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# Persistence and Leaching of the Herbicide Imazapyr in Soil

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For each organic chemical which comes in contact with the soil, extensive information is required about its persistence and leaching. With herbicides this is important for agronomic and environmental reasons. The persistence of a herbicide in soil determines its biological efficacy and possible carry-over problems with rotation crops while its leachability influences weed control efficacy and crop selectivity and determines its possible contamination of ground water.

Imazapyr [2-(4-isopropyl-4-methyl-5-oxo-2 imidazolin -2-yl) nicotinic acid] is a new herbicide, recently registered in Greece under the trade name Arsenal 25 SL (imazapyr 25% w/v), belonging to the group of imidazolinones. It is recommended for weed control on non-crop areas against grass and broadleaved annual and perennial weeds (Anonymous, 1984). So far there has been very little information in the literature concerning the persistence and leaching of imazapyr in soil and to the best of our knowledge, no bioassay methods for determining imazapyr residues in soil has been published. The objective of the present work was to develop a bioassay method for determining imazapyr residues in soil and by using this bioassay to get information about the persistence and leaching of the herbicide.

## METHODS AND MATERIALS

The two soils used were a clay loam with pH 7.4, organic matter 3.9%, saturation capacity 54.8% and cation exchange capacity 17.4 (meg/100 g), numbered in this text as soil A, and a loam with pH 7.75, organic matter 3.4%, saturation capacity 45.8% and cation exchange capacity 19.84 (meg/100 g), numbered as soil B.
A fresh sample of wheat (*Triticum vulgare* L.) cv.Yekora was chosen as the best indicator-plant among other plants

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for the bioassay as it was found to be sensitive to low doses of imazapyr and it was easy to assess shoot fresh weight. The soils used were air-dried, sieved through sieve and placed in plastic pots (8.5X8.5X9 cm). Ten wheat seeds were sown 4.0 cm deep embryo down. The appropriate amounts of imazapyr in water solution were pipetted on the pots soil surface to give a series of concentrations between 0 and 2 mg/kg. There were five replications of each treatment. The pots were watered to give a soil moisture content equal to 75% of their field capacity and placed in the greenhouse. After emergence the seedlings were thinned to five plants per pot. The developed shoots were cut at ground level after 25-30 days and fresh weight were recorded. The data were fitted to the linear model y=a+ logx where y is the percentage reduction of the shoot fresh weight in comparison with the control and x is the concentration of imazapyr in mg/kg.

The experimental system for estimation of imazapyr leaching in the laboratory consisted of polyvinylchloride (P.V.C.) columns (50 cm long by 10 cm internal diameter). Each column was made by joining 3 cm P.V.C. rings together with cellotape. The columns were filled with successive amounts of 260±30 g of sieved air dry soil. Each sample was watered with a pipette to give the required moisture content before another sample was added to the soil columns. In this way a reproducible bulk density of 1.1±0.13 $g/cm^3$ was achieved with the soils used. At the bottom of each soil column an iron net having holes of 1 mm was fitted to retain the soil in the columns. The soil moisture of the columns was adjusted to 75% of their field capacity. The soil columns were sprayed with Arsenal 25 SL at a rate 3 kg/ha (approximately 0.58 mg imazapyr per soil column). Arsenal 25 SL was applied at 500 l/ha with an air-pressurized sprayer equipped with a rod having 4 Tee-jet nozzles under a pressure of 2 Atm. One day after spraying a new ring was added at the top of the columns and filled with sand. Simulation rainfall was added from a burette at increments of 14 mm/hour and 27 mm total rainfall per day. In three days, a total amount of 81 mm simulated rainfall was given. The excess water coming out of the columns (leachate) was collected each day. At the end of the experiment the soil present in two successive rings, starting from the first ring soil, was collected and bioassayed. The collected leachates were also bioassayed.

The estimation of persistence and leaching of imazapyr under field conditions was carried out on an experimental area at the Agricultural University of Athens (Soil A). The experimental area (4X5 $m^2$) was cultivated to a depth of 15 cm, levelled and sprayed with Arsenal 25 SL at a

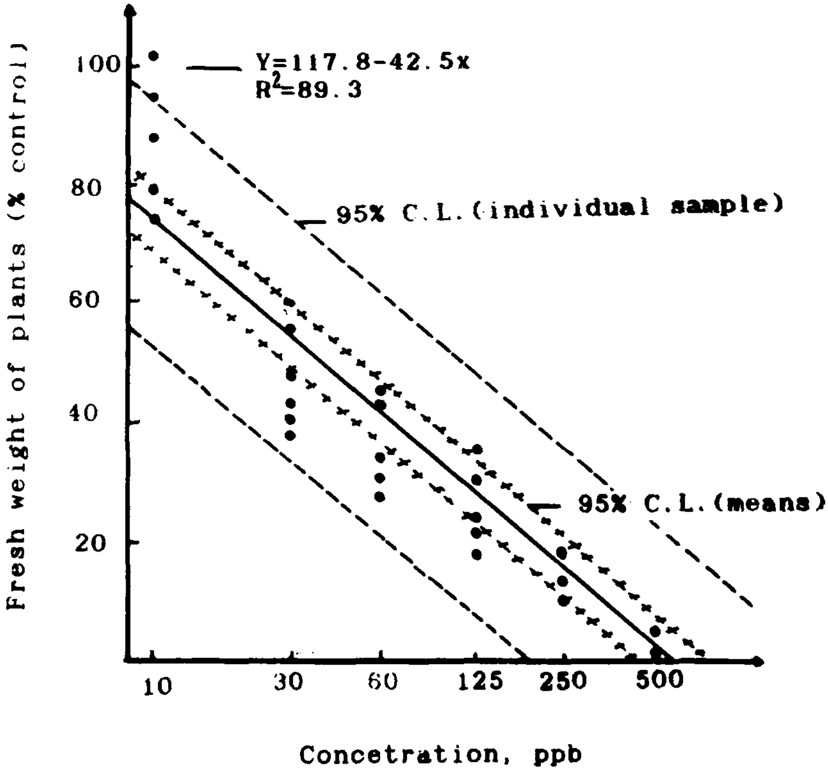


Figure 1. Dosage response curve of wheat to imazapyr in soil A. (C.L.= confidence limits)

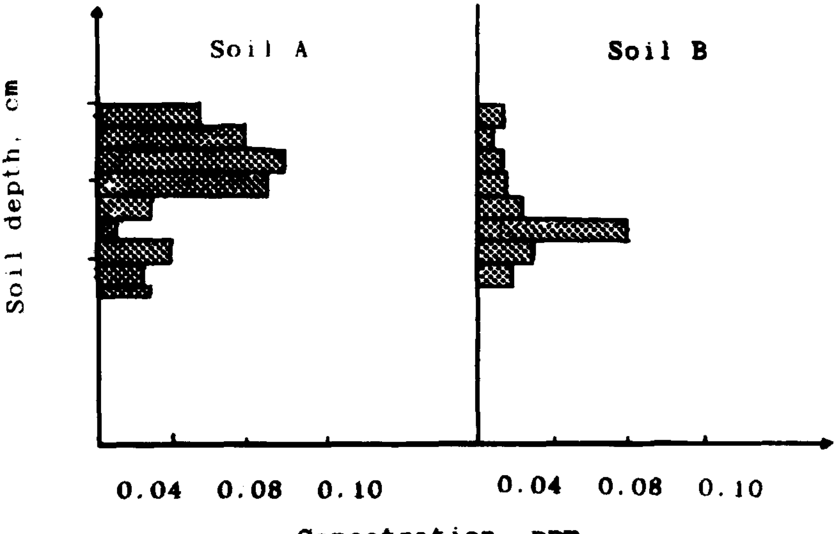


Figure 2. Leaching of imazapyr in soil columns as influenced by soil type.

rate 4 kg/ha (1 kg active ingredient/ha). The application of Arsenal 25 SL was done under the same experimental conditions as described above (soil columns) on the 21st December 1989.

At different time intervals after spraying, samples were collected from different soil depths. An aluminium tube-type soil sampler with handles was used to provide cores. Eight points in the treated field were sampled to depths of 0-10, 10-20, 20-30 and 30-45 cm according to a sampling plan (Hormann <u>et al</u>, 1973). The soil samples air-dried, passed through a 2 mm sieve and stored at -18°C until bioassayed. Control soil samples were also obtained from an area adjacent to the treated one. For determining the half-life of the imazapyr, the data were fitted to first-order Kinetics and the general formula of the regression line was y=2-bx, where y=log (%) of the growth reduction, x the time in months and the common intercept equal to 2 represents log 100% of the full growth. The slope was calculated by using the formula

$$b = \frac{\Sigma(yi-2)xi}{xi^2}$$

as reported elsewhere (Vizantinopoulos, 1981).

## RESULTS AND DISCUSSION

Figure 1 shows the results abtained using the bioassay procedure on soil A at a temperature range 23-35°C. The sensitivity of the biaoassay is good (0.01 ppm) and the fitting of the obtained data to the model y = a+logx was satisfactory ($R^2$=0.89). Table 1 gives the values of slopes and intercepts by fitting the obtained data to the regression model. Soils A and B responded similarly to imazapyr at the same temperature regime but comparison of the regressions of soil A under different temperature regimes resulted in statistically different values of slopes showing indirectly decreased adsorption of imazapyr with an increase of temperature.

The vertical distribution of imazapyr in the soil columns is shown in Fig. 2. Soil B adsorbed less imazapyr than soil A. This difference may be attributed to the difference of soil characterestics since soil A had more clay and organic matter content than soil B. Imazapyr was leached down out the soil columns and its presence in the leachates was identified by bioassay. The amount leached out of the column filled with the soil A was calculated to be at least 65% of the initial application. In contrast the value calculated for the soil B, was 80% of the initial amount. The $R_f$ values for imazapyr ranged from 0.5 to 0.95 (Mangels, 1991) indicate that imazapyr is a mobile compound and our results confirm it.

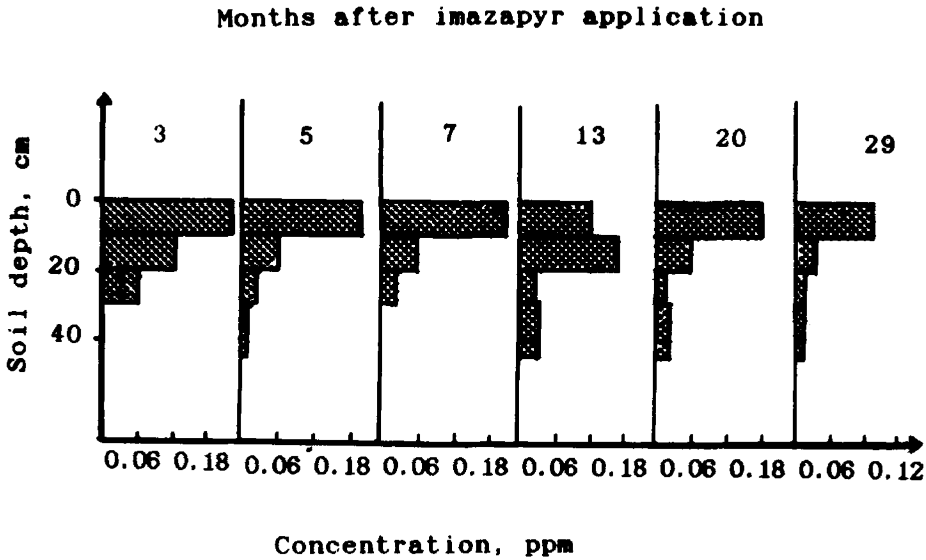


Figure 3. Imazapyr distribution in soil under field conditions and different time periods after its application.

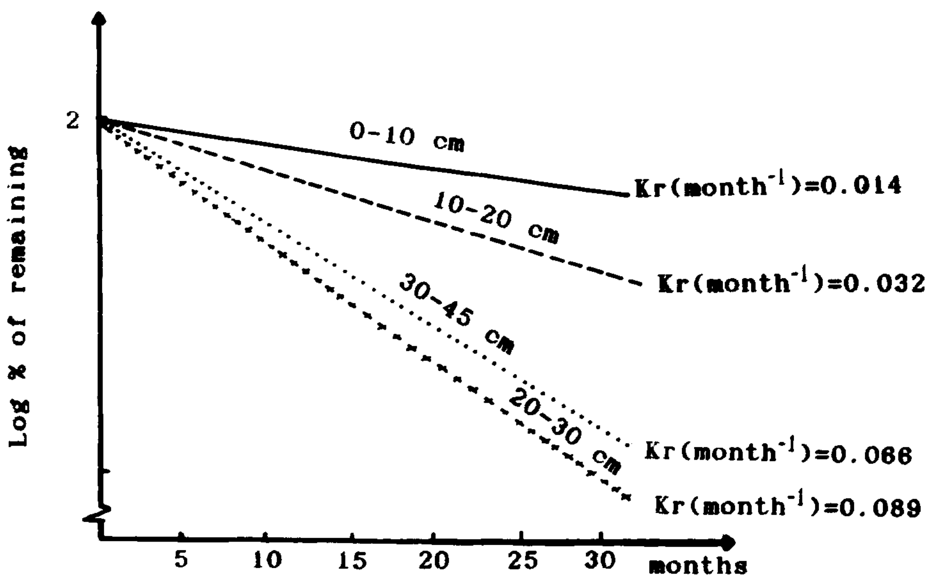


Figure 4. Breakdown of imazapyr at different soil depths under field conditions.

Table 1. Regression analysis of the obtained data by using the bioassay procedure fitted to the model y=a+logx (x=concentration in ppb) for different temperature regimes and soil types

| Values of the dependent variable | | Standard error | T | Soil Type | Temperature regime |
|---|---|---|---|---|---|
| Intercept<br>Slope | 71.401<br>-22.49 | 3.23<br>1.206 | 22.05<br>-16.64 | A | 8-15° C |
| Intercept<br>Slope | 117.76<br>-42.50 | 5.55<br>2.56 | 21.20<br>-16 | A | 23-35° C |
| Intercept<br>Slope | 83.80<br>-24.66 | 5.08<br>2.22 | 14.0<br>-11.06 | B | 8-15° C |
| Intercept<br>Slope | 77.60<br>-23.57 | 3.95<br>1.47 | 19.6<br>-15.98 | A,B* | 8-15° C |

* Comparison of the obtained regressions for the soi s A and B at the temperature regime 8-15° C gave the joint regression line y=77.60-23.57x.

The measured imazapyr distribution in the differrent soil layers and at different time after its application in the field are presented in Figure 3. Figure 4 shows the obtained decomposition lines for imazapyr. The imazapyr degradation was relatively similar at the depths 20-30 and 30-45 cm but was slower at the surface soil layers. In all cases, the breakdown of imazapyr was found to be very slow. The half-time calculated from the formula T 1/2 = 0.693/kr ranged from 49.5 months (soil layer 0-10 cm) to 7.78 months (soil layer 20-30 cm). These values are in general agreement with those found by the producer of the product (data in registration file) and reported in the literature (Mangels, 1991)

By calculation of the amounts of imazapyr in the different soil layers, we can conclude that significant quantities of imazapyr leached down to 45 cm depth. This amount is estimated to be about 40-70% of the initial theoretical applied dose (0.1 mg/$cm^1$). This finding confirms the laboratory studies and indicates indirectly the potential leachability of imazapyr. The total amount of rainfall during the whole period of the experiment was only 873 mm while some simulation rainfall equall to 160 mm was also given. In an effort to express the leachability of imazapyr as a GUS value (Gustafson, 1989) the Koc of imazapyr was calculated by using the formula log Kom = 0.52 log Kow + 0.65 derived by Briggs (1973). For imazapyr the Kow is 1.3 (value taken from registration file) and by using the conversion factor

1.724 for determination the organic carbon content (Hamaker and Thompson, 1972) the Koc for imazapyr was found to be 8.81. By placing in the formula GUS = log (t 1/ 2 ) X [4 - $log_{10}$ (Koc)] the above value of Koc for imazapyr and the lowest half-time value found in our field axperiment (233 days) the GUS value for imazapyr is 7.23. This value is much higher than that of 2.8 and indicates the high potential of imazapyr to leach and its possible contamination of the ground water (Gustafson, 1989).

The above results show that imazapyr is quite persistent and very mobile in the soil. Since it is used on non-crop areas e.g. roadsides, forestry the registration approval of imazapyr should be re-examined in some cases e.g. its application on light soils and in regions with annual rain fall more than 500 mm and high level of ground water. Moreover more research is needed to determine the role of some soil factors e.g. microorganisms, pH, organic matter on imazapyr behaviour in soils.

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