

## Atrazine persistence in some South African soils

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### Summary

Atrazine application in maize restricts recropping options for crops which are susceptible to the herbicide. Extremes in soils and weather suggest a modelling approach for predicting atrazine persistence with the view to refine current recrop intervals. Field and greenhouse experiments were conducted, firstly to test the validity of the current recropping periods recommended for certain crops, and secondly, to illustrate that soil factors could be important predictors of atrazine persistence in soil. Results indicate that recropping intervals could be refined by considering differences in crop tolerance towards atrazine, and by taking into account the varying degradation rate of atrazine from one soil to another. It is suggested that a modelling approach is required for prediction of atrazine persistence under South African conditions.

### Introduction

In South Africa, atrazine is the most widely used herbicide in maize (*Zea mays* L.), which is cropped on more than three million hectares annually. Carry-over of atrazine occasionally causes injury to susceptible crops grown in rotation with maize. Problems of excessive persistence (1) and contamination of water (4) are encountered worldwide.

In order to manage the use of atrazine in a way that acceptably limits the risks of damage to follow-up crops, and residues reaching surface and groundwater, an understanding of factors which govern its availability for uptake by plants, crop sensitivity and the active lifetime of the compound in soil is required. The authors have shown that certain soil properties are correlated with atrazine persistence (3). The aims of the present study were: (a) to evaluate the applicability of current waiting periods recommended for growing dry beans (*Phaseolus vulgaris* L.) and sunflower (*Helianthus annuus* L.) subsequent to atrazine application in maize (*Zea mays* L.), (b) to determine the sensitivity of these crops to atrazine on diverse soils, and (c) to illustrate the diversity in atrazine half-lives in local soils.

### Material and Methods

**Field trials:** Eight experiments were conducted at six sites. Atrazine was applied in maize, and 12 months (one season) later dry beans (cv. Teebus) and sunflower (cv. S0222) were seeded on the same plots. The two follow-up crops were subsequently only grown again (24 months after treatment) at localities where significant yield reductions occurred the previous season. Herbicide rates included the recommended rate for a particular site, and both higher and lower rates than the one prescribed. Plant height, plant density and seed yield of the two follow-up crops were determined and expressed as percentage damage relative to untreated controls. Weeds were eliminated by hand-hoeing.

**Greenhouse exp. A:** Ten soils and ten atrazine rates were employed in separate bioassays with dry beans (cv. Teebus) and sunflower (cv. S0222). Atrazine rates ranged from 0.025 to 0.5 mg a.i. kg<sup>-1</sup>. Experimental conditions were standardized, i.e. the water content of soil was maintained at 75 % of field capacity, the day/night temperature regime was 27/17 °C, a 12 h day/12 h night period, and a 21 day growth period from seeding until harvesting of seedling top growth. Data were expressed as percentage damage.

**Greenhouse exp. B:** Three atrazine rates (0.2, 0.4 and 0.6 mg a.i. kg<sup>-1</sup>) were applied in a loamy sand, sandy clay loam and clay soil. Pots were lined

with polyethelene bags to prevent drainage. Soils were incubated in the dark under the conditions described for experiment A. At specific intervals (0, 15, 30, 60 and 120 days) after atrazine application, pots were removed from the incubator and bioassayed with oats (*Avena sativa* L. cv. SWK001) in a greenhouse under conditions described above. Parallel bioassays were conducted on days 0, 15, 30, 60 and 120 to obtain dose-response curves (% reduction in dry matter yield against atrazine concentration) with which measured residual activities (% growth reduction) were transformed into herbicide concentrations. Atrazine half-lives were estimated for the soils.

### Results and Discussion

**Field trials:** Twelve months after application of the recommended atrazine rate in maize, residues caused total failure of both follow-up crops only on the montmorillonite soil - 35% clay, 0.4 %C, pH(H<sub>2</sub>O)=7.8 (Table 1). On all other soils (kaolinite clay type) the reduction in yield of dry beans was negligible, whilst in the case of sunflower significant yield reductions occurred at all but two of the eight trial sites. Data in Table 1 indicate that dry beans cv. Teebus could have been cropped with low risk 12 months after application of atrazine in maize, whilst the growing of sunflower constituted a much higher risk in most of the soils. Therefore the current waiting period of 18 months recommended for both crops was justified for sunflower only, but then only on the kaolinitic soils. Results show that a waiting period in excess of 24 months would have been required for the montmorillonite soil. The relatively high pH and high adsorptive capacity of this soil probably slowed the dissipation rate of atrazine.

**Table 1. Yield reduction (%) of dry beans (cv. Teebus) and sunflower (cv. SO222) seeded 12 and 24 months after application of the recommended atrazine rate in maize at eight localities.**

Crop	Time (mo.)	Clay % % C	23	37	29	53	25	41	17	35
			.4	.8	.7	2	.4	.6	.5	.4
Dry beans	12		3	1	0	0	0	0	0	<u>100</u>
	24		-	0	-	-	-	-	-	<u>38</u>
Sunflower	12		<u>21</u>	<u>17</u>	<u>14</u>	2	<u>16</u>	4	<u>20</u>	<u>100</u>
	24		0	-	0	-	0	-	0	<u>29</u>

Underlined values: significant (P=0.05) yield reduction compared to control.

**Table 2. Relative sensitivity of dry beans (cv. Teebus) and sunflower (cv. SO222) towards atrazine as demonstrated by the % reduction in dry matter yield of seedlings that was caused by two selected (low and high) herbicide levels in ten soils.**

Atrazine (mg kg <sup>-1</sup> )	Test plant	Clay % % C	37	16	4	53	16	31	50	8	25	35
			.8	.3	.3	2	.8	3	1	.1	.4	.4
0.05	Dry beans		-11	5	2	-7	9	-3	0	52	-5	9
	Sunflower		5	17	20	-10	13	-8	-6	84	4	17
0.40	Dry beans		61	68	67	8	46	-6	1	69	66	61
	Sunflower		84	87	89	27	82	-3	43	89	84	86

**Greenhouse exp. A:** The relative susceptibility of dry beans cv. Teebus and sunflower cv. SO222 was confirmed under controlled conditions. Results for two of the ten atrazine rates used show that the dry bean cultivar was generally more resistant to atrazine than sunflower cv. SO222 (Table 2). For all but one of the soils used, this trend was reflected by regression equations that describe the relationships between atrazine rate and growth inhibition of seedlings. On one soil, atrazine elicited virtually no response from the test plants, probably due to the inactivation of the herbicide in this soil with

a relatively high organic matter content.

Greenhouse exp. B: Insignificant differences in rates of loss between applications of 0.2, 0.4 and 0.6 mg kg<sup>-1</sup> in the sandy loam and sandy clay loam soils, and between doses of 0.2 and 0.4 mg kg<sup>-1</sup> in the clay soil, suggest that the first-order rate law was followed in these instances. With first-order kinetics, rate constants should be independent of initial concentrations (2). However, the disproportionately slow degradation rate for 0.6 mg kg<sup>-1</sup> atrazine in the clay (montmorillonite) soil did not support this view. In the latter case it is doubtful that the reduced degradation rate at the high initial atrazine concentration could be ascribed to a limitation in the number of reaction sites in the soil. On the same soil, excessive persistence of atrazine caused the yield of dry beans and sunflower to be significantly reduced 24 months after application of 2.4 kg a.i. ha<sup>-1</sup> herbicide (Table 1). Except for the 0.6 mg kg<sup>-1</sup> atrazine rate in the clay soil, the calculated half-lives for atrazine in a particular soil were essentially the same for all three rates used, i.e. about 60 days in the loamy sand soil, about 80 days in the sandy clay loam soil, and about 120 days in the clay soil (Table 3).

**Table 3. Rates of degradation for 0.4 mg kg<sup>-1</sup> atrazine applied in three soils - based on calculations made by means of bioassays.**

Days after treatment	Atrazine remaining (% of day 0 concentration)			
	Soil clay % :	16	25	55
	Soil % C :	0.36	0.42	0.77
15		91	94	93
30		87	87	93
60		55	66	79
120		1	10	48

Bioassays proved useful for calculating atrazine concentrations in soil after application of 0.2 and 0.4 mg kg<sup>-1</sup> on day zero. The values obtained were within 0.02-0.03 mg kg<sup>-1</sup> of the rates intended. However, the 0.6 mg kg<sup>-1</sup> rate was underestimated with 0.1-0.15 mg kg<sup>-1</sup>. This was due to the relatively high percentage damage recorded at this herbicide rate, thus causing atrazine concentration to be underestimated at the leveled off upper limit of the dose-response curves.

### Conclusions

Information on the relative sensitivity of crop species (and probably even cultivars) and the half-lives of atrazine in different soils should increase the reliability of existing computer simulation models that could be used for prediction of atrazine persistence in South African soils.

Bioassays can give quite accurate projections of the amount of atrazine in a soil. However, the utility of this technique is dependent upon the shape of dose-response curves and the amount of herbicide in the soil under investigation.

### References

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