

SORPTION BEHAVIOUR OF 3-(3,4-DICHLOROPHENYL)-1,1-DIMETHYL UREA ON SOIL

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The sorption capacity of three soil samples containing organic matter between 0.52 and 1.66% and clay fraction between 1.30 and 4.60% for 3-(3,4-dichlorophenyl)-1,1-dimethyl urea (diuron) in aqueous solution was examined at 29°C. It was found that between 40 and 60% of the herbicide was adsorbed by the soils and that the sorption capacity depended on the total colloidal fraction of the soils. The soil/water adsorption coefficient, K_p , of the herbicide was used to assess the relative phytotoxicity of the herbicide in the given soils.

Key words: Sorption capacity, Colloidal fraction, Dimethyl urea.

Introduction

Weed control is an important aspect of an effective, intensive and sustainable agricultural development, since more than six hundred weed species are known to compete with crops. Herbicides are usually applied to soil or weed foliage, therefore soil and soil drainage water become the ultimate recipient of part or all of the herbicide application (Ross and Lembi 1985; Goetz *et al* 1987). To achieve desired effects, sufficient quantity of herbicide should remain in active state with soil, although prolonged herbicide persistence in soil may cause injury to plants and could lead to accumulation of herbicide residues in the food chain. Therefore, knowledge of the fate of herbicide in soil environment is necessary for effective and sustainable weed control practice. With most soil-applied herbicides, adsorption by soil is generally considered an important factor affecting its persistence in soil. The capacity of soils to adsorb herbicides is influenced by properties of the soil, the herbicide, and the adsorption medium (Sheets 1958; Nearpass 1965; Talbert and Fletchal 1965; Hamaker and Thompson 1972; Rahman and Mathews 1979; Peter and Weber 1985).

Diuron is a pre- and post-emergent herbicide used in the control of a wide range of annual weeds in cereals, potatoes, carrots, etc (Roberts 1982). This paper examines the sorption capacity of soil samples obtained from the south western part of Nigeria for Diuron.

Experimental

Diuron obtained from the USA Environmental protection Agency (as 80% formulated wettable powder) was used with-

out further purification. The soil samples were provided by the Agronomy Division of the Nigerian Institute for Oil Palm Research (NIFOR), Benin City. Some characteristics of the soil samples are given in Table 1.

Equilibrium sorption of diuron on the soil samples was carried out at 29°C using various initial concentrations of the herbicide. In a typical experiment, 0.5g of the soil sample was dispersed in 100ml of aqueous diuron solution. The mixture was continuously shaken in a well-stoppered flask for 2h and then filtered. The residual concentration of diuron in the filtrate was determined spectrophotometrically after appropriate clean-up (Knulsi 1964; Hance 1965). The amount of diuron removed from solution by the soil sample was taken as the difference between the initial and residual diuron concentrations (making corrections for the diuron content of the volume of the solution retained in the soil).

Results and Discussion

Sorption capacity. The sorption behaviour of diuron on the soil samples (Table 2) show that up to 60% of the initial amount of the herbicide is adsorbed by the soil samples. Table 2 shows that the adsorption capacity of the soil for the herbicide is dependent on the colloidal fraction of the soil. Although the colloidal fraction of the soil samples is low (less than 6%), the relatively high proportion of the herbicide absorbed by the soil suggests that the soil pH may play an important role in the sorption process. A similar observation was made for the sorption of 2-chloro-4-(ethyl amino)-6-(isopropylamino)-s-triazine, atrazine on soils (Okieimen *et al* 1991).

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Sorption coefficient. The extent of adsorption of diuron on soil may be expressed in terms of distribution or sorption coefficient, k_d of the herbicide between the soil phase and the bulk aqueous phase in contact. This parameter is important in determining herbicide phase distribution and mobility. Although k_d for most organic compounds is dependent on soil characteristics, some organic compounds tend to have low or high k_d values. A low k_d value indicates that the herbicide has little tendency to adsorb onto the soil, is highly mobile and, therefore will not be available in the soil in sufficient quantity to achieve the desired level of weed control. Whereas a high k_d indicates greater phytotoxicity. Table 3 shows the sorption coefficient of diuron in the soil samples. The value of k_d shows relatively less variation with changes in the residual concentration of diuron in the aqueous phase except for soil sample S_3 in which the soil/water sorption coefficient shows a three-fold variation with less than a two-fold change in the equilibrium concentration of the herbicide.

The results in Table 3 also show that the values of the soil/water sorption coefficient are relatively high and indicate that the mobility of diuron in the soil samples will be low. The relative phytotoxicity of diuron in the soils will be of the order $S_1 > S_2 > S_3$.

Table 1
Some properties of the soil samples

Soil sample	pH	CeC*	Organic matter content (%)	Sand (%)	Clay (%)	Silt (%)
S_1	6.7	6.60	1.66	92.2	4.3	3.5
S_2	6.2	4.04	0.52	88.8	4.8	6.4
S_3	8.1	3.42	1.07	96.2	1.3	2.5

a, cation exchange capacity expressed as milliequivalent per 100g of soil.

Table 2
Sorption behaviour of diuron on some soils

Initial herbicide concentration (mg 100 ml ⁻¹)	Equilibrium herbicide concentration (mg 100 ml ⁻¹)			Amount of herbicide adsorbed (mg g ⁻¹)		
	S_1	S_2	S_3	S_1	S_2	S_3
0.4	0.12	0.16	0.30	0.048	0.040	0.012
0.5	0.16	0.19	0.35	0.060	0.054	0.022
0.6	0.24	0.28	0.38	0.064	0.054	0.036
0.7	0.30	0.35	0.43	0.072	0.062	0.046
0.8	0.36	0.43	0.47	0.080	0.069	0.054
0.9	0.44	0.47	0.50	0.084	0.074	0.072

Sorption isotherm. Sorption data usually follows Freundlich or Langmuir isotherms. The two classical isotherms can be mathematically represented as:

$$\frac{x}{m} = KC_e^{1/n} \dots \dots \dots (1)$$

$$\frac{Ce}{(x/m)} = \frac{1}{bX_m} + \frac{Ce}{X_m} \dots \dots \dots (2)$$

where x = amount of adsorbate removed from solution (mg); m = mass of adsorbent (g); K, n = Freundlich constants (coefficient and exponent of the isotherm respectively); C_e = equilibrium (residual) concentration of adsorbate (mg l⁻¹); b = constant related to the energy of adsorption; X_m = maximum adsorption capacity (mg g⁻¹ adsorbent).

If sorption followed the Freundlich isotherm, then the plot of $\log(x m^{-1})$ versus $\log C_e$ would be linear from which K and n values could be calculated from the intercept and slope, respectively. Alternatively, if sorption followed the Langmuir isotherm, then a linear relationship would be obtained between $C_e/(x m^{-1})$ and C_e from which the constant, b and X_m , could be calculated (Fig 1). The constants for the Freundlich isotherm and the maximum diuron binding capacity of the soil samples are shown in Table 4. The value of the exponent of the Freundlich isotherm equation has been related to the mechanism of sorption process and the ease of leaching adsorbate molecules from an adsorbent (Chanda *et al* 1983). It has been suggested that a value of n much lower than unity indicates sorption process in which the adsorbate can be readily leached from adsorbent (Chanda *et al* 1983).

Table 3
Sorption coefficient of diuron on the soil samples

Soil sample	Diuron concentration solution at equilibrium	Sorption coefficient K_d^*
S_1	0.12-0.44	0.40-0.17
S_2	0.16-0.47	0.25-0.14
S_3	0.30-0.50	0.04-0.12

* (mg diuron soil sample⁻¹)/(mg diuron L solution⁻¹)

Table 4
Parameters of the Freundlich and Langmuir isotherm equations

Soil sample	K	n	X_m (mg g ⁻¹)	b (ml ³ mg ⁻¹)
S_1	2.68	0.34	0.08	11.54
S_2	8.59	0.48	0.10	5.12
S_3	-1.30	0.32	--	--

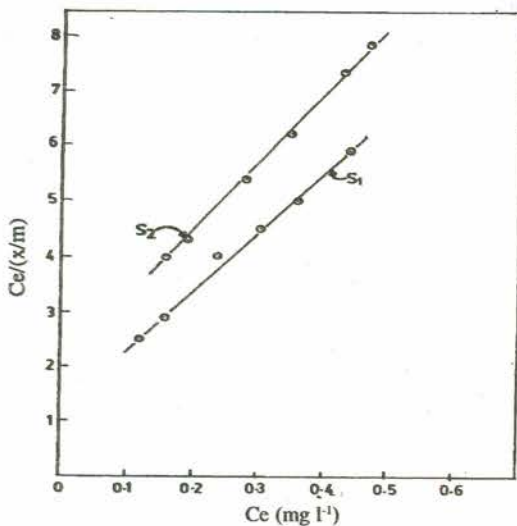


Fig 1. Application of the Langmuir equation to sorption of diuron on soils.

The results (Table 4) suggest that diuron may be leached from the soil samples and that the leachability would be of the order $S_3 > S_1 > S_2$. The leachability of herbicides has implications for effective weed control.

Fig 1 shows the application of the Langmuir equation to sorption of diuron on soils. The sorption data of diuron on soil sample S_3 did not fit the Langmuir isotherm equation. The values of X_m and b are calculated from the least squares fit. As can be seen (Table 4), the values of X_m are 0.08 mg g^{-1} and 0.10 mg g^{-1} whereas the b values are 11.54 and $5.12 \text{ ml}^3 \text{ mg}^{-1}$ for soil samples S_1 and S_2 , respectively.

Conclusion

These experiments have provided some information on the behaviour of diuron in soil environment. The results show that up to 40% diuron applied to soil may not be retained by the soil particles to affect the desired phytotoxicity, and that leaching of diuron may be an important wastage process in the application of the herbicide.

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