# CHAPTER 6

# RESIDUAL EFFECT OF ATRAZINE ON FIELD-GROWN DRY BEANS AND SUNFLOWER

## Introduction

In the previous field study it was shown that organic matter content, soil pH and P-reversion accounted for 35%, 19% and 14%, respectively, of the variation in atrazine bioactivity measured six months after its application. Also, it was found that the dissipation of atrazine varied considerably from soil to soil and from one locality to another. The persistence of a compound is bound to be variable because it is not an intrinsic characteristic of a chemical, and soil and climatic factors greatly influence the processes of herbicide dissipation and the availability of the herbicide to the following crop (Hurle & Walker, 1980; Duffy, 1991).

Reports by Haigh & Ferris (1991) and Wood *et al.* (1991) attest to the universality of problems caused by excessive persistence of atrazine. In South Africa, carry-over of atrazine occasionally causes injury to susceptible crops grown in rotation with maize. To minimize the possibility of injury to rotational crops, recropping intervals with wide safety margins are specified on the product label. However, this restricts the choice of follow-up crops. In addition, fixed recropping periods fail to reflect the wide extremes in soils and climatic conditions in South Africa. Lack of flexibility in recropping options are exacerbated when a response to changing market trends or forced recropping is demanded. Also, despite long recropping intervals, injury to susceptible crops does occur. Ideally labels should reflect local differences with the view to vary the recropping interval on the basis of soil and climatic factors which govern the dissipation of atrazine.

The aims of the present study were to evaluate the applicability of current waiting periods by growing dry beans and sunflower subsequent to atrazine application in maize, and to compare the sensitivity of these crops to atrazine on diverse soils.

**Materials and Methods**

Trials were conducted under dry land conditions. Eight of a total of eleven experiments were successfully completed at six sites. Certain characteristics of the soils at these sites appear in Table 25. Atrazine was applied pre-emergence in maize during the 1987/88 growing season. Dry beans (cv Teebus) and sunflower (cv SO 222) were first seeded on the original plots during the 1988/89 season. The two follow-up crops were subsequently only grown again during the 1989/90 season (i.e. 24 months after treatment) at localities where significant yield reductions occurred the previous season.

Atrazine was applied at each site at the rate recommended for use in maize, and at both higher and lower rates than the one prescribed. Herbicide rate increments were 0.2 kg $ha^{-1}$ for light soils, 0.3 kg $ha^{-1}$ for medium soils, and 0.4 kg $ha^{-1}$ for heavy soils. Six atrazine rates were used in each experiment. The atrazine rates applied at each site appear in Table 26.

**Table 25** Certain characteristics of soils at different localities

| Locality | Clay % | Organic C % | pH $H_2O$ | CEC cmol(+) $kg^{-1}$ | P-reversion mg P $kg^{-1}$ | Clay mineral content (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Kaolinite | Montmorillonite | Illite |
| Bapsfontein A | 37 | 0.84 | 5.8 | 7.7 | 35 | 70 | 15 | 10 |
| Bapsfontein B | 29 | 0.69 | 6.4 | 5.4 | 55 | 75 | 15 | 5 |
| Carletonville | 23 | 0.48 | 5.7 | 4.2 | 150 | 75 | 10 | 10 |
| Delmas | 17 | 0.57 | 7.2 | 3.9 | 75 | 83 | 15 | - |
| Kroonstad | 19 | 0.36 | 5.6 | 4.8 | 75 | 70 | 15 | 10 |
| Pretoria A | 25 | 0.42 | 6.4 | 4.6 | 105 | 70 | - | 15 |
| Pretoria B | 41 | 0.66 | 6.2 | 10.5 | 85 | 83 | 12 | - |
| Vryheid | 53 | 2.04 | 5.5 | 15.8 | 25 | 80 | 5 | 5 |
| Warmbad | 35 | 0.50 | 7.8 | 26.6 | 69 | 10 | 80 | - |

Weed control efficacy was evaluated as part of a study (not reported on in detail here), which was conducted to refine atrazine application rates in maize (Nel *et al.*, 1989). In that study, maize yield on particular sites did not differ significantly between plots treated with different atrazine rates. The maize cultivar grown at each site and mean grain yield on plots treated with atrazine were the following: Carletonville - cv PNR 6549: 4.5 ton $ha^{-1}$; Delmas - PPPxK64R: 3.8 ton $ha^{-1}$; Pretoria A - cv PNR 6528: 5.3 tons $ha^{-1}$; Pretoria B - cv PNR 6528: 6.0 ton $ha^{-1}$; Bapsfontein A - cv PNR 6528: 5.1 ton $ha^{-1}$; Bapsfontein B - cv PNR 6528: 5.3 ton $ha^{-1}$; Kroonstad -cv PNR 6528: 4 ton $ha^{-1}$; Vryheid - cv PNR 6528: 4.7 ton $ha^{-1}$; Warmbad - cv PNR 542: 5.6 ton $ha^{-1}$.

Except at the Vryheid site where *Digitaria sanguinalis* (L.) Scop. (resistant to atrazine) was the main weed species, weed spectra at the other trial sites were dominated by various broadleaf weeds and the grass species *Eleusine indica* L. Gaertn. which were all adequately controlled (90-100% control) by the recommended atrazine rate applied at particular sites. A field sprayer which delivered 200 L $ha^{-1}$ at 300 kPa was used to apply atrazine. A 2.7 m spray boom with five flat fan nozzles was used on 5.4x7.0 m plots. Treatments were replicated five times in a randomized block design. Untreated control strips of 4 m width were situated between replicates. There were no weed control measures in maize apart from that provided by the application of atrazine. In the recropping (persistence) experiments, shallow tillage (100 mm) with a hand-directed rotovator between rows and hand-hoeing within rows were used to eliminate interference from weeds in all plots.

Dry beans and sunflower were planted in alternate rows on the same plots. Seeding densities of approximately 100 000 and 37 000 plants $ha^{-1}$, in rows 900 mm apart, were used at each planting for dry beans and sunflower, respectively. At the second planting of these crops (i.e. during 1989/90), positions of plant rows were shifted 250 mm (the maximum allowable distance within the confines of plots treated with atrazine the previous season) to avoid seeding on previous rows. Broadcast application of fertilizer [ 300 kg 3:2:1 (25%) $ha^{-1}$] was made for each experiment, prior to seedbed preparation. A side-dressing application of N, equivalent to 50 kg N $ha^{-1}$, was made on individual plots about 6-8 weeks after planting.

Test crop response to atrazine residues was evaluated through plant counts and seed yield in two randomly selected 2 m rows per net plot (4.4x5 m). These data were also expressed as percentage damage relative to untreated controls in order to compare atrazine persistence between localities. The only reasonable comparison of persistence between localities can be made at the atrazine rates which are recommended for use in maize. The other rates were not deliberately chosen for the present persistence study, but rather to assess weed control efficacy in that crop in a preceding study which was aimed at refining atrazine application rates in maize.

**Table 26** Atrazine rates applied in maize at different localities

| Locality | Atrazine rate (kg ai $ha^{-1}$)[a] | | | | | |
|---|---|---|---|---|---|---|
| Bapsfontein A | 2.0 | 2.4 | 2.8 | 3.2 | 3.6 | 4.0 |
| Bapsfontein B | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 |
| Carletonville | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 |
| Delmas | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 |
| Kroonstad | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 |
| Pretoria A | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 |
| Pretoria B | 1.8 | 2.2 | 2.6 | 3.0 | 3.4 | 3.8 |
| Vryheid | 2.6 | 3.0 | 3.4 | 3.8 | 4.2 | 4.6 |
| Warmbad | 1.8 | 2.1 | 2.4 | 2.7 | 3.0 | 3.3 |

[a]Underlined values are the recommended atrazine rates for particular soils.

## Results and Discussion

The persistence of recommended amounts of atrazine at various trial sites are shown by the data for percent reduction in yield of dry beans (Table 27) and sunflower (Table 28) recorded 12 and 24 months after treatment (m.a.t.). The original yield and stand data that were recorded for both test crops, at all the herbicide rates initially applied in maize, appear in Appendix B in the following tables: Table 5B (dry beans: 12 m.a.t. - yield data), Table 6B (dry beans: 12 m.a.t. - stand data), Table 7B (sunflower: 12 m.a.t. - yield data), Table 8B (sunflower: 12 m.a.t. - stand data), Table 9B (dry beans: 24 m.a.t. - yield and stand data), Table 10B (sunflower: 24 m.a.t. - yield data), and Table 11B (sunflower: 24 m.a.t. - stand data).

The effect of locality on the reduction in yield caused by residues of recommended atrazine rates that were applied in maize was significant for sunflower only, at both 12 m.a.t. and 24 m.a.t. (Tables 27 & 28). Except at the Warmbad site, the reduction in dry bean yield 12 m.a.t. was less than 10% (Table 27). In contrast, sunflower suffered considerably more damage in terms of yield than dry beans at most of the trial sites at the same stage after atrazine application. This greater susceptibility of sunflower compared to dry beans was again found at the subsequent planting 24 m.a.t. (Table 28). These results confirm the difference in susceptibility to atrazine that was established for the same dry bean and sunflower cultivars in an experiment reported in Chapter 3.

**Table 27** Percent reduction in seed yield of dry beans and sunflower on plots treated with recommended atrazine rates 12 months previously (ANOVA for sunflower data in Table 25A[1])

| | Yield reduction (%) | |
|---|---|---|
| Soil | Dry beans | Sunflower |
| Bapsfontein A | 2 | 17 |
| Bapsfontein B | 2 | 15 |
| Carletonville | 7 | 21 |
| Delmas | 6 | 16 |
| Krooonstad | 3 | -[a] |
| Pretoria A | 1 | 13 |
| Pretoria B | 1 | -2 |
| Vryheid | 9 | 1 |
| Warmbad | 100[b] | 100[b] |
| $LSD_T$ (P=0.05) | ns | 10 |

[1]ANOVA not conducted for dry beans due to insignificant percentages damage in yield.
[a]Sunflower ignored at Kroonstad due to unsatisfactory seedling emergence in all plots.
[b]Data for Warmbad were not analyzed statistically. The LSD-value given here does not apply to Warmbad data.

**Table 28** Percent reduction in seed yield of dry beans and sunflower on plots treated with the recommended atrazine rates 24 months previously (ANOVA for sunflower data appears in Table 26A[1])

| | Yield reduction (%) | |
|---|---|---|
| Soil | Dry beans | Sunflower |
| Bapsfontein a | - | 0 |
| Bapsfontein B | - | 1 |
| Carletonville | - | 1 |
| Delmas | - | 1 |
| Pretoria A | - | -1 |
| Warmbad | 38[1] | 29 |
| $LSD_T$ (P=0.05) | - | 5 |

[1]Data for dry beans were analyzed for the Warmbad site only (Data in Table 9B; ANOVA in Table 31A). Trials conducted only where more than 10% damage was recorded the previous season. Dash (-) denotes that a trial was not conducted.

The persistence of residues of atrazine rates recommended in maize varied considerably between localities (Tables 27 & 28). Dry bean yield was not reduced significantly by the recommended atrazine rates, 12 m.a.t. on soils in which the kaolinite clay mineral predominated (Table 27). At that stage, however, herbicide residues had reduced sunflower yield by between 13 and 21% at five of the seven trial sites. Damage in terms of yield was negligible only at Pretoria B and Vryheid. Although a lower recommended rate of atrazine was applied at the Pretoria A site (2 kg ai $ha^{-1}$) than the rate prescribed for Pretoria B (3 kg ai $ha^{-1}$), residues caused significantly more damage at the former site (Table 27). As the two sites are only 200 m apart, soil factors may have been more important than climatic factors in the determination of atrazine persistence at the Pretoria locality. This trend was not observed at Bapsfontein where the two trials were about 50 m apart, possibly because the recommended atrazine rates and soil properties at these sites differed less than at the two sites of the Pretoria locality.

Atrazine persisted longest in the Warmbad soil (80% montmorillonite clay; pH 7.8). Twelve months after application of the recommended atrazine rate in maize, residues of all atrazine rates applied the previous season caused total failure of both follow-up crops on this soil (Table 27). Most dry bean and sunflower seedlings died within two weeks after emergence. Dry bean and sunflower plants of the second planting (24 m.a.t.) reached maturity on the Warmbad soil, but with substantial yield loss (Table 28). Residual activity in this soil was no longer detectable in subsequent bioassays conducted in a glasshouse 36 months after atrazine application. Soil samples taken from two soil layers (0-200 mm and 200-400 mm) in plots initially treated with the maximum atrazine rate (3.3 kg ai $ha^{-1}$) were bioassayed.

Results indicate that the dry bean cultivar Teebus could have been cropped with relatively low risk 12 months after application of atrazine on most of the soils (except at Warmbad), whilst the growing of sunflower constituted a higher risk in most of the soils (Table 27). Therefore the current waiting period of 18 months recommended for both crops was justified for sunflower only, but then only on the kaolinitic soils and not on the montmorillonite soil. Recropping intervals for both crops should be longer than 24 months for soils in which the rate of atrazine degradation is restricted, e.g. in montmorillonite soils with a neutral pH. This finding is in contrast with the computer simulation of the persistence of atrazine that was reported by Walker (1991) for the same Warmbad soil. Walker (1991) used the model of Walker & Barnes (1981), with weather and soil data inputs which were collected during the first 12 months at the Warmbad trial site, to predict that phytotoxic atrazine residues would persist for 8 to 12 months in this soil.

According to Weber (1972), the montmorillonite clay mineral has a greater propensity for binding atrazine than kaolinite. Walker +23 others, (1983) found for simazine, as Allen & Walker (1983) did for metribuzin, that increased adsorption in heavier soils presumedly protected the compounds from degradation. In contrast, apparent adsorption-catalyzed degradation of atrazine and other chlorotriazines have been reported by Armstrong & Chesters (1968) and Hance (1979). Probably the most plausible explanations for the extended persistence of atrazine in the montmorillonite soil is the expected high degree of chemical stability of the compound in this relatively high pH soil (Armstrong *et al.*, 1967), as well as limited leaching in this soil type.

It can be expected that different crops and even cultivars are bound to respond differently to atrazine residues in soil. Mennega *et al.* (1990a,b) found that sunflower was less tolerant than dry beans to atrazine. They reported differences in the tolerance of local dry bean lines and cultivars, amongst them cv Teebus, to atrazine. In tests with ten sunflower cultivars including cv S0 222, at atrazine rates four times lower than those used in the tests with dry beans, Mennega *et al.* (1990a) demonstrated equally high sensitivity amongst cultivars.

Lack of day-to-day, on-site rainfall data, and no information on how it affected the leaching behaviour of atrazine in a particular soil, precludes speculation about the influence that rainfall had on atrazine persistence. Rainfall and temperatures recorded at the nearest weather station to each locality, from after atrazine application in maize until dry beans and sunflower were first established, appear in Tables 12B-18B (Appendix B). Although the total monthly rainfall at some localities was apparently either lower or higher than the long-term normal for certain months, the total amount of rain recorded for approximately one year after atrazine application did not deviate much from the long-term average. Mean daily maximum and minimum temperatures showed even less divergence from the long-term averages.

Results demonstrate that the single recropping interval (18 months) specified for both dry beans and sunflower are not based on the relative atrazine tolerance of these crops, at least not for the cultivars tested. Refinement of recropping intervals should at least be based on variation in soil characteristics known to influence atrazine persistence. Information on rainfall and temperatures that prevail after atrazine application would further increase the predictability of its persistence, provided the relationships between persistence and these weather factors are adequately defined. Computer simulation models that incorporate modules for the prediction of the responses of susceptible crops to atrazine residues, as well as routines which simulate herbicide dissipation, would probably be the best way to assess recropping risks. This topic is discussed in more detail in Chapter 9B. The effects of soil type, soil water content and temperature on the persistence of atrazine were demonstrated in a subsequent experiment.