainfall condition under laboratory conditions in packed soil columns. Signori and Deuber (1979) revealed the higher leaching of pendimethalin in loamy soil than in clay soils.

Overall, approximately 90% of the applied herbicide was found distributed in 0–30 cm soil depth, and only 1.99% and 1.37% could leach to the depth of 50–60 cm in soil column at 1.0 and 2.0 kg a.i. ha^{-1} application rates indicating slow mobility in sandy–loam soil.

Residues of pendimethalin in leachates were low, and only 0.4% of pendimethalin was recovered from leachates. The data generated here clearly indicated less mobility of pendimethalin in sandy–loam soil column, but continuous rainfall can result in leaching of pendimethalin up to 60 cm depth that is significant in terms of groundwater contamination.

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