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

by

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ABSTRACT

Variable tolerance to herbicides occurs amongst cultivars of several crop species, including: dry beans (*Phaseolus vulgaris* L. and *P. coccineus* L.), maize (*Zea maize* L.), soybean (*Glycine max* L.), sunflower (*Helianthus annuus* L.), rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L). De Beer (1988) reported that several dry bean plantings suffered from acetanilide herbicide injury during the 1982 / 83 season. Mennega, Nel & Le Court de Billot (1990) and Fouché (1996) have also reported differences in herbicide tolerance between dry bean cultivars in South Africa. Due to expected differences in herbicide tolerance between local dry bean cultivars, a study was undertaken to evaluate the influence of selected pre-emergence herbicides on: (a) the growth and yield of 10 cultivars; (b) seed yield on four soil types; and (c) the use of chlorophyll *a* fluorescence as a tool for screening the herbicide tolerance of cultivars. Dry bean morphology and cell ultrastructure were also evaluated, and guidelines were developed for routine assessments of the herbicide tolerance of dry bean cultivars. Using the parameters of plant growth and seed yield, the tolerance of dry bean cultivars to pre-emergence herbicides was compared in a field trial at the Grain Crops

Institute of the Agricultural Research Council (ARC) in Potchefstroom (North West Province) during the 1996/97 growing season. Tolerance of the dry bean cultivar Helderberg was investigated in a field trial in each of the districts Chrissiesmeer, Lichtenburg, Potchefstroom and Reitz during 1996/97. Completely unfolded leaves of cultivar Helderberg, grown in a glasshouse in the presence of herbicides for 14 days, were sampled to study the influence of herbicides on cell ultrastructure by means of transmission electronmicroscopy. Chlorophyll *a* fluorescence was measured on the primary leaves and first trifoliate leaf of cultivars Kranskop and OPS-RS1 21 days after planting, after a dark adaptation period of 25 min., with a fluorescence measuring system (Plant Efficiency Analyser, Hansatech, UK). In the field experiment at Potchefstroom, cultivars Kranskop, Monati and Cerillos were significantly less tolerant than Helderberg, Teebus, Katberg and SSN1, based on seed yield. In general, the dry bean cultivars were significantly more tolerant to dimethenamid, imazethapyr or metazachlor than to flumetsulam + metolachlor or metolachlor. The 2x-rate of herbicides caused an overall significant reduction in seed yield. In respect of foliage dry mass, Kranskop, Monati and Cerillos were less tolerant than the other seven cultivars. In the series of field experiments done at four localities, the only significant reductions in yield of cultivar Helderberg were caused by flumioxazin. In assessing the potential of chlorophyll *a* fluorescence as a tool for predicting herbicide tolerance, dimethenamid, flumioxazin, flumetsulam + metolachlor and metazachlor caused significant decreases in instantaneous fluorescence yield (Fo) of the primary leaves of Kranskop. For the same cultivar, metazachlor had a similar effect in the first trifoliate leaf. Both dimethenamid and flumioxazin caused significant decreases in Fo of the first trifoliate of cultivar OPS-RS1. The ratio of variable fluorescence (Fv) to maximum fluorescence (Fm) of the primary leaves was significantly increased by flumioxazin, flumetsulam + metolachlor and metazachlor. Significant decreases in Fo and significant increases in Fv/Fm are typical of herbicides acting at Photosystem II of the photosynthesis process. Further research regarding the extent to which

herbicides with this site of action might be expected to influence yield is suggested. The electronmicroscopy study indicated ultrastructural changes in leaves treated with various herbicides. None of the herbicides caused drastic changes in the structure of chloroplasts. Except for imazethapyr, herbicides did cause a reduction in the number of stroma and granum lamellae. With the exception of imazethapyr-treated plants, starch granules in treated plants appeared depleted and were rounder in shape than those of control plants. Disruption of mitochondria was characterized by swollen and chaotically arranged crystae, except in imazethapyr-treated plants. These changes are probably manifestations of inhibition by imazethapyr of acetyl Co enzyme A which is needed in the formation of chlorophyll, and is an important part of the mitochondria-based Krebs cycle. As a result of this mechanism of action, both photosynthesis and respiration efficiency should be influenced negatively, which in turn would adversely affect plant growth and yield. This study confirmed the existence of differential tolerance to herbicides amongst *P. vulgaris* and *P. coccineus* cultivars. More research, especially field trials, should be conducted to identify high-risk herbicide / cultivar combinations.

INTRODUCTION

The main crops produced in the summer rainfall region of South Africa are dry beans (*Phaseolus vulgaris* L. and *P. coccineus* L.), groundnuts (*Arachis hypogaea* L.), maize (*Zea mays* L.), sorghum (Sorghum vulgare L.), soybeans (*Glycine max* L.), sunflower (*Helianthus annuus* L.), and wheat (*Triticum aestivum* L). For the most important crop, maize, yields of approximately eight million tons have been produced annually over the last decade on ± 3.5 million hectares (ARC-Grain Crop Institute & NAMPO, 1999). The total production of dry beans in South Africa was 71 446 tons on approximately 69 052 hectares in 1999/2000, and averaged 58 000 tons on ± 56 000 hectares over the last decade.

The genus *Phaseolus* consists of more than 50 herbaceous species that range in type from annual to perennial, prostrate to erect, climbing to bush. According to Lloyd & Liebenberg (1986) three of these species are of agricultural importance in South Africa, i.e. *Phaseolus vulgaris* L. (common dry bean and green beans), *Phaseolus coccineus* L. (kidney bean) and *Phaseolus acutifolius L.* (tepary bean). The common dry bean is the most widely grown of the three species. Currently there are 51 cultivars on the dry bean variety list. There are eight seed types which differ in size, colour and shape, and within each seed type there are cultivars that differ in agronomic adaptation, disease resistance and other properties (Liebenberg & Steenekamp, 1997).

Inadequate weed control is a major problem in dry bean production. Weeds compete vigorously with dry beans and yield reductions exceeding 70% have been recorded (Parker & Fryer, 1975; Blackshaw & Esau, 1991). Dawson (1964) showed that the first five to seven weeks after planting is the most critical period for beans in terms of weed control. Weeds emerging during this period were more competitive than those germinating later. Weeds that emerged above the bean canopy were the most competitive.

Mechanical weed control has various disadvantages, e.g. weeds directly in the crop row are not removed, and weather conditions can prevent control of weeds at the most critical times (Nel, 1973). Control by early post-emergence herbicides is another alternative but could similarly be delayed, and could be more expensive than pre-emergence herbicides and should only be used in emergencies. That is, for example, when pre-emergence herbicides fail to control the weeds adequately. The use of effective pre-emergence herbicides in combination with mechanical control seems highly desirable. There is, however, a very fine balance between optimum weed control and maximum crop safety.

Cultivar tolerance to herbicides has been variable for numerous grain crops such as maize (Renner, Meggitt & Penner, 1988), rice (*Oryza sativa* L.) (Snipes, Street & Boykin, 1987), soybean (Barrentine, Hartwig, Edwards & Kilen, 1982; Buzzell & Hamill, 1988; Fourie, Rothman & de Beer, 1990; Osborne, Shaw & Ratliff, 1995), sunflower (Meissner, Nel & Beyers, 1987), and wheat (Runyan, McNeill & Peeper, 1982; Driver, Peeper & Guenzi, 1992). Various researchers have reported differences in herbicide tolerance between dry bean cultivars (De Beer, 1988; Mennega, Nel & Le Court de Billot, 1990; Wilson & Miller, 1991; Arnold, Murray, Gregory & Smeal, 1993; Fouché, 1996; Urwin, Wilson & Mortenson, 1996).

In light of expected differences between dry bean cultivars in respect of herbicide tolerance, a study with the following objectives was undertaken to:

- Evaluate the influence of dimethenamid, imazethapyr, flumetsulam + metolachlor, metazachlor and metolachlor on the growth and yield of ten dry bean cultivars.
- Evaluate the influence of soil type (locality) on dry bean tolerance to dimethenamid, imazethapyr, flumetsulam + metolachlor, flumioxazin, metazachlor and metolachlor.
- Assess the use of chlorophyll *a* fluorescence as a tool for screening dry bean cultivars for herbicide susceptibility.
- Study the influence of dimethenamide, flumetsulam + metolachlor, metazachlor and metolachlor on dry bean morphology and cell ultrastructure.
- Set guidelines for the routine assessment of the herbicide tolerance of dry bean cultivars.