Adsorption of Fluometuron, Prometryne, Sencor, and 2,4-D by Soils[1]

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INTRODUCTION

Considerable effort has been made in the past 2 decades to study adsorption characteristics of phenoxyacetic acid (2,4,9,21), triazines (2,3,4,7,8,9,10,13,14,16,17,19,20,21,22,23) and substituted urea herbicides (2,4,5,6,7,8,9,10,15,24). Most of the work reported, however, was conducted under edaphic conditions foreign to our area. Information concerning the adsorption characteristics of the above groups of herbicides by local soils is rather limited. Such information is useful not only for adjusting the rate of herbicide application but also for predicting the relative mobility of various herbicides in our ecosystem. To date, the only published work on this subject relevant to Puerto Rico is that by Liu et al. (12), wherein data was presented concerning the adsorptive capacity of 34 native soils of two of the most commonly used herbicides, namely, 2-chloro-4-(ethylamine)-6-(isopropylamine)-s-triazine (Atrazine), and 3-tert-butyl-5-chloro-6-methyl uracil (Terbacil). The present research is a continuation and expansion of our previous work. This paper reports the adsorption of 1,1-dimethyl-3-(trifluro-m-toyl) urea (Fluometuron), 2,4 bis (isopropylamine)-6-(methylthio)-s-triazine (Prometryne), 4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H) one (Sencor), and 2,4-dichlorophenoxyacetic acid (2,4-D) by 48 local soils. Prometryne is used commercially to control noxious weeds in coffee (*Coffea arabica*), plantain (*Musa paradisiaca* L.), and pigeonpea (*Cajanus cajan*). 2,4-D is used widely as a post-emergence herbicide for the control of broad-leaved weeds in various crops of economic importance in Puerto Rico. Fluometuron and Sencor have shown promising results for weed control in sugarcane (*Saccharum officinarum*).

MATERIALS AND METHODS

Samples from the upper layer (6 inches) of 48 different soils were collected from various regions of Puerto Rico representing a wide variety of climatic and edaphic conditions. The samples were air-dried, ground and passed through a 0.25-mm. screen. The physical and chemical properties of these soils were determined by methods similar to those employed previously (11).

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To determine the extent to which Fluometuron, Prometryne, Sencor and 2,4-D were adsorbed by each soil type, the slurry-type procedure outlined by Talbert and Fletchall (16) was followed. Stock solutions (concn. 5 p.p.m.) of Fluometuron, Prometryne, and Sencor were prepared with 0.01 M $CaCl_2$ in a 2,000-ml. volumetric flask. Another stock solution (concn. 35 p.p.m.) of 2,4-D was similarly prepared. Ten ml. of each herbicide were added to individual Erlenmeyer flasks containing 1 g. of soil sample each. The flasks were stoppered and agitated in a reciprocal shaker for 5 hours. Individual samples were then transferred to 15-ml.-capacity glass tubes and centrifuged for 10 minutes at 3,700 r.p.m. Subsequently, 5 ml. of the supernatant were removed and placed in a cuvette for spectrophotometric determination. A series of standard curves were constructed by plotting observed absorbances against known concentrations. The known concentrations used were 0, 0.3125, 0.625, 1.25, 2.50 and 5.00 p.p.m. for Fluometuron, Prometryne, and Sencor. Other known concentrations were used for 2,4-D, namely, 0, 2.188, 4.375, 8.75, 17.50 and 35.00 p.p.m. The analytical wavelengths used were 240, 222, 230 and 283 mμ for Fluometuron, Prometryne, Sencor, and 2,4-D, respectively. All the determinations were made in triplicate except when the soil samples were insufficient; in those cases they were made only in duplicate. The difference in herbicide concentration in solution before and after equilibrium with the soil represents the amount of herbicide adsorbed.

RESULTS

The physical and chemical properties of the 48 soils used in the study are presented in table 1. The adsorption percentage for Fluometuron, Prometryne, Sencor, and 2,4-D are presented in table 2. Data obtained indicated that Prometryne was adsorbed the most, followed by Fluometuron and Sencor with approximately the same percentage, and 2,4-D the least. The adsorption of Prometryne ranged from 7 to 99 percent with a mean of 37.0 percent; that of Sencor from 1 to 61 percent with a mean of 23.0 percent; that of Fluometuron from 2 to 73 percent with a mean of 22.6 percent; and that of 2,4-D from 0 to 33 percent with a mean of 12.4 percent. The high adsorptive capacity for these 48 soils, recorded for Prometryne, agrees with the results obtained by Talbert and Fletchall (16) and Harris (7). The high levels of adsorption by the soils could be attributed to the protonated molecular configuration of the herbicide as suggested by Weber et al. (20). This same mechanism does not seem to operate in the case of Sencor, another triazine herbicide. The low to moderate adsorption of nonionic Fluometuron by soils has also been reported by Abernathy and Davidson (1). The adsorption of nonionic phenylurea herbicides, including Fluometuron, is probably the result of a dipole-ion or dipole-dipole bonding mechanism (18). The low adsorption of 2,4-D by the tested soils as re-

TABLE 1.—*Chemical and physical properties of 48 soils of Puerto Rico*

Soil type	P p.p.m.	pH	Meq. per 100 g.				Percent			
			CEC	Ca	Mg	K	Organic matter	Sand	Silt	Clay
Aguadilla loamy sand	17	7.4	10.0	17.1	3.3	0.20	2.5	74.4	19.5	6.1
Aguirre clay loam	22	9.0	14.3	18.3	28.8	1.44	1.3	27.6	35.6	36.8
Aguirre clay	32	8.4	59.0	39.0	37.5	.58	3.9	16.6	13.0	70.4
Alonso clay	4	5.1	13.8	5.4	2.0	.91	3.2	14.9	39.3	45.8
Altura loam	33	8.0	27.6	32.2	7.8	1.94	3.7	49.2	28.8	22.0
Bayamón sandy clay loam	6	4.7	5.0	2.7	1.5	.19	1.7	68.1	4.4	27.0
Cabo Rojo sandy clay	1	4.3	9.0	1.0	.5	.10	3.1	56.4	8.0	35.9
Caño Tiburones muck	6	5.5	86.0	61.9	14.0	.80	36.0	36.0	36.0	28.0
Catalina clay	1	4.7	11.8	0.7	.6	.08	1.9	6.6	28.9	64.5
Cartagena clay loam	53	7.7	36.1	25.6	19.2	.69	1.7	47.2	17.4	35.4
Cataño sand	14	7.9	6.9	—	.2	.15	2.1	89.0	7.3	3.7
Cintrona clay loam	31	8.3	25.0	29.9	13.5	1.35	2.5	43.4	25.2	31.4
Cayaguá sandy loam	4	5.2	7.3	32.2	7.8	1.94	2.0	58.8	23.4	17.8
Cialitos clay	5	5.4	18.6	6.9	7.0	.54	4.9	13.3	34.8	51.9
Coloso clay	8	5.7	23.0	14.9	5.8	.15	3.7	22.7	37.4	39.9
Corozal clay	0	4.6	17.0	6.1	.9	.52	4.3	26.0	18.6	55.4
Coto clay	13	7.7	14.0	16.6	.7	.35	3.2	23.4	24.8	51.8
Estación clay loam	14	5.9	10.0	6.7	5.4	.08	.9	48.0	20.6	31.4
Fe clay loam	13	7.5	27.6	8.7	20.8	.81	3.4	39.1	29.7	32.2
Fortuna silty clay loam	5	5.4	23.3	9.2	10.1	.15	3.3	15.0	50.7	34.3
Fraternidad clay	15	6.3	36.0	24.0	10.4	.46	2.1	15.5	32.5	52.0
Fraternidad clay (Lajas)	33	5.9	58.0	27.6	19.0	.65	4.2	11.1	23.8	65.1
Guánica clay	36	8.1	52.1	41.5	37.7	2.58	4.8	6.4	19.6	74.0
Humacao sand	9	6.3	4.0	3.7	.7	.15	1.1	84.4	8.4	7.2
Humata silty clay loam	4	4.5	10.1	2.2	.9	.27	1.7	10.1	50.9	39.0
Josefa silty loam	5	6.0	16.8	7.4	9.5	.22	3.3	26.6	53.5	20.9
Juncos silty clay	9	6.2	13.4	16.6	28.8	.17	2.7	15.2	41.6	43.2
Mabí clay	16	7.0	55.2	19.1	43.7	.50	3.9	19.9	33.4	46.7
Mabí clay loam	3	5.7	31.0	11.5	14.2	.56	4.9	22.7	40.7	36.6
Machete sandy loam	8	6.5	8.0	5.2	4.1	.19	2.2	76.0	13.4	10.6
Mercedita silty clay	25	8.1	19.9	49.9	9.9	1.02	2.4	14.9	42.8	42.3
Moca clay	6	5.8	31.0	23.4	4.7	.22	3.8	26.3	27.7	46.0
Múcara loam	6	5.8	19.6	13.6	7.8	.14	3.3	28.0	47.0	25.0
Nipe clay loam	2	5.7	11.9	4.4	2.5	.05	5.3	22.0	49.2	28.0
Pandura sandy loam	5	5.7	7.7	5.5	2.4	.13	2.0	59.4	28.2	12.4
Río Piedras silty clay	4	4.9	11.5	3.9	2.0	08	3.5	13.4	43.6	43.0
Sabana Seca clay	23	7.4	23.0	23.4	6.5	.18	3.9	39.0	24.6	36.4
San Antón clay loam	22	7.4	28.0	11.7	1.9	1.20	4.9	47.0	24.4	28.6
Santa Isabel loam	42	7.4	28.0	16.2	11.9	1.11	2.1	57.0	18.6	24.4
Soller clay loam	18	6.9	53.0	46.1	5.7	.37	10.4	46.0	20.0	34.0
Talante sandy loam	7	5.1	4.0	.9	.2	.17	1.4	73.4	19.4	7.2
Toa clay	33	8.0	36.0	43.7	.8	.29	5.1	35.0	24.6	40.4
Toa loam	2	5.3	13.0	6.9	1.5	.23	2.0	41.5	38.3	20.2
Toa sandy loam	8	6.0	8.0	6.2	1.4	.17	.6	60.9	25.1	14.0
Vega Alta sandy loam	2	5.0	5.6	1.1	1.3	.02	3.5	73.7	12.6	13.7
Vía loam	3	5.1	39.9	3.9	3.5	.10	2.3	45.2	36.8	18.0
Viví loam	3	4.8	14.0	4.0	2.5	.12	2.2	62.4	19.6	18.0
Voladura clay	1	4.3	17.7	.5	.5	.21	4.5	15.0	23.4	61.6

TABLE 2.—*Adsorption (percentage) of Fluometuron, Prometryne, Sencor, and 2,4-D by 48 local soils*

Soil type	Adsorption percentage			
	Fluometuron	Prometryne	Sencor	2,4-D
Aguadilla loamy sand	12	28	20	4
Aguirre clay loam	15	17	27	17
Aguirre clay	50	30	21	10
Alonso clay	21	42	24	13
Altura loam	16	27	8	5
Bayamón sandy clay loam	10	25	12	8
Cabo Rojo sandy clay	16	50	35	18
Caño Tiburones muck	73	99	59	33
Catalina clay	28	37	46	12
Cartagena clay loam	19	22	25	7
Cataño sand	25	7	8	4
Cintrona clay loam	28	34	24	22
Cayaguá sandy loam	9	28	9	11
Cialitos clay	27	40	22	—[1]
Coloso clay	30	45	16	23
Corozal clay	22	45	29	15
Coto clay	22	28	25	13
Estación clay loam	14	23	12	8
Fe clay loam	33	49	23	6
Fortuna silty clay loam	17	61	20	6
Fraternidad clay	16	25	15	7
Fraternidad clay (Lajas)	20	35	28	17
Guánica clay	30	34	30	9
Humacao sand	13	28	12	10
Humata silty clay loam	19	48	14	5
Josefa silty loam	13	47	12	6
Juncos silty clay	31	29	18	5
Mabí clay	16	17	32	7
Mabí clay loam	35	39	61	9
Machete sandy loam	21	32	24	12
Mercedita silty clay	10	28	35	11
Moca clay	29	51	29	8
Múcara loam	8	46	5	—[1]
Nipe clay loam	25	55	23	24
Pandura sandy loam	19	7	11	4
Río Piedras silty clay	8	45	26	19
Sabana Seca clay	22	23	25	12
San Antón clay loam	27	21	40	28
Santa Isabel loam	29	47	26	5
Soller clay loam	41	97	32	16
Talante sandy loam	12	22	23	14
Toa clay	40	57	44	13
Toa loam	16	35	6	7
Toa sandy loam	2	12	1	5
Vega Alta sandy loam	31	29	22	5
Vía loam	10	32	6	13
Viví loam	20	36	17	20
Voladura clay	37	61	22	44
Mean	22.6	37.0	23.0	12.4

[1] No value; negative adsorption.

vealed by this study, indicates the great potential of this herbicide to leach or move away from the site of its application. This low adsorption could be attributed to the fact that negatively charged soil colloids tend to repel the negatively charged anionic 2,4-D predominating in the neutral aqueous system (18).

Correlation studies of the soil properties and herbicide adsorption percentages indicated that organic matter was the soil component most highly correlated with adsorption of Fluometuron, Prometryne, Sencor, and 2,4-D (table 3). The following regression equations were obtained from the rela-

TABLE 3.—*Influence of certain soil properties on adsorption percentage for the herbicides Fluometuron, Prometryne, Sencor and 2,4-D, using 48 soil types*

Factors correlated	P	pH	CEC	Ca	Mg	K	Organic matter	Sand	Silt	Clay
Adsorption percentage for Fluometuron	0.13	0.14	0.63**	0.48**	0.24	0.09	0.72**	−0.20	−0.07	0.32*
Adsorption percentage for Prometryne	−.17	−.25	.43**	.31*	−.10	−.07	.66**	−.30*	.26	.20
Adsorption percentage for Sencor	.12	.09	.46**	.37*	.18	.14	.52**	−.31*	.02	.39**
Adsorption percentage for 2,4-D	−.14	−.20	.22	.08	−.14	.02	.45**	−.21	.03	.24

* Significant at 5-percent level.
** Significant at 1-percent level.

tion between the organic matter content of the soil and the percentage of herbicide adsorption: $Y = 1.783X + 15.833$ for Fluometuron; $Y = 2.425X + 27.712$ for Prometryne; $Y = 1.337X + 17.890$ for Sencor; and $Y = 0.737X + 9.585$ for 2,4-D (fig. 1). Using the above mentioned relationships, the unknown percentage of adsorption of each of the four herbicides by a given soil can be predicted through the known amount of organic matter present in the soil. Cation exchange capacity was found to be the next in importance with respect to adsorption of Fluometuron, Prometryne, and Sencor by the soils. However, such was not the case with 2,4-D. Correlation between clay content and adsorption of Fluometuron and Sencor was statistically significant. In contrast, no significant correlation was noted between clay content and adsorption of Prometryne and 2,4-D.

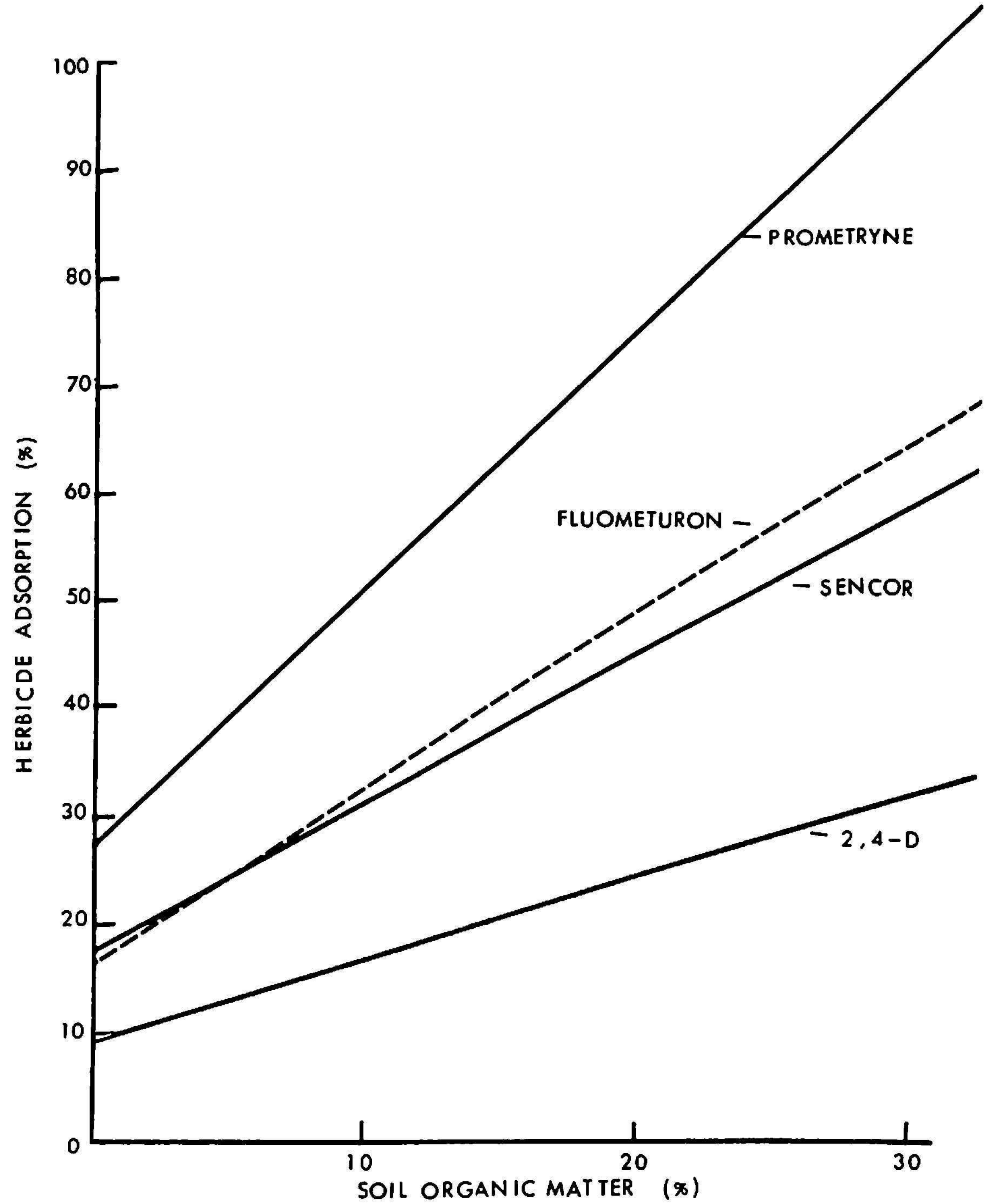

FIG. 1.—Theoretical relationship between soil organic matter content and herbicide adsorption of Fluometuron, Prometryne, Sencor, and 2,4-D for 48 soils of Puerto Rico.

SUMMARY

The adsorption capacity of Fluometuron, Prometryne, Sencor, and 2,4-D by 48 local soils was determined spectrophotometrically. The mean adsorptivities of the four herbicides by these soils were as follows: Prome-

tryne 37.0 percent, Sencor 23.0 percent, Fluometuron 22.6 percent, and 2,4-D 12.4 percent. The results indicated that organic matter content was the factor most highly correlated with adsorption of these herbicides by the 48 soils. Cation exchange capacity was found to correlate significantly with adsorption of Fluometuron, Prometryne, and Sencor. Such was not the case with 2,4-D. Correlation between clay content and adsorption of Fluometuron and Sencor was statistically significant. In contrast, no significant correlation was noted between clay content and adsorption of Prometryne and 2,4-D.

RESUMEN

Se estudió en el laboratorio, usando métodos espectrofotométricos, la capacidad relativa de 48 tipos de suelos de Puerto Rico para adsorber los yerbicidas Fluometuron, Prometryne, Sencor y 2,4-D. Las capacidades promedio de los suelos para adsorber estos cuatro yerbicidas fueron las siguientes: Prometryne 37.0 por ciento, Sencor 23.0 por ciento, Fluometuron 22.6 por ciento y 2,4-D 12.4 por ciento. Los resultados indicaron que el contenido de materia orgánica fue el factor más altamente correlacionado con la capacidad de estos 48 suelos para adsorber los antedichos yerbicidas. Se demostró que existe una correlación positiva entre el intercambio de cationes y la adsorción de Fluometuron, Prometryne y Sencor por los suelos. Sin embargo, no fue así en el caso del 2,4-D. Se determinó que la correlación entre el contenido de arcilla y la adsorción de Fluometuron y Sencor fue estadísticamente significativa. Por contraste, no se notó una correlación significativa entre el contenido de arcilla y la adsorción de Prometryne y 2,4-D.

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