DISTRIBUTION OF HERBICIDE ACTIVITY IN LEACHING COLUMNS OF THREE SOIL TYPES UNDER DIFFERENT AMOUNTS OF WATER

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SUMMARY

Soil columns filled with a sandy loam, a heavy clay or a calcareous clay were used to study the distribution of herbicidal activity of alachlor, linuron, pendimethalin and prometryn after leaching with 30 mm, 150 mm and 300 mm simulated rainfall over a 30-day period. There was little movement with 30 mm rain in any soil. With more rainfall pendimethalin activity was evident at 2.5 cm in the two heaviest soils and at upto 5 cm in the sandy loam. Some herbicides showed activity down to 10 cm or more.

ΠΕΡΙΛΗΨΗ

Σε πειράματα σε στήλες εδάφους έγινε μελέτη η μετακίνηση των ζαζανικοκτόνων αλαχλόρ, λινούρον, πεντιμέθαλιν και προμετρυν σε τρεις τύπους εδαφών και σε συνθήκες με τρία ποσά νερού (30, 150 και 300 χλμ.) για περίοδο 30 ημερών, υπολόγισε ότι σε όλα τα εδάφη υπήρχε μικρή κίνηση με το χαμηλό ποσό νερού. Με περισσότερο νερό η δραστηριότητα του πεντιμέθαλιν ήταν αυξημένη στα 2.5 εκ. στα βαρετά εδάφη και 5 εκ. στο ελαφρό εδάφος. Τα υπόλοιπα ζαζανικοκτόνα κυνηγήθηκαν στα 10 εκ. η περισσότερο.

INTRODUCTION

Movement of herbicides in the soil is dependent upon several factors, including physico/chemical properties of the herbicide (Harris, 1967; Helling, 1971 a,b), soil properties (Upchurch and Pierce, 1958; Best and Weber, 1974; Weber and Peepere, 1977) and intensity and frequency of applied water (Upchurch and Pierce, 1957; Weber and Pepeere, 1982). The mobility of a herbicide is generally inversely related to its affinity for soil adsorption (Webber and Swain, 1986). Herbicides that are strongly adsorbed to soil will require large amounts of water to move from the soil surface to the plant roots (Moyer, 1987). Studies with metribuzin (Laddie et al., 1976), simazine (Nicholls et al., 1984), trifluralin, atrazine and bromacil (Signori et al., 1978), showed that the rate of movement in soils was greatest for herbicides with high water solubility. This 14C-metribuzin had greater mobility in soil thin-layer plates than 14C-atrazine, because of differences in water solubility and basicity (Laddie et al., 1976).

Among the chemical properties of soils that influence herbicide mobility are the organic matter (O.M.) content and cation exchange capacity (C.E.C.) (Abernathy, 1973). Studies on the movement of herbicides in different soils have shown that movement was greatest in soils low in both organic mat-

The herbicides studied and plant species used in bioassays are shown in Table 1, while characteristics of test soils are shown in Table 2.

Table 1. Herbicides and indicator species

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Rate kg a.i./ha</th>
<th>mg/column applied</th>
<th>Bioassay species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alachlor</td>
<td>3.0</td>
<td>2.4</td>
<td>Barley</td>
</tr>
<tr>
<td>Linuron</td>
<td>1.0</td>
<td>0.8</td>
<td>Lettuce</td>
</tr>
<tr>
<td>Pendimethalin</td>
<td>1.6</td>
<td>1.3</td>
<td>Wheat</td>
</tr>
<tr>
<td>Prometryn</td>
<td>1.5</td>
<td>1.2</td>
<td>Barley</td>
</tr>
</tbody>
</table>

Table 2. Soil characteristics

<table>
<thead>
<tr>
<th>Soil type</th>
<th>O.M. (%)</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
<th>pH</th>
<th>CaCO3 (%)</th>
<th>C.E.C. (meq/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.21</td>
<td>13.7</td>
<td>26.7</td>
<td>58.7</td>
<td>7.8</td>
<td>1.15</td>
<td>63.2</td>
</tr>
<tr>
<td>B</td>
<td>0.41</td>
<td>61.1</td>
<td>25.0</td>
<td>13.7</td>
<td>7.5</td>
<td>1.15</td>
<td>38.2</td>
</tr>
<tr>
<td>C</td>
<td>1.32</td>
<td>43.5</td>
<td>34.1</td>
<td>22.4</td>
<td>7.5</td>
<td>5.02</td>
<td>26.8</td>
</tr>
</tbody>
</table>

* A: Sandy loam; B: Heavy clay; C: Calcareous clay.

Three different amounts of irrigation were compared, namely 30, 150 and 300 mm over a 30-day period. These amounts were taken considering the water crop requirements for the winter, spring and summer periods, respectively, which correspond to the respective evaporation losses, measured by class A pan, for the Nicosia area (Fig. 1).

![Figure 1. Mean monthly pan evaporation (mm/day) in the Nicosia area](image)

Plastic PVC pipes of 25 cm length and 10.16 cm diameter were cut into sections to give depths of 0 to 2.5, 2.5 to 5.0, 5.0 to 7.5, 7.5 to 10.0 and > 10.00 cm. The five sections (depths) were fastened together with silicone sealer and plastic tape in such a way that a 2 to 5 mm ridge of silicone sealer extended into the interior of the column at each section. The silicone sealer eliminated the possibility of water and/or herbicide seeping out of the sections. The stacked columns were filled with the test soils, care being taken to consolidate the soil homogeneously.

After filling and pressing, the columns were flooded and left to drain to field capacity. Each column was stood in a saucer containing quartz sand to absorb leachate and prevent it from contaminating adjacent columns. Solutions of the test herbicide were prepared on the basis of a spray volume of 500 l/ha and the amount indicated in Table 1 was made up to 5 ml aliquots and dispensed onto each column using macro pipettes. After the herbicides were applied to the surface of each column they were equilibrated with the soil for 24 h before the leaching process was initiated. Water was applied to the columns daily (1.5 and 10 mm) for a period of 30 days with an Oxford macro-set pipetting system.

Treatments were replicated three times in a randomized complete block design. At the end of the leaching period the columns were allowed to drain for two days before they were sectioned. The soil from the various treated sections, including the untreated control, was placed in pots where fifteen seeds of the appropriate indicator crops were sown. Thinning followed after emergence leaving ten plants in each pot, which were allowed to grow for 2 to 3 weeks depending on the crop. At the end of this period plants were harvested at ground level and their fresh weight was immediately determined. The data were expressed as percentage of untreated plant fresh weight.

**RESULTS AND DISCUSSION**

**Alachlor**

Under the low irrigation regime (30 mm), alachlor did not move in significant amounts beyond the 2.5 cm zone. Some non significant movement in the light soil to the 5 cm zone did occur. Under moderate irrigation (150 mm), movement of alachlor beyond the 10 cm zone was significant in both
Figure 2. Alachlor mobility in three soil types at three moisture regimes

Figure 3. Linuron mobility in three soil types at three moisture regimes
the light and heavy soils, but not in the calcareous soil, where such movement was restricted to the top 2.5 cm layer. A heavy irrigation regime (300 mm) resulted in the leaching of alachlor to a depth greater than 10 cm in the light soil, as evidenced by the fresh weight reduction of barley in the soil horizon below 10 cm. In the heavy soil phytotoxic concentrations of alachlor were present in all horizons down to a depth of 10 cm, but not beyond. This is rather strange in view of movement under 150 mm of water. In the calcareous soil even this amount of water failed to leach alachlor in significant amounts beyond the top 2.5 cm zone (Fig. 2).

The deeper distribution of alachlor activity in the light soil relative to the heavy soil is attributed to the larger pore spaces in the former and the greater adsorptive capacity of the latter. The very restricted movement in the calcareous soil, even under 300 mm of irrigation, is most likely primarily due to strong adsorption owing to the organic matter, clay and CaCO₃ content of that soil.

**Linuron**

Distribution of linuron under the low irrigation regime was similar to that of alachlor, being restricted mainly to the top 2.5 cm, although in the light soil significant activity of linuron occurred down to the 5 cm layer. Under a moderate irrigation regime of 150 mm of water, linuron activity was again similar to that of alachlor light and heavy soils, while in the calcareous soil significant leaching of linuron occurred down to 7.5 cm. With 300 mm water, linuron activity occurred beyond the 10 cm depth in both the light and heavy soils, but in the calcareous soil, activity was again confined to the 7.5 cm layer (Fig. 3). Fresh weight figures for all three soil types indicate a progressive leaching of linuron to deeper soil layers.

As shown from the mean fresh weights of lettuce (Fig. 3), linuron distribution was similar to that of alachlor in two of the three soil types under the three irrigation regimes, with the proviso of differential species sensitivity. In the calcareous soil, linuron exhibited greater mobility than alachlor under the two higher amounts of water. The results for linuron mobility are in agreement to a large extent with the findings of Walker (1987), who, working under field conditions, found that following autumn application linuron moved to a soil depth of 12 cm during winter, while after spring application, where precipitation was lower, it moved to less than 6 cm.

**Pendimethalin**

Pendimethalin, which is essentially insoluble in water (0.5 ppm at 35 oC), did not leach beyond the top 2.5 cm layer in any soil at the lowest irrigation regime. Even with the greater water amounts it failed to leach beyond 2.5 cm in either the heavy or the calcareous soil. Leaching was evident only in the light soil with large pore spaces and low adsorptive capacity. At the intermediate water amount pendimethalin moved only down to a depth of 7.5 to 10 cm, while deeper movement was only achieved at the highest rate of irrigation (Fig. 4). Given the very low solubility of pendimethalin, it is suggested that movement in the light soil was the result of purely physical movement downwards either along the column walls or adsorbed on soil particles. The present results are in agreement with those of Pinho (1981), who found that herbicide leached more in soils comprising larger aggregates compared with finer aggregates and that movement in clay soil was limited. The very limited leaching of pendimethalin found in the present study is also in agreement with the findings of Signori and Deuber (1979), who found that in some cases there was no detectable leaching of that herbicide.

**Prometryn**

Prometryn activity remained in the top 2.5 cm of all three soil types at the lowest level of irrigation. At the intermediate level it was unpredictably mobile in the heavy soil, whereas in the calcareous and light soils it was less mobile, being restricted to 7.5 and 10 cm respectively. At the highest level of irrigation prometryn residues occurred at injurious concentrations down to a depth of 10 cm in the calcareous soil, below 10 cm in the light soil and in the heavy soil appears to have leached out of the column probably because of the nature of the clay in the heavy soil, for which prometryn had little affinity and, therefore, adsorption was low (Fig. 5). Results were similar with those observed by Perez and Gomez, (1978), who working on the leaching in soil columns of ametryn, pro-
Figure 1. Lignin mobility in three soil types at three moisture regimes

Figure 5. Prometryn mobility in three soil types at three moisture regimes
metryn, diuron and metribuzin with a red ferralitic soil with 2.99% organic matter and C.E.C. of 15 to 14 meq/100 g found the following order of leaching of the compounds: prometryn>ametryn>metribuzin>diuron.

However water applied in their experiment was more than the high level of 10 mm per day used in the present study.

Mobility of all herbicides increased with increasing amounts of water resulting in some cases in leaching out of the column of all toxic residues. Herbicide movement in the three soil types was mainly in the order sandy loam>clay>calcareous soil. This is explained by comparing the characteristics of the three soil types where the sandy loam (light) and heavy clay (heavy) were low in organic matter content, while in the calcareous clay it was higher. Moreover, clay content also was high in the calcareous soil and low in the sandy loam. Ando et al. (1987), investigating the movement of alachlor, diphenamid, lenacil, simazine and nitralin, found that herbicides moved more easily in soils of low organic matter and clay content and that the degree of movement increased with increasing volume of precipitation. Savage (1976), in studies on the adsorption and mobility of metribuzin on 16 soils as a function of soil properties, found that metribuzin sorption and mobility were significantly correlated with each other and that both parameters were significantly associated with clay content, organic matter and amount of water applied.

The important role of the type of clay in the mobility of some herbicides tested in this study might also be a reason for the higher leaching in the heavy soil than in the calcareous soil and even than in the light soil in the case of prometryn. Paulo et al. (1979) working on the leaching of metribuzin in two soil types using soil columns found that metribuzin reached 9 cm in clay with 60 mm of water and 18 cm with 120 mm, while in the loam it reached 21 cm with both levels of precipitation. Leaching appeared to be affected by the content and type of clay rather than by organic matter content.

Mobility of herbicides was different and in most cases was dependent on soil type and amount of water. This is because several soil and herbicide properties determine the herbicide position following water application. These include amount of rainfall, amount of moisture in the soil, soil composition, adsorption of the herbicide to soil particles, permeability and amount of clay dispersion. However, some herbicides probably seep through large soil pores and cracks to the root zone with moderate rainfall; thus, all crops should have a certain degree of physiological tolerance in addition to depth protection for assured selective action to occur (Leistra, 1980; Walker, 1980). While it is possible to classify herbicides according to their relative mobility in soil by using soil columns with uniformly ground soil where steady water flow occurs, it is difficult to use this information to predict the position of a herbicide in a normal cultivated field. The variable nature of a field soil (variety of aggregate sizes, clods and cracks, wetting and drying cycles) will affect the adsorption and mobility of herbicides in the field. However, the relative mobility of herbicides in the laboratory seem to be related to their relative mobility in the field. Thus, results from laboratory leaching experiments can be used to explain certain aspects of efficacy and selectivity of herbicides in the field (Moyer, 1987).

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REFERENCES


