CHAPTER 2

EFFECT OF PRE-EMERGENCE HERBICIDES ON THE GROWTH AND YIELD OF DRY BEAN CULTIVARS

Introduction

Not only does the interaction of herbicides with various environmental factors (physical, chemical and biological) impact on yield (Wood, Powell & Anderson, 1977) but the interaction with plant factors, of which genetic content is of major importance, may also influence yield negatively. Various mechanisms exist by means of which plants transform foreign compounds. These include oxidation reactions that result in aromatic ring- and alkyl hydroxylation, N-dealkylation, O-dealkylation and sulphoxidation, hydrolic reactions, deamination, and conjugation with carbohydrate residues (glycosidation) or with the tripeptide glutathione (Jensen, 1982; Shimabukuro *et al.*, 1982; Cole, 1983; Shimabukuro, 1985; Hathway, 1986; Cole *et al.*, 1987).

The acetanilides (e.g. dimethenamid, metazachlor, metolachlor) and their degradation products undergo conjugation with glutathione and / or glucose (Duke, 1985), whereas rapid metabolic degradation of the imidazolinones (e.g. imazethapyr) (Ashton & Monaco, 1991) and triazolopyrimidine sulfonamides (e.g. flumetsulam) (Chambers, 1997) may explain their differential tolerance.

Differences between dry bean cultivars with regard to herbicide tolerance have been shown by various researchers (De Beer, 1988; Mennega *et al.*, 1990; Wilson & Miller, 1991; Arnold *et al.*, 1993; Fouché, 1996; Urwin *et al.*, 1996). De Beer (1988) demonstrated the importance of environmental and genetic factors in the response of dry beans to alachlor and metolachlor. Cultivar Nuweveld was found to be less tolerant to alachlor and metolachlor than either Nep 2 or Kamberg. The tested cultivars were also less tolerant to alachlor than to metolachlor. Fouché (1996) reported that the small white cultivar Helderberg varied in tolerance to pre-emergence herbicides from tolerant to less tolerant in the order: dimethenamid > imazethapyr > metolachlor > metazachlor > flumetsulam + metolachlor.

Dimethenamid (Frontier® 900 EC), flumetsulam + metolachlor (Bateleur® 816 EC), imazethapyr (Hammer® 100 SL) and metazachlor (Pree® 400 EC) are pre-emergence herbicides used to control certain broadleaf weeds and grasses (Vermeulen *et al.*, 1998). Imazethapyr is also registered for post-emergence application. Metolachlor (Dual-S® 930 EC) is a pre-emergence herbicide registered for control of grasses in beans. Pree® 400 EC has since undergone a name change to Preecede® 400 EC and was withdrawn from the market in 1998.

The present study was conducted to evaluate the effects of these pre-emergence herbicides on the growth and yield of 10 South African dry bean cultivars. These cultivars are divided into eight seed types on the basis of size, colour and shape. Within each seed type there are cultivars that differ in agronomic adaptation, disease resistance and other properties (Liebenberg & Steenekamp, 1997). It is envisaged that the results of this study could be used to identify yield-reducing cultivar / herbicide combinations, thus adding another dimension to the selection of cultivars.

Materials and Methods

The tolerance of 10 dry bean cultivars to five pre-emergence herbicides was investigated in a field trial at the Grain Crops Institute of the Agriculture Research Council (ARC-GCI) in Potchefstroom (North West Province) during the 1996/97 growing season.

The trial was conducted on a clay loam soil (34 % clay) with a pH(H_2O) of 6.5, and the following macronutrient concentrations: P (23.7 mg kg^{-1}), K (122.0 mg kg^{-1}), Ca (1260.0 mg kg^{-1}) and Mg (385.0 mg kg^{-1}). Standard fertilizer [2:3:4 (30) + urea] was broadcast at a rate (60 kg ha^{-1}) based on the soil analysis. The bean cultivars chosen represented the commercially important bean types in South Africa at the time. They included the small white canning beans (Helderberg and Teebus), red-speckled sugar beans (Kranskop, Enseleni and Monati), Alubia bean (Cerrillos), yellow haricot bean (Katberg), carioca bean (Mkuzi) and yellow sugar bean (Majuba). The only available large white kidney bean cultivar, SSN1, was also used.

Seeds were hand-planted at a depth of 5.5 cm with an inter-row spacing of 91 cm and within-row spacing of 8 and 15 cm for *P. vulgaris* and *P. coccineus* respectively. The experimental design was a split-plot (main-plots = cultivars, sub-plots = herbicides) with three replicates. Each plot consisted of two rows of 2.5-m length. The herbicides were applied at two rates, i.e. registered and double the registered dosage (Table 2) and were sprayed diagonally across the rows with a CO_2 field sprayer which delivered 200 L of water per hectare at 2.5 kPa. Control plants were left untreated.

Sprinkler irrigation (25 mm) was applied immediately after herbicide application and was provided throughout the growing season (Table 1C in Appendix C). All plots were kept weed-free, by hand and implement, to eliminate weed interference.

The early effect of the herbicides on plant growth was measured 21 days after planting. Three plants of each treatment were harvested and their aboveground dry mass measured. Yield was eventually determined by harvesting two 1-m rows for each treatment. In addition, the 100-seed mass for each treatment was also determined using these samples. Data for seed yield and aboveground (top growth) dry mass were expressed as percentage of the corresponding controls (zero herbicide). Percentage data were subjected to statistical analysis for which standard analysis of variance (ANOVA) procedures were used. Means were compared at the 5% level of significance by using the least significant difference test of Tukey.

Table 2 Active ingredients, commercial names and registered dosages of herbicides used in the bean cultivar tolerance trial at Potchefstroom

Active ingredient (a.i.)	**A.I. Concentration ($g\ L^{-1}$)**	**Product**	**Registered dosage ($L\ ha^{-1}$)**
Dimethenamid	900	Frontier®	1.25
Flumetsulam + metolachlor	16 + 800	Bateleur®	1.90
Imazethapyr	100	Hammer®	0.50
Metazachlor	400	Pree®	1.50
Metolachlor	930	Dual®	2.00

Results and Discussion

Data for seed yield and aboveground dry mass are given in Table 3 and Table 4 respectively. Data for 100-seed mass (Table 3A of Appendix A) are not discussed in detail since this parameter did not provide more information on herbicide tolerance than did the other two parameters.

Seed yield. In the case of seed yield only the main effects were significant (P = 0.05) (Table 1B of Appendix B). The red-speckled sugar bean cultivars (Kranskop and Monati) and Alubia cultivar (Cerillos) were significantly less tolerant than the small white

(Helderberg and Teebus), yellow haricot (Katberg) and large white kidney (SSN1) bean cultivars (Table 3). The latter cultivar was the most tolerant. Mennega *et al.* (1990) showed that the large white kidney bean is the most tolerant dry bean cultivar to atrazine in South Africa while the small-seeded cultivars are the most susceptible. They ascribed these differences in tolerance to seed size. This seems not to have been the case in the results presented here since both the red-speckled sugar bean and Alubia cultivars have larger seed sizes than the small white, yellow haricot and yellow sugar cultivars.

The dry bean cultivars were significantly more tolerant to dimethenamid, imazethapyr or metazachlor than metolachlor or flumetsulam + metolachlor. This is in accordance with findings by Fouché (1996) who concluded that Helderberg is less tolerant to flumetsulam + metolachlor and metolachlor than dimethenamid or imazethapyr. As expected, the 2x-rate of herbicides caused an overall significant reduction in seed yield (Table 3).

Renner (1997) reported differences in tolerance towards dimethenamid of dry bean cultivars grown in Michigan (USA). Dark- and light-red kidney beans were most tolerant to dimethenamid. Wilson & Miller (1991) and Bauer *et al.* (1995) have also demonstrated differences in dry bean cultivar tolerance towards imazethapyr. Renner (1996) demonstrated differences in dry bean cultivar tolerance towards metolachlor. He concluded that metolachlor caused less injury to bean cultivars than dimethenamid. De

Beer (1988) also reported that South African dry bean cultivars varied in tolerance to alachlor and metolachlor. He concluded that the tested dry bean cultivars were less tolerant to alachlor than metolachlor at the recommended rates.

Table 3 Seed yield expressed as percentage of the control for ten dry bean cultivars exposed to five herbicides at both the recommended (1x) and 2x-rates on one soil (ANOVA in Table 1B of Appendix B)

Herbicides (a.i. g ha $^{-1}$)		Helderberg	Teebus	Kranskop	Enseleni	**Cultivar** Monati	Cerillos	Katberg	Mkuzi	Majuba	SSN1	**Mean (Herbicide)**
Dimethenamid												
1125		113.8	92.1	75.5	93.0	83.0	88.6	124.6	101.4	107.1	106.6	97.5
2250		99.3	89.9	70.3	100.6	99.2	68.5	134.0	99.5	91.8	110.6	
Flumetsulam + metolachlor												
1550		82.5	107.4	87.6	84.6	86.5	86.5	83.6	87.7	83.6	128.6	84.5
3100		80.9	100.8	84.2	79.1	61.4	77.9	73.3	48.2	66.9	99.1	
Imazethapyr												
50		119.7	98.1	91.8	102.2	89.7	104.3	132.1	108.5	110.2	116.1	101.8
100		94.0	92.7	71.0	98.9	101.2	98.1	101.0	100.7	80.2	124.0	
Metazachlor												
800		125.8	98.2	102.1	86.8	94.2	89.8	106.6	98.4	120.0	108.6	96.3
1600		92.3	90.0	83.0	73.9	84.0	80.0	103.5	100.3	84.5	103.8	
Metolachlor												
1860		99.0	88.0	92.5	106.4	82.4	90.2	109.1	96.9	105.0	90.8	91.7
3720		86.5	82.9	80.6	79.8	79.5	86.4	100.7	77.5	68.8	131.6	
Mean (Cultivars)		99.4	94.0	83.9	90.5	86.1	87.0	106.8	91.9	91.8	112.0	
Mean Rate	1	99.3										
Mean Rate	2	89.3										
LSD_T (P = 0.05)		Herbicide = 4.39		Rate = 3.25		Cultivar = 7.25						

Aboveground dry mass. For aboveground dry mass all the main effects, except herbicide rate, were significant (Table 2B of Appendix B). Except for the herbicide x cultivar interaction, the other interaction effects for this parameter were significant also. Variation in plant size between the cultivars would have contributed to the significance of the herbicide x rate x cultivar interaction, and therefore, percentage data are appropriate for discussion (Table 4).

For dimethenamid, aboveground DM was not significantly reduced for cultivars Helderberg, Monati, Majuba and SSN 1 (Table 4). Kranskop was the least and Monati the most tolerant to dimethenamid. This parameter was significantly reduced by flumetsulam + metolachlor for cultivars Kranskop and Katberg. Kranskop was again the least and Helderberg and SSN 1 the most tolerant to flumetsulam + metolachlor.

Imazethapyr caused no significant growth reductions. Kranskop was, however, the least and SSN 1 the most tolerant to imazethapyr. For metazachlor, aboveground DM was significantly reduced for cultivars Kranskop, Enseleni, Cerillos and Majuba. Kranskop was the least tolerant and SSN 1 the most tolerant to metazachlor. In the case of metolachlor this parameter was significantly reduced for cultivars Kranskop, Enseleni, Cerillos and Mkuzi. Mkuzi was the least and SSN 1 the most tolerant to metolachlor.

At the recommended rate, the two red-speckled sugar bean cultivars (Kranskop and Monati) and the Alubia bean cultivar (Cerillos) were more susceptible than the other seven cultivars (Table 4). The large white kidney bean was once again the most tolerant cultivar. Imazethapyr caused the least reduction in aboveground DM across cultivars.

At the 2x-rate, dimethenamid significantly reduced the DM of Kranskop, Enseleni and Cerillos (Table 4). At the same rate, flumetsulam + metolachlor significantly reduced the DM of Helderberg, Kranskop, Enseleni, Cerrillos and Katberg. Also at that rate, imazethapyr caused a significant reduction in DM of Enseleni, and metazachlor inhibited the growth of all cultivars, except Teebus, Monati and SSN1. Metolachlor (2x-rate) significantly reduced the DM of Kranskop, Enseleni and Katberg. The phenomena that in some cases the 1x-rate reduced DM more than the 2x-rate (Table 4) could be partly due to experimental error.

Wilson & Miller (1991) found that the light-red kidney cultivar Sacramento and the pinto cultivar Agate were injured less by imazethapyr than the great northern cultivars Beryl and GN1140 or pinto cultivars UI114 and Olathe. Bauer *et al.* (1995) found similar differences in herbicide tolerance with imazethapyr application to pinto cultivars Sierra and Olathe. Differences in bean tolerance to dimethenamid also exist. Adzuki beans are very sensitive to most herbicides and will not tolerate alachlor, dimethenamid or metolachlor. Dark and light red kidney beans, pinto beans and cranberry beans are tolerant to pre-emergence applications of dimethenamid (Renner 1997). The two bean classes that appear to be least tolerant to dimethenamid are navy and black beans. Renner (1996) applied metolachlor and dimethenamid at the recommended rate and double the rate to several cultivars and classes of beans. No injury was found to any pinto, great northern, kidney or cranberry cultivars from dimethenamid or metolachlor at both application rates. Some injury to the navy and black bean cultivars was observed from both herbicides. Dimethenamid caused more injury than metolachlor to the navy and black bean cultivars.

Table 4 Aboveground dry mass expressed as percentage of the control for ten dry bean cultivars exposed to five herbicides at both the recommended (1x) and 2x-rates on one soil (ANOVA in Table 2B of Appendix B)

	Cultivar									
Herbicides (a.i. g ha $^{-1}$)	Helderberg	Teebus	Kranskop	Enseleni	Monati	Cerillos	Katberg	Mkuzi	Majuba	SSN1
Dimethenamid										
1125	90.4	66.0	50.6	72.7	101.6	74.3	79.0	64.4	94.4	94.4
2250	97.2	94.3	56.9	79.6	107.8	68.8	88.6	125.3	91.2	121.6
Flumetsulam + metolachlor										
1550	121.1	86.1	66.6	100.1	106.2	84.6	78.5	105.1	99.1	120.3
3100	75.1	102.9	80.2	76.2	112.7	72.7	56.0	99.2	98.3	112.7
Imazethapyr										
50	102.1	106.5	84.9	90.8	98.3	100.3	93.0	104.3	109.6	118.1
100	103.7	99.6	91.5	76.9	141.1	94.0	86.0	84.0	111.9	136.8
Metazachlor										
800	84.4	103.8	57.7	79.7	103.9	69.8	92.0	95.1	75.4	107.5
1600	81.4	82.9	72.0	74.2	108.8	73.7	77.6	62.8	77.8	103.4
Metolachlor										
1860	121.9	111.0	81.4	80.8	128.9	77.1	102.7	76.0	84.0	122.5
3720	105.8	87.1	66.9	74.8	125.8	104.2	80.8	91.4	96.7	135.9

LSD_T (P = 0.05)

Herbicide x Rate x Cultivar = 17.51

100-Seed mass. The herbicide x cultivar interaction effect and both main effects were significant for 100-seed mass (Table 3B of Appendix B). Helderberg and Monati were the only cultivars where 100-seed mass was reduced significantly (Table 3A of Appendix A). This was probably due to the large variation in seed size of these two cultivars. As indicated earlier, 100-seed mass was not considered to be a particularly good indicator of herbicide tolerance in this study, probably due to the large variation in seed size within cultivars.

Visual bean injury. Early stunting (30 days after planting) of seedlings was the major injury symptom observed. Imazethapyr caused less stunting than dimethenamid, metolachlor or metazachlor. The cultivars showed stunted growth in response to flumetsulam + metolachlor. Most of the cultivars, except Kranskop, recovered from the stunting effect. Cupping and crinkling of primary leaves were also observed in some cases but those plants eventually recovered fully.

Several herbicides and herbicide combinations are used in dry beans. These herbicides effectively control many weed species but some of them have affected either dry beans or related crops negatively. Crop injury does not always culminate in measurable yield losses. The earliest and most obvious negative effects are reflected in plant morphology. Some of the morphological changes which have been evoked in beans or related crops by various herbicides are: shorter, larger or distorted stem growth; changes in leaf number, size and photosynthetic surface; pruned, distorted or proliferated root growth (De Beer, 1988; Nkwen-Tamo *et al*., 1989; Wilson & Miller, 1991; Johnson & Mullinix, 1996; Urwin *et al*., 1996). Even though some changes in morphology may occur, plants could recover without any yield losses, or losses might be incurred.

Conclusions

Results of this study show that South African dry bean cultivars vary in tolerance to selected registered herbicides. Differences in tolerance also exist within dry bean types. The tested cultivars were generally more tolerant to dimethenamid, imazethapyr and metazachlor than to flumetsulam + metolachlor or metolachlor. If one regards 10% as a "economically significant " yield loss, certain existing herbicide / cultivar combinations should be avoided. The most important yield-reducing combinations were for those cultivars (Helderberg, Kranskop, Enseleni, Monati, Cerrillos, Katberg, Mkuzi and Majuba) treated with flumetsulam + metolachlor. However, all the herbicides tested are very effective in controlling weeds, and therefore, acceptance of small losses in yield must be considered.

Discovering significant differential tolerances only as late as harvesting could be catastrophic, and therefore it would be very helpful if this could be done during screening tests in a glasshouse as will be discussed in Chapter 4.