

SECTION B - PERSISTENCE STUDIES

CHAPTER 5

RESIDUAL BIOACTIVITY OF ATRAZINE AS AFFECTED BY CERTAIN SOIL PROPERTIES: FIELD STUDY

Introduction

Despite increased public concern about the presence of residues of persistent pesticides in the environment, the economic state of agriculture in South Africa is bound to dictate that atrazine remains an essential component of many crop production systems. Atrazine is one of the cheapest and most effective herbicides available. The time for which this herbicide persists in soil is of particular importance as this has already been shown to have serious implications for the safety of sensitive following crops both locally and overseas (Eagle, 1978; Caverley, 1983; Gottesbüren, Pestemer, Wang, Wischnewsky & Zhao, 1991).

In South Africa, the persistence of atrazine under field conditions is often longer than 12 months, which may seriously affect rotational crops. It is important that crop producers know if there are any limitations or restrictions in the sequence of crops that can be grown after using a persistent herbicide. Thus considerable information concerning crop sensitivity and herbicide persistence is required (Walker, 1987).

Bioactivity of herbicides at any stage after application to soil is closely associated with adsorption and degradation processes. In addition to the large number of edaphic factors, climatological conditions play a determining role in the eventual bioactivity of soil-applied herbicides (Walker & Barnes, 1981). Factors that cause degradation of atrazine are important in neutralizing residual phytotoxic effects on rotational crops exhibiting low tolerances to the herbicide.

Since the persistence of atrazine over long periods has not been researched in this country, a series of field trials were conducted to compare the persistence of the herbicide in different soils. The aim was to determine relationships between the bioactivity of atrazine and selected soil properties at certain time intervals (maximum one year) after atrazine application in the field.

Materials & Methods

The initial bioactivity of atrazine, which was investigated in ten field trials, was reported in Chapter 4. In the present study, atrazine persistence was monitored on seven of those trial sites, six and twelve months after herbicide application. The original plots were reseeded six months (182 days) and again twelve months (365 days) after the initial planting on day 0. The position of plant rows were offset 250 mm in subsequent plantings to avoid planting directly on previous rows. This was done to minimise the already small effect that uptake by previous plants would have had on the concentration of herbicide residues in the soil. Procedures for establishing and maintaining the test species were similar to those described in the previous chapter.

Atrazine bioactivity was assessed by measuring dry mass of shoots, 35 days after each planting, in five randomly distributed 2 m rows per nett plot (4.4 x 8 m). Percent damage was calculated as the percentage reduction in shoot dry mass compared to the unsprayed controls. Analyses of variance and regression analyses were performed. Atrazine bioactivity was correlated with selected soil properties. Simple correlation coefficients were determined across herbicide levels. Separate regression analyses were also performed at individual rates to ascertain whether the order of importance of relationships was rate-dependent. The significance of differences between r^2 values were determined through pairwise comparisons between these values according to the procedure of Bonferroni (Krishnaiah, 1984). The limited number of soils employed in the study precluded the determination of multiple correlation coefficients (R values) for models containing more than one soil variable.

Results & Discussion

Bioactivity after 182 days

Results for the reduction in growth that was caused by five atrazine rates at seven localities in bioassays initiated 182 days after atrazine application appear in Figure 4. The Atrazine rate x Locality interaction was significant. In the five soils where bioactivity was clearly discernable, activity was still positively related to the atrazine rates applied six months previously. Bioactivity caused by residues of the 0.25 and 0.5 kg atrazine ha⁻¹ rates applied six months earlier was significantly lower in both the Bapsfontein A and Ermelo soils compared with the other soils. Bioactivity induced by those two herbicide rates was significantly lower at Bapsfontein A than at Bapsfontein B after six months (Figure 4), despite an insignificant difference in initial activity

(Figure 3, Chapter 4). Differences in the organic matter content and pH of these two soils might explain the difference in atrazine persistence on these trial sites which were only 50 m apart. The organic matter content of Bapsfontein A soil (1.12% C) was higher than that of Bapsfontein B (0.76% C), while the pH of the former soil (pH 5.6) was lower than that of the latter (pH 6.4). Anderson *et al.* (1980) states that availability of atrazine for uptake by plants is negatively correlated with the organic matter content of soil. They also established that the persistence of the herbicide increases by a constant time period for every unit increase in the soil pH. It is unlikely that climatic factors were involved in the variation in atrazine persistence between the Bapsfontein A and B sites because of their proximity to one another.

The purported roles of organic matter and soil pH suggested above are supported by similar atrazine persistence in the Warmbad A and B soils (Figure 4). These soils had similar organic matter content and pH characteristics (Table 22) and were only about 100 m apart.

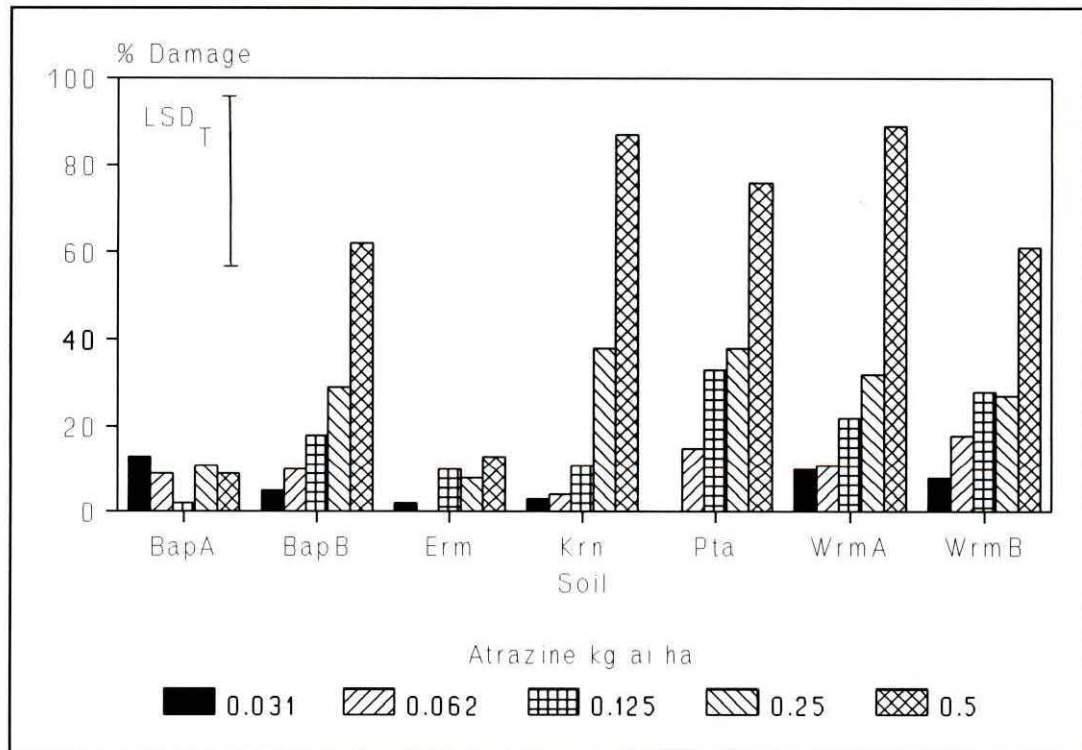


Figure 4 Percent damage to oats (% reduction in shoot dry matter yield) caused by atrazine at seven localities, 182 days after application (ANOVA in Table 23A; data in Table 3B)

Correlation coefficients to describe the relationships between atrazine bioactivity, 182 days after application, and the soil properties appear in Table 24. The relative importance of the soil properties on the prediction of bioactivity was as follows:

% C > pH > P-reversion > CEC > total clay %. Organic matter content gave the best prediction of bioactivity ($r = -0.59$). Whereas six months previously soil pH was only weakly associated with bioactivity, it was now ranked second to % C, with an r value of $+0.49$. Clay content ($r = +0.14$) was now the poorest predictor of atrazine bioactivity (Table 24).

The above-mentioned order of importance of relationships was found at the three highest initial atrazine rates, namely 0.125, 0.25 and 0.5 kg ha⁻¹. The orders of importance at 0.031 and 0.062 kg atrazine ha⁻¹ differed from this one and also from each other. This inconsistency was most likely due to the low residual herbicide activity at the two lowest atrazine rates (Figure 4).

A negative correlation between organic matter content and atrazine bioactivity has been found by many researchers, *inter alia* by Talbert & Fletchall (1965), Weber *et al.* (1969), and Anderson *et al.* (1980). The role of P-reversion is not as well documented, but this soil variable has been shown in the previous chapter and by Smit *et al.* (1980, 1981) and Ehlers *et al.* (1987, 1988) to be positively correlated with atrazine bioactivity.

The relatively strong positive relationship between pH and residual atrazine bioactivity suggests that phytotoxic residues were more readily available for uptake by plants at high compared to low soil pH levels. The stronger relationship found between soil pH and bioactivity in this study than in previous work (Chapter 4; Ehlers *et al.*, 1987, 1988) suggests another role for soil pH apart from its effect on adsorption, namely that soil pH also determines the rate of hydrolysis of the compound. The adsorption of various triazines has been shown to decrease as the soil pH increased (Colbert *et al.*, 1975; Harris & Hurle, 1979; Weber & Whitacre, 1982; Appleby, 1985). This would explain the positive correlations found between pH and atrazine bioactivity. Also, chemical hydrolysis of atrazine to inactive hydroxyatrazine occurs more readily at low pH levels than under high pH conditions (Armstrong *et al.*, 1967; Gamble & Khan,

1985). This implies that at high pH levels, atrazine molecules, although perhaps not strongly held on colloids, would be afforded protection against hydrolysis.

Granted that hydrolysis is a major route for the dissipation of atrazine, and that soil pH governs the rate of hydrolysis, this soil property can be expected to be a more important predictor of the persistence than the short-term bioactivity of the herbicide. Through lack of enough levels for the time factor, the present study was not ideal for assessing the importance of soil variables in the prediction of atrazine persistence. The approach followed in Chapter 9 was specifically aimed at linking degradation rates to selected soil properties.

Table 24 Simple correlation coefficients (r) and r^2 values to describe the relationships between atrazine bioactivity and selected soil properties 182 and 365 days after application

Variable in model	Day 182		Day 365	
	r	r^2	r	r^2
% Organic C	-0.59*	0.35a	+0.07	0.01a
CEC	+0.19	0.03b	-0.18	0.03a
% Clay	+0.14	0.02c	+0.29	0.08a
pH(H ₂ O)	+0.43*	0.19ab	-0.16	0.02a
P-reversion	+0.37*	0.14ab	-0.27	0.07a

Coefficient of determination ($r^2 \cdot 100$) = % 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 $P=0.05$.

Bioactivity after 365 days

The results are illustrated in Figure 5. Only the main effect for soil was significant. Atrazine, or biologically active residues of the herbicide, were only detected in the Bapsfontein B, Pretoria and Warmbad A soils. Dissipation of atrazine was virtually complete in the other soils. Although not significant, apparent stimulation of growth occurred in some of the soils where atrazine bioactivity was negligible (Figure 5). The phenomenon of growth stimulation by sub-lethal triazine herbicide concentrations is well documented (Ashton & Crafts, 1981).

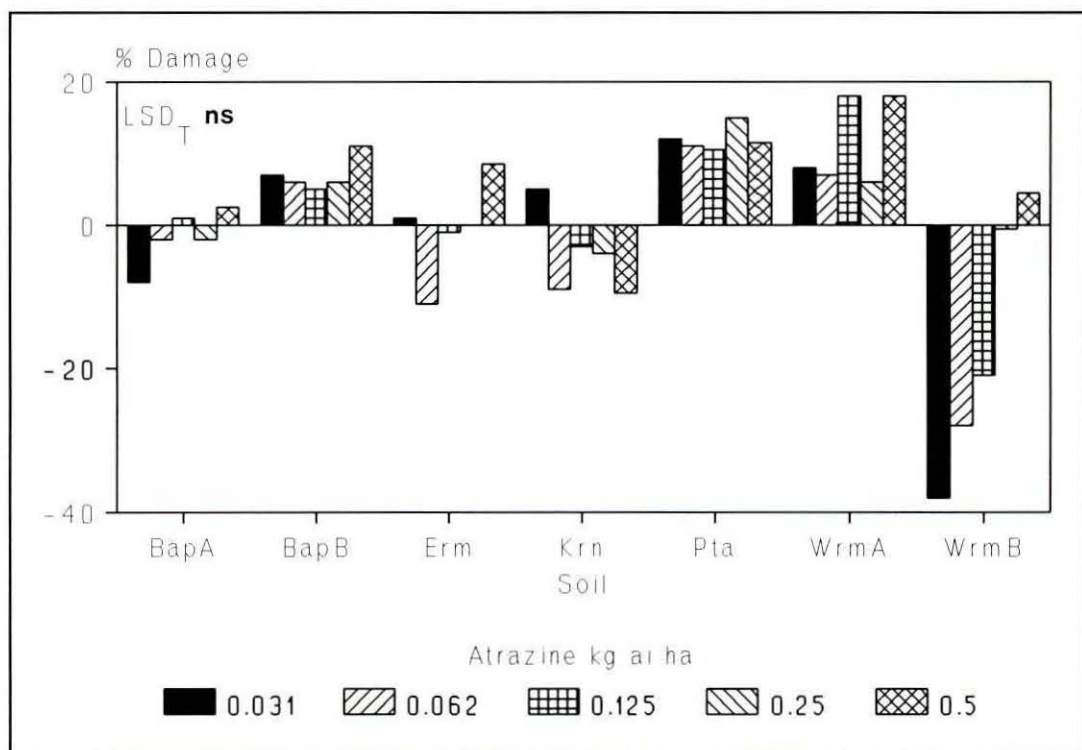


Figure 5 Percent damage to oats (% reduction in shoot dry matter yield) caused by atrazine at seven localities, 365 days after application (ANOVA in Table 24A; data appear in Table 4B)

The relationships between atrazine bioactivity and the soil properties were extremely poor at 365 days after herbicide application (Table 24). This is ascribed to the lack of atrazine bioactivity in most of the soils.

In conclusion, residues of atrazine applied at the relatively low rates used in this study persisted for at least six months in most of the soils tested and up to twelve months in a few soils. Persistence at two localities was found to vary over relatively short distances. This implies that persistence was more closely linked to soil characteristics than to climatic factors. Recropping periods that are specified for follow-up crops do not distinguish between soil types. Results presented above suggest that recropping periods could be refined. It is envisaged that recropping periods might be either shortened or extended, depending on whether the herbicide dissipation rate was high or low. The applicability of the waiting period that is specified for two atrazine-sensitive crops commonly grown in rotation with maize was assessed in work that is reported in the next chapter.

The work reported in this chapter has been published (Reinhardt et al., 1990).