CHAPTER 4

BIOACTIVITY OF ATRAZINE AS AFFECTED BY SELECTED SOIL PROPERTIES: FIELD STUDY

Introduction

The greatest drawback of field studies is that results often apply to one particular location and season. There are valid reasons why attempts to extrapolate results obtained under controlled conditions to the field situation are subject to criticism. Firstly, the level of any one environmental parameter seldom stays the same for an extended period of time in the field. Secondly, levels of many factors are changing in this way, resulting in the exposure of plants to an almost infinite number of permutations of environmental conditions. Thirdly, plants grown and treated indoors almost certainly differ in a number of ways from plants cultivated in the field (e.g., in cuticle development and rooting pattern). Consequently, results obtained indoors may not truly reflect the field situation.

The methodology followed in the present study was designed to match results generated in the field with those obtained previously under controlled conditions. The aim was to compare the relationships found between the bioactivity of atrazine and selected soil properties during a particular growing season in the field with those relationships which were obtained in previous bioassays (Nel & Reinhardt, 1984; Ehlers *et al.*, 1987, 1988; Nel, Reinhardt & Ehlers, 1988).

Materials & Methods

The bioactivity of atrazine was investigated in ten field trials, situated in eight districts of the summer grain region of South Africa. Soil was selected on which no atrazine had been applied during the previous three years. Soils used differed with respect to organic matter content, clay content, CEC, relative P-reversion and soil pH levels (Table 22).

No fertilizers were applied as soil analyses indicated that all trial sites had adequate soil nutrient reserves. All soils were irrigated to field capacity before seedbed preparation. Seedbeds were fine and firm, with no stubble on the soil surface.

Commercial atrazine (Gesaprim® 500 FW) applications of 0, 0.031, 0.062, 0.125, 0.25 and 0.5 kg ai ha^{-1} were made. A field sprayer mounted on bicycle wheels, which delivered 200 L ha^{-1} at 300 kPa, was used for these applications. A 2.7 m spray boom with five flat fan nozzles was used on 5.4 x 10 m plots. Weeds were hand-hoed when necessary. Treatments were replicated five times in a randomized block design. The precise positions of individual plots were demarcated with marker beacons. This was done to ensure that subsequent persistence experiments (see Chapter 5) were conducted on precisely the same plots.

Oats (*Avena sativa* L. cv SWK 001) was used as the test species. The same cultivar was employed in the bioassay conducted by Ehlers *et al.* (1988) in a glasshouse. Seed were treated with thiram, a broad spectrum fungicide. A plant density of approximately

300 000 plants ha^{-1}, in rows 900 mm apart, was used. Atrazine was applied directly after oats were planted.

Atrazine bioactivity was evaluated by harvesting the shoots of the plants, 35 days after planting, in five randomly distributed 2 m rows per net plot (4.4 x 8 m). Data were expressed as percent damage, i.e. percentage reduction in shoot dry mass compared to the untreated controls. Analyses of variance and regression analyses were performed on these data.

The relationships between atrazine bioactivity and selected soil properties were evaluated by means of correlation studies. Simple correlation coefficients (r values) were determined across herbicide rates. Since the order of importance of soil properties in the prediction of atrazine bioactivity and persistence could conceivably change in accordance with initial herbicide rates, separate regression analyses were also performed at individual rates to ascertain whether the order of importance of relationships was rate-dependent. It was found that herbicide rate did not influence the relative importance of relationships, and therefore these data are not presented. The significance of differences between r^2 values of the regression analyses were determined through pairwise comparisons between r^2 values according to the procedure of Bonferroni (Krishnaiah, 1984). It was considered inappropriate to perform multiple regression analyses (more than one soil variable in the model), since the number of soils, and thus the data base, was limited.

Table 22 Some chemical and physical properties of soils

Locality	% Clay	% C	CEC $cmol^{(+)}\ kg^{-1}$	$pH(H_2O)$	P-reversion $mg\ kg^{-1}$	Clay mineral content (%)		
						Kaolinite	Montmor.	Illite
Bapsfontein A	34	1.12	37	5.6	54	70	15	10
Bapsfontein B	27	0.76	34	6.4	75	75	15	5
Ermelo	16	0.79	8	5.3	82	65	-	10
Kroonstad	7	0.15	10	5.8	119	65	5	-
Nelspruit	4	0.29	2	6.8	170	40	-	10
Pretoria	20	0.50	24	6.7	151	72	3	-
Standerton	8	0.74	12	6.6	122	20	35	5
Ventersdorp	9	0.23	3	6.1	135	65	-	15
Warmbad A	29	0.47	59	7.7	83	10	80	-
Warmbad B	52	0.53	55	7.9	51	-	85	-

Results & Discussion

Results of the bioassays conducted at 10 sites are shown in Figure 3. The Atrazine rate x Soil interaction was significant. This can be explained by the relatively high atrazine bioactivity where rates of 0.125, 0.25 and 0.5 kg ai ha^{-1} were applied on the Kroonstad and Nelspruit soils. Application of these rates at Kroonstad caused growth reduction that ranged from 77 to 100%, whilst maximum damage at Nelspruit was already observed at 0.125 kg atrazine ha^{-1}. The same three rates were less phytotoxic in the other soils. The least variation in bioactivity amongst soils was observed at the lowest (0.031 kg ai ha^{-1}) atrazine rate used.

The low organic matter and clay contents of the Kroonstad, Nelspruit and Ventersdorp soils probably accounted for the relatively high atrazine bioactivity in them. According to the postulation of Smit *et al.* (1980, 1981), high P-reversion values would be indicative of low sorption capacities for atrazine in soils. Their hypothesis is based on the assertion that atrazine may be adsorbed to positive charge on the (Al.Fe.OH) component through free electrons on parts of the herbicide molecule. This is in contrast to the generally accepted view that the adsorption of atrazine to soil colloids involve sorption of atrazine cations on only negative sites on clay and organic matter colloids (Weber, 1991a). The significant positive correlation between P-reversion and herbicide bioactivity found in the present study (Table 23) ostensibly supports the theory of Smit *et al.* (1980, 1981) that atrazine may bind to sites with positive charge by means of free electrons which concentrate at N atoms in the molecule. However, it must be stressed that a significant correlation between a soil variable and atrazine

activity does not reveal much about the nature of the adsorption mechanism involved.

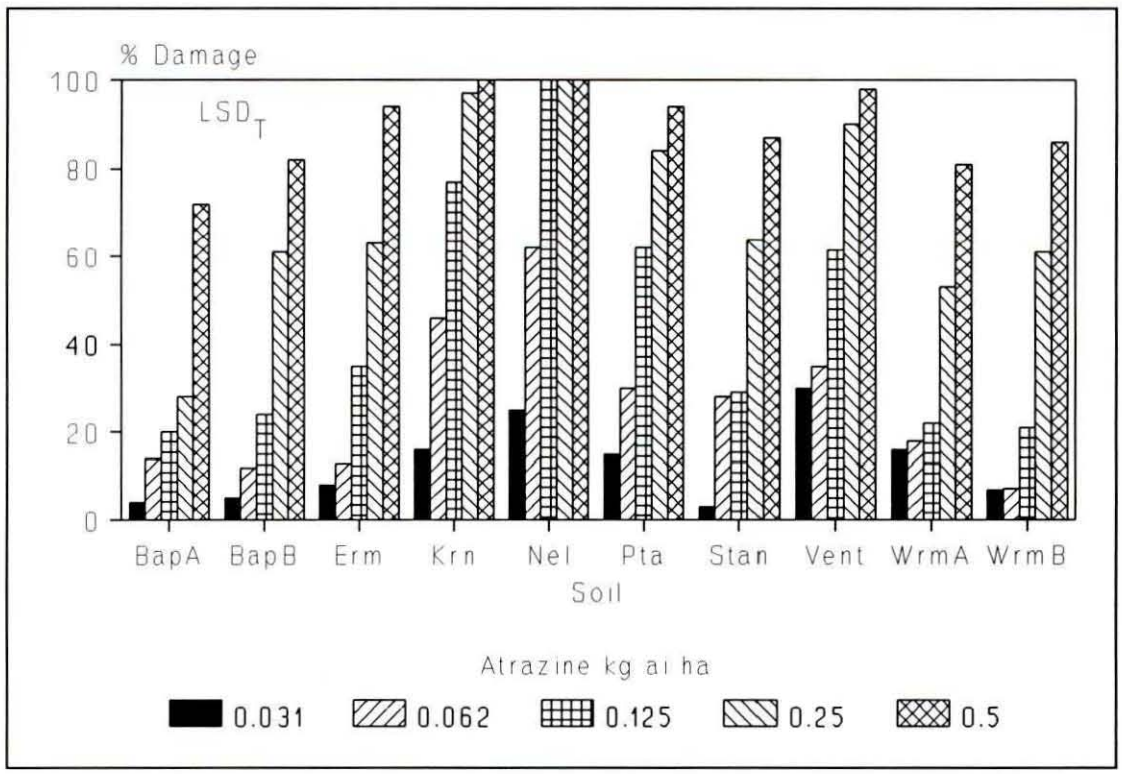

Figure 3 Percent reduction in shoot dry mass of oats treated with five atrazine rates at ten sites (ANOVA in Table 22A; data appear in Table 2B)

The relationships between atrazine bioactivity and the soil properties listed in Table 22 were evaluated by means of regression analyses. Simple correlation coefficients and r^2 values appear in Table 23. The order of importance of the soil properties for predicting atrazine bioactivity was as follows: P-reversion $\geq$ % C $>$ total clay % $\geq$ CEC $>$ pH. The order of importance was not dependent on herbicide rate. Both P-

reversion and organic matter content were better predictors than total clay content. Cation exchange capacity and soil pH were significantly less important than these three characteristics. These results correspond with those reported locally by: (a) Smit *et al.* (1981) - oats (cv Santon) the test plant in a glasshouse study, (b) Nel & Reinhardt (1984) - oats (cv SWK 001) in a glasshouse, (c) Ehlers, Reinhardt & Nel (1987) - soybeans [*Glycine max* (L.) Merr. cv Hutton] in a field study, (d) Ehlers *et al.* (1988) - oats (cv SWK001) in a glasshouse, and (e) Nel, Reinhardt & Ehlers (1988) - grain sorghum [*Sorghum bicolor* (L.) Moench cv NK 222] in a glasshouse.

In the bioassay with grain sorghum, rates of atrazine (0.5-4.0 kg ai ha^{-1}) were more representative of field application rates (Nel *et al.*, 1988). With grain sorghum being a moderately tolerant crop to atrazine, and oats and soybeans very sensitive, less herbicide was applied in experiments with oats (0.1-0.4 mg atrazine kg^{-1}) and soybeans (0.062-0.5 kg atrazine ha^{-1}). The relationships between atrazine bioactivity and certain soil properties could conceivably have been different at the much higher atrazine rates used in the grain sorghum study, but the order of importance for the above-mentioned five soil characteristics was found to be similar to those reported for the other test species.

The characteristics of the total of 56 soils used by Nel & Reinhardt (1984), Ehlers *et al.* (1987, 1988), and Nel *et al.* (1988) covered a wide spectrum with total clay ranging from 4 to 55%, organic matter 0.08 to 1.6% C (with only seven above 1% C), CEC 1.3 to 59 cmol(+) kg^{-1}, P-reversion 5 to 199 mg P kg^{-1}, and soil pH 4.2 to 7.9. These

soils were from various soil forms, the predominant clays being kaolinite (in about 53% of soils) and montmorillonite (about 21% of soils). In the remainder, these two clay minerals were represented in fairly equal proportions. According to Harrison *et al.* (1976) and Smit *et al.* (1981) the relationship between atrazine bioactivity and clay percentage in predominantly kaolinitic soils is relatively weak. In the present study, kaolinite predominated in all but the two Warmbad soils where montmorillonite was the main clay mineral component (Table 22).

Table 23 Simple correlation coefficients (r) and r^2 values to describe the relationships between atrazine bioactivity and selected soil properties

Variable in model	r	r^2
% Organic C	-0.71*	0.51**a**
CEC	-0.60*	0.36**a**
% Clay	-0.62*	0.38**a**
pH(H_2O)	-0.10	0.01**b**
P-reversion	+0.74*	0.55**a**

Coefficient of determination (r^2.100) = % variation in bioactivity explained by variable in model.
*Significant at P=0.05.
[a,b]Values followed by the same letter do not differ significantly at P=0.05.

Since recommendations for the application of atrazine in South Africa are currently based solely on total clay in the soil, the present findings and those of Nel & Reinhardt (1984), Ehlers *et al.* (1987, 1988) and Nel *et al.* (1988) pointed to a need for additional criteria on which to base atrazine rate recommendations.

In studies conducted over many years at the University of Pretoria (Smit *et al.*, 1981; Ehlers *et al.*, 1987, 1988; Nel *et al.*, 1988), combinations of P-reversion, % C and % clay in multiple regression equations always predicted atrazine bioactivity better than any one of these three soil properties alone. From data of the field and glasshouse studies mentioned, Nel, Smit & Reinhardt (1989) derived a formula for calculating atrazine application rates in maize. The formula is basically a multiple regression equation with % clay, % organic carbon (C) and P-reversion the independent variables, and atrazine rate the dependent variable. According to the proposed formula, atrazine dosage for a particular soil can be determined as follows:

$$\textit{kg atrazine } ha^{-1} = 1.0 + 0.03(\textit{clay \%}) + 1.0(\textit{\% C}) - 0.005(\textit{P-reversion mg } kg^{-1})$$

It was proposed that this formula be added to application recommendations which appear on atrazine product labels (Nel *et al.*, 1989).

Results presented in this chapter have been published (Reinhardt, Ehlers & Nel, 1990).