

# CARRYOVER EFFECT OF FOMESAFEN, APPLIED ON EDIBLE BEAN, ON SUCESSIONAL MAIZE<sup>1</sup>

TARCÍSIO COBUCCI<sup>2</sup>, JOÃO B. SILVA<sup>3</sup> e HÉLIO T. PRATES<sup>3</sup>

## RESUMO

### Efeito de resíduo no solo de fomesafen, aplicado no feijão, no milho em sucessão

Em dois experimentos fomesafen foi aplicado em pós-emergência em culturas do feijoeiro nas doses de 0; 0,125; 0,25; 0,375 e 0,5 kg/ha, em 1992 (abril e agosto) e em 1993 (março e agosto) em parcelas distintas, para avaliar os efeitos de seus resíduos no solo argiloso (Latossolo Vermelho-Escuro) na cultura do milho. O milho foi plantado em sucessão 65 e 198 dias após aplicação de fomesafen em 1992 e 65 e 212 dias em 1993. Resíduos de fomesafen no solo foram determinados por cromatografia líquida e foram detectados até 20 cm de profundidade, porém a maior concentração encontrada foi a 0-10 cm de profundidade. Nesta profundidade, a concentração de fomesafen variou de 21 a 24 e 55

a 60 ppb aos 212 e 65 dias após aplicação de 0,25 kg.ha<sup>-1</sup> de fomesafen, respectivamente, enquanto que a aplicação de 0,5 kg.ha<sup>-1</sup>, apresentou concentrações de 46 a 61 e 137 a 193 ppb aos 212 e 65 dias após aplicação, respectivamente. No plantio de milho aos 65 dias após aplicação de fomesafen, resíduos do herbicida no solo reduziram o teor de clorofila na folha e volume de raiz do milho aos 10 dias após emergência. A diminuição do teor de clorofila na folha e volume de raiz, entretanto, não afetaram o rendimento de grãos.

**Palavras chave:** difenil-éter, persistência, sucessão, *Phaseolus vulgaris*, *Zea mays*.

## ABSTRACT

Carryover effects of fomesafen on successional maize were studied in clay soil. Fomesafen was applied as postemergence at five rates (0; 0.125; 0.25; 0.375, and 0.5 kg/ha<sup>-1</sup>) to edible beans. Maize was planted 198 and 65 days after fomesafen application in 1992 and 212 and 65 days after fomesafen application in 1993. Fomesafen residues were detected in soils up to 20cm depth but residue concentration was higher in 0-10 cm soil depth. Fomesafen residues reduced

leaf chlorophyll content and root volume of 10 days old maize when planted 65 days after application but were not affected when planted 212 days after application. However, the decreases in leaf chlorophyll and root volume did not affect the maize yield.

**Key words:** Diphenylether herbicide, herbicide persistence, crop rotation, *Phaseolus vulgaris*, *Zea mays*.

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<sup>2</sup>Pesquisador, Dr., Embrapa - Centro Nacional de Pesquisa de Arroz e Feijão (CNPAP), Caixa Postal 179, 74001-970 Goiânia. GO. e-mail: cobucci@cnpap.embrapa.br.

<sup>3</sup>Pesquisador, Ph.D., Embrapa - Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS), Caixa Postal 151, 35701-970 Sete Lagoas, MG.

## INTRODUCTION

The Brazilian Savanna, locally known as Cerrado, is the region where grain production has been improved, has distinct dry and wet seasons. The soils have excellent physical properties but are chemically poor. It is possible to grow two crops per year with irrigation. Edible bean is planted from March to July, and maize in November. The herbicide fomesafen is used to control broadleaf weeds in edible bean but the effect of soil fomesafen residue on maize following edible bean is unknown.

Fomesafen is a diphenylether herbicide and its degradation in anaerobic conditions occurs in less than 3 weeks, and in aerobic soil conditions, herbicide half-life ranged from 6 to 12 months (Johnson & Talbert, 1993). Oymada & Kuwatsuka (1988), studying the conditions of diphenylethers (chlornitrofen [2,4,6-trichlorophenyl 4-nitrophenyl ether], nitrofen [2,4-dichlorophenyl 4-nitrophenyl ether] and chlometoxynil [2,4-dichlorophenyl 3-methoxy-4-nitrophenyl ether]) degradation, reported that the half-life periods varied largely with soil conditions: 9 to 173 days for chlornitrofen, 3 to 87 days for nitrofen and 8 to 64 days for chlometoxynil. The herbicides degrade rapidly in anaerobic conditions.

Weber (1993) reported that fomesafen exhibited weakly acidic properties.  $pK_A = 3,0$  (ionized to anionic species as pH increased). Mobility, bioavailability and degradability of the herbicide fomesafen in soil is expected to be lower at low pH than at high or neutral pH, due to high sorption on soil coloids.

Johnson & Talbert (1993) determined carryover potential of fomesafen ( $0,28 \text{ kg}\cdot\text{ha}^{-1}$ ) to snap bean (*Phaseolus vulgaris*), watermelon (*Citrullis lonatus*), cucumber (*Cucumis sativus*),

mustard (*Brassica nigra*) and sunflower (*Helianthus annuus*). **The herbicide injured all crops initially, but did not injure snap bean, sunflower, watermelon and cucumber planted 16 weeks after application.**

Santos (1991) applied fomesafen in edible bean and detected that the herbicide persisted until 100 days after application (DAA) of  $0,25 \text{ kg}\cdot\text{ha}^{-1}$  and 180 DAA of  $0,375 \text{ kg}\cdot\text{ha}^{-1}$ , using sorghum as a test crop.

Weissler & Poole (1982) tested the application of fomesafen ( $0,3 \text{ kg}\cdot\text{ha}^{-1}$ ) in columns, and leached with 660 mm of water. More than 60% of the herbicide was located in the top 10 cm, 63 DAA. In soils with 6,0% and 2,1% of organic matter, herbicide concentrations, at the same depth, were 185 and 100  $\text{mg}\cdot\text{dm}^{-3}$ , respectively.

The objective of the present experiment was to determine the effect of carryover fomesafen residue on leaf chlorophyll, root volume and grain yield on successional maize and to estimate the level of these residues under Brazilian Cerrado soil conditions.

## MATERIAL AND METHODS

Experiments were carried out in 1992 and 1993 (one in each year) in a dark red latosol of the National Maize and Sorghum Research Center of Embrapa, Sete Lagoas, Minas Gerais, Brazil, to evaluate the soil residue effects of fomesafen on maize. The herbicide was applied on a previous edible bean crop.

Both experiments consisted of a  $5 \times 2$  factorial with five different rates of fomesafen (0; 0.125; 0.250; 0.375 and  $0,5 \text{ kg}\cdot\text{ha}^{-1}$ ) and two periods of application before planting maize (65 and 198 days in 1992 and 65 and 212 days in 1993). Treatments were arranged in a split-plot design, with six replications, where the main plot

represented fomesafen rates, and the sub-plot the two periods of application.

The soil characteristics of each

experimental site are presented in Table 1. Precipitation and temperature data during the experimental period are presented in Table 2.

**TABLE 1.** Textural class and some chemical characteristics of the soil. Sete Lagoas, MG, Brazil, 1992/1993.

Experiment/ year	Soil texture <sup>a</sup>	Org. Mat. (%)	CEC (Cmol <sub>c</sub> .dm <sup>-3</sup> )	Soil pH
1/1992	Clay (71% clay and 11% sand)	3.01	8.97	6.1
2/1993	Clay (61% clay and 26 % sand)	3.92	12.12	6.1

<sup>a</sup> Red dark latosol.

**TABLE 2.** Precipitation and temperature data during crop season in Sete Lagoas, MG, Brazil, 1992-1993.

Year	Month	Precipitation <sup>a</sup> (mm)	Average temperature (°C)	
1992	Mar	61.1	17.6	
	Apr	191.4	17.6	
	May	19.7	15.1	
	June	20.0	13.1	
	July	42.4	12.4	
	Aug	64.0	13.8	
	Sept	108.2	16.0	
	Oct	106.9	17.4	
	Nov	407.1	17.5	
	Dec	133.6	18.1	
	1993	Mar	61.2	17.9
		Apr	138.1	17.3
May		83.5	13.5	
June		27.4	11.9	
July		50.0	12.0	
Aug		103.8	12.9	
Sept		10.5	16.2	
Oct		102.6	17.0	
Nov		187.6	18.3	
Dec		230.8	18.7	

<sup>a</sup> Rain + irrigation.

Edible bean was planted on March, 18 and July, 27, in each sub-plot, respectively, and the herbicide fomesafen was applied on April, 7 and August, 8 in 1992 with a CO<sub>2</sub>-pressurized backpack sprayer delivering 250 l.ha<sup>-1</sup> at 275 kPa. In 1993, edible bean was planted on March, 2 and July, 16, in each sub-plot and herbicide was applied on March, 22 and August, 16.

**Fomesafen residue:** Chemical analysis of soil fomesafen residue were performed in the second year (1993), in the plots which received 0.25 and 0.5 kg.ha<sup>-1</sup> of fomesafen. Soil samples composed of five subsamples taken at 0 to 5, 5 to 10 and 10 to 20 cm deep 29, 64, 136, 189 and 232 DAA in the plots where fomesafen was applied 212 days before maize and 42 and 85 DAA in the plots where it was applied 65 days before maize. Fomesafen residue was extracted by shaking 20 g of soil with 100 ml of acetonitrile: hydrochloric acid (98:2), for 30 min in a horizontal shaker. The extract was filtered through a celite pad under vacuum. Residue was washed with 50 ml of acetonitrile. The extract (70 ml) - water (100 ml) mixture was transferred to a separatory funnel and shaken for 3 min with 100 ml of dichloromethane, and the lower phase (dichloromethane) was collected. This procedure was repeated with an additional 50 ml of dichloromethane. The combined dichloromethane extracts were evaporated to dryness at 35 C on a rotary evaporator. The residue was taken up in chloroform (3 ml) and passed through a silica adsorption column chromatography. The elute was evaporated to dryness and taken up with 1 ml of acetonitrile: water (pH 2.5) 50:50. The amount of fomesafen was determined with a high performance liquid chromatography. The analytical conditions were: Shim-pach CLC-ODS (M), reverse-phase, with 4.6mm x 25cm in

stainless steel and 5 mm pore diameter, column temperature of 40°C, mobile phase acetonitrile:water (pH 2.5) 50:50, flow rate of 2.0 ml.min<sup>-1</sup>, UV detector at 290 nm wavelength, sample amount of 20 ml. A linear calibration curve was constructed using known fomesafen concentrations (0, 200, 600 and 1000 mg.dm<sup>-3</sup>). The solutions of known concentration consisted of analytical herbicide (chemical purity > 99%). The concentration of fomesafen in soil sample extracts was determined by entering peak area values into a regression equation describing the calibration curve. Fomesafen recovery from soil samples was 100%. The lower limit for detection of fomesafen in soil samples was 5 mg.dm<sup>-3</sup>

**Effect of fomesafen residue on maize:** Maize cultivars, Cargill 805, were sown on October, 22 in 1992 and BR 201 on October, 20 in 1993 in 90 cm rows, using 65.000 seeds ha<sup>-1</sup> and were mown 30 days after emergence. The seedling emergence, leaf chlorophyll concentration and root volume were measured 10 days after emergence. Chlorophyll concentration was estimated by Arnon's method (Arnon, 1949). The samples were taken at the middle portion of the first leaf of 10 plants per plot. The roots were washed and plunged into graduated tubes containing 50 ml of water to determine root volume by water volume difference. Maize grain yield was estimated using the two center rows of each plot and adjusted to 13% of moisture.

## RESULTS AND DISCUSSION

**Fomesafen residue:** Average data for fomesafen concentrations in the soil are presented in Table 3. For both periods of fomesafen application before maize (212 and 65 days), the ANOVA showed significant main effects for

fomesafen rate, soil depth and DAA. A significant interaction between depth and DAA was observed. Based on these results, the study was carried out using the average fomesafen rate (0.25 and 0.5 kg.ha<sup>-1</sup>).

**TABLE 3.** Fomesafen residue ( $\mu\text{g}\cdot\text{dm}^{-3}$ ) as affected by rate of application, depth (cm) and days after application (DAA) in two application dates before maize, Sete Lagoas, MG, Brazil, 1993.

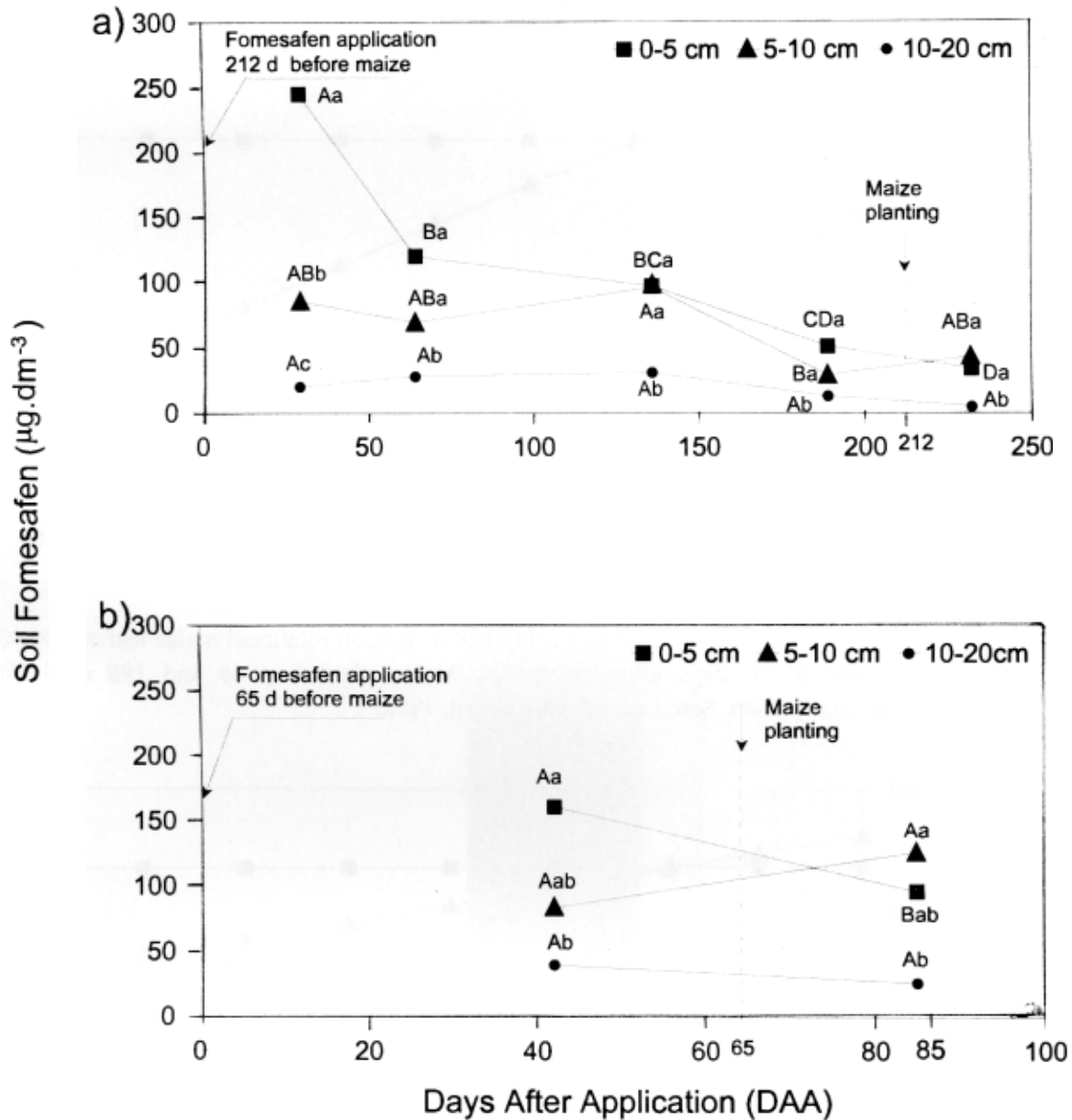
Application before maize (days)	DAA	Fomesafen residue					
		0.25 kg.ha <sup>-1</sup>			0.5 kg.ha <sup>-1</sup>		
		0 to 5	5 to 10	10 to 20	0 to 5	5 to 10	10 to 20
		----- $\mu\text{g}\cdot\text{dm}^{-3}$ -----					
212	29	209	77	<5	281	93	41
	64	83	42	<5	157	95	54
	136	66	90	21	128	103	38
	189	40	41	<5	63	18	27
	232	21	24	<5	46	61	11
65	42	134	34	32	188	135	49
	85	55	60	12	137	193	40

When the herbicide was applied 212 and 65 days before maize, a significant decrease of its soil concentration 0 to 5 cm deep was observed as DAA increased (Figures 1a and 1b). This was probably due to microbial decomposition. According to Johnson & Talbert (1993), fomesafen dissipation in the soil occurs mainly by microbial degradation. Oymada & Kuwatsuka (1988) reported that diphenylether herbicides are degraded faster under reductive than oxidative conditions, and that there are many microorganisms in the soil which reduce the nitro group of such herbicides.

In Figures 1a and 1b, it can be observed that fomesafen residue concentrated more at 0 to 10 cm in the soil profile. Weessler & Poole (1982) observed that 63 DAA (0.3 kg.ha<sup>-1</sup> of fomesafen) in a loamy sandy soil (2.1% O.M.) and with 660 mm of precipitation, 60% of fomesafen

was located 0 to 10 cm deep. The authors concluded that fomesafen has a moderate mobility in the soil profile.

The low fomesafen vertical movement can be explained by its adsorption on the soil colloids, mainly in the organic matter. Under test soil (latosol), adsorption may have occurred on Fe and Al oxides (gibbsite, goethite and hematite). These soil mineral components have pH-dependent charges and become positively charged at low pH values (Tisdale *et al.*, 1985). The pH value resulting in neutrality is referred to as the zero point of charge (ZPC) (Hingston *et al.*, 1972). The ZPC for the aforementioned minerals is between 5 and 7 (Hingston *et al.*, 1972). At normal soil pH levels (4.5 to 6.5), fomesafen appears mainly in anionic form, favoring adsorption by Fe and Al oxides (Newby & White, 1981 e Weber, 1993).

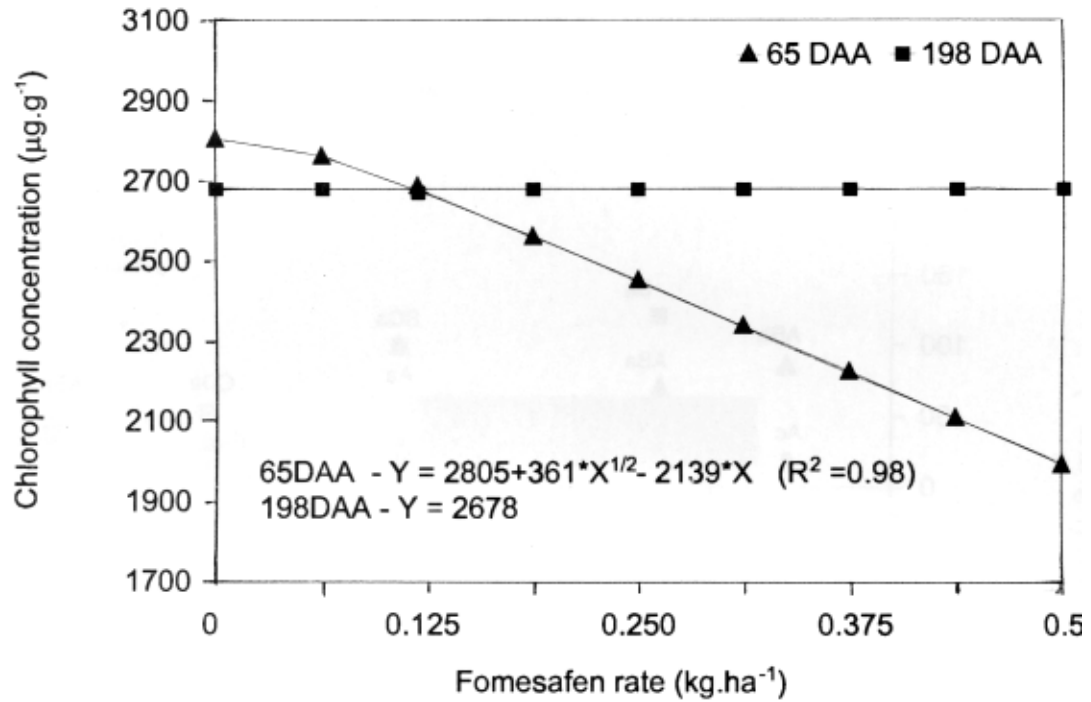


**FIGURE 1.** Soil fomesafen residue (means of 0.25 and 0.5 kg.ha<sup>-1</sup> rates) as affected by DAA at three depths and two application dates. Means followed by the same letter are not significantly different according to Tukey's test at 0.05 level of probability. Capital letters were used to compare means among DAA for any depth and small letters to compare means among depths for any DAA. Sete Lagoas, MG, Brazil, 1993.

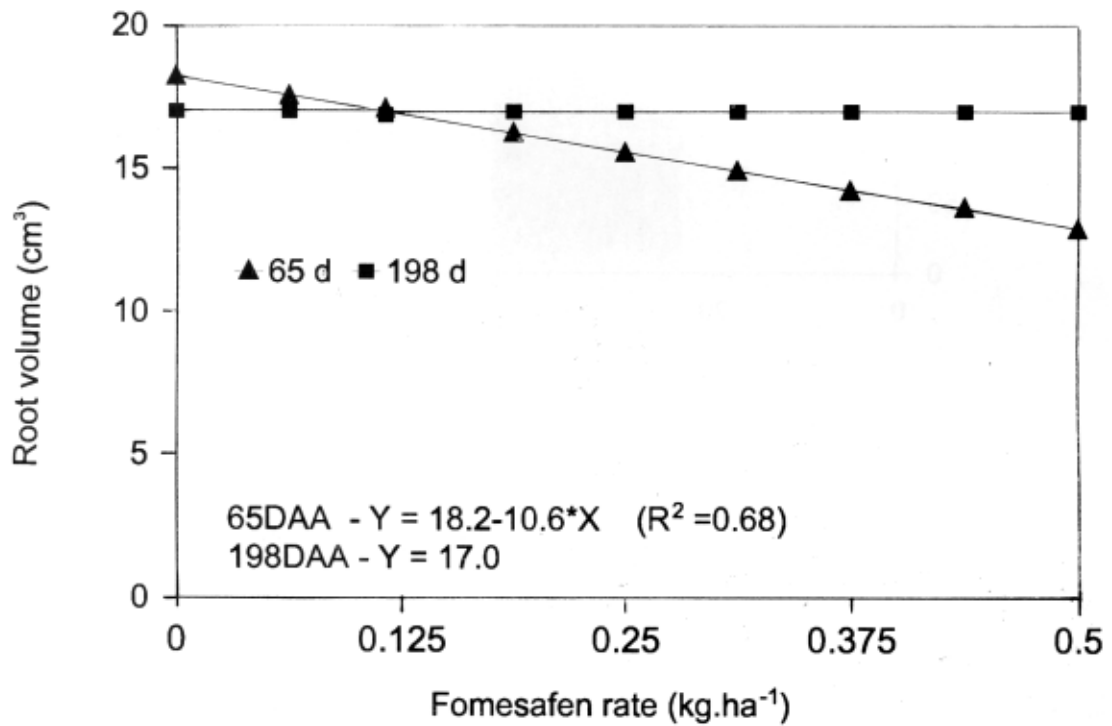
**Effect of fomesafen residue on maize:** In 1992, when the interval between fomesafen application and maize planting was 65 days, the leaf chlorophyll concentration and root volume, measured 10 days after emergence, decreased with increased fomesafen rates (Figures

2 and 3). There was no significant difference among the fomesafen rates concerning concentrations determined - 198 DAA. Santos (1991) detected fomesafen residue until 180 DAA, using sorghum as a test crop.

Carryover effect of fomesafen, applied on edible bean, on sucessional maize.



**FIGURE 2.** Effect of fomesafen carryover residue from edible bean on rotational maize leaf chlorophyll concentration at 10 days after emergence. Maize planted at 65 and 198 days after fomesafen application. Sete Lagoas, MG, Brazil, 1992.

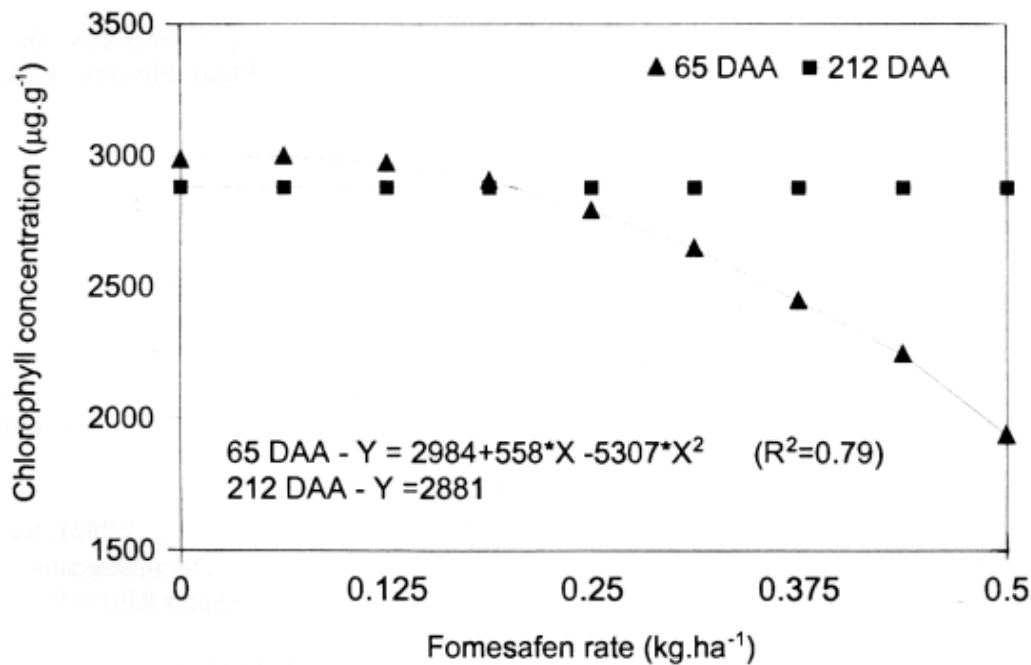


**FIGURE 3.** Effect of fomesafen carryover residue from edible bean on rotational maize root volume at 10 days after emergence. Maize planted at 65 and 198 days after fomesafen application. Sete Lagoas, MG, Brazil, 1992.

The decrease of leaf chlorophyll concentrations related to fomesafen residue in the soil can be explained by the protoporphyrinogen oxidase inhibition (enzyme in chlorophyll synthesis pathway). Then, non-enzymatic oxidation occurs, which forms protoporphyrin IX that interacts with oxygen and light, resulting in singlet oxygen forms. The non-enzymatic protoporphyrin IX is not an acceptable substrate for Mg chelatase and contributes to the decrease in chlorophyll synthesis (Weller & Warren, 1992). The yellow stripes that appear on the leaves are the main symptom of fomesafen residue effect on maize. This may be due to decrease in chlorophyll concentration.

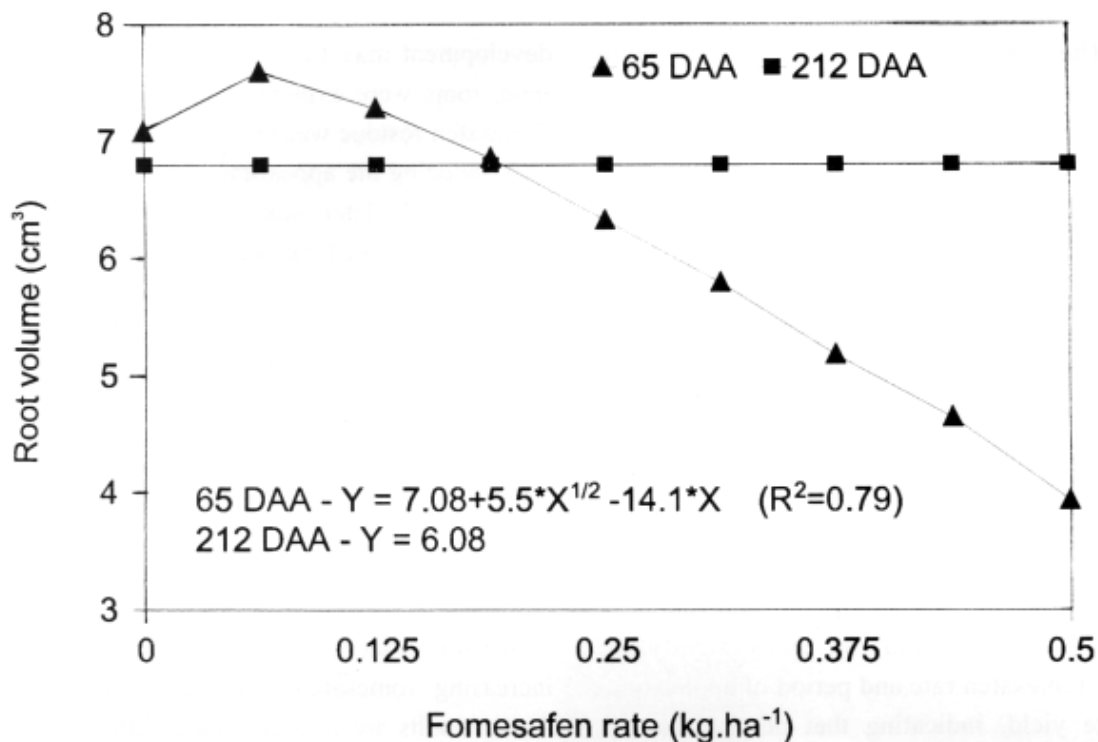
The ANOVA did not show significant effect for fomesafen rate and period of application for maize yield, indicating that despite residue damage to maize plants observed 10 days after emergence, the crop is capable to recover with no negative effects on yield. One explanation for the symptoms observed in the initial stage of maize

development may be due to the fact that, at that time, roots were exploring the soil profile where fomesafen residue was more concentrated (0 to 10 cm), inducing the appearance of yellow stripes on the leaves. In later stages of plant growth, with deeper root proliferation, effects of fomesafen residue were overcome. It is important to notice that initial stand of maize was not affected by soil fomesafen residue. Seedlings death did not occur even with the highest rates of fomesafen ( $0.5 \text{ kg. ha}^{-1}$ ) or with the smallest interval between fomesafen application and maize planting (65 days). In 1993, within the same time range period (65 days), a significant decrease in leaf chlorophyll concentration and root volume of maize was observed 10 days after emergence with increasing fomesafen rates (Figures 4 and 5). These results are in accordance with those found in the previous year (1992), confirming the negative effect of fomesafen residue on initial stages of maize growth. As in 1992, fomesafen residue did not affect maize yield significantly.



**FIGURE 4.** Effect of fomesafen carryover residue from edible bean on rotational maize leaf chlorophyll concentration at 10 days after emergence. Maize planted at 65 and 212 days after fomesafen application. Sete Lagoas, MG, Brazil, 1993.





**FIGURE 5.** Effect of fomesafen carryover residue from edible bean on rotational maize root volume at 10 days after emergence. Maize planted at 65 and 212 days after fomesafen application. Sete Lagoas, MG, Brazil, 1993.

The results obtained in this study demonstrated that fomesafen application in edible bean crop, at the recommended rate of 0.25kg.ha<sup>-1</sup>, did not affect maize yield, even when the interval between application and maize planting was 65 days. Nevertheless, it is worth to point out that the persistence of herbicides in the soil may vary according to several factors, such as soil type, precipitation and temperature. On this basis, data presented here should be considered according to the test conditions.

#### ACKNOWLEDGMENTS

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