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Persistence of Herbicide Sulfentrazone in Soil Cultivated with Sugarcane and Soy and Effect on Crop Rotation

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1. Introduction

In the deployment of an agricultural area through a cultivation system, there are serious and significant changes in geomorphic subsystems, edaphic and biological, making them simpler (agroecosystem), compared with the ecosystem, this, a more complex system. This change results in drastic reduction of the self-regulatory system, making it more unstable and susceptible to energy inputs. One major consequence of this transformation is the excessive increase of some species of insects, microorganisms and nematodes populations, and wild plants in such a way as to significantly impair the production, making uneconomical the productive units, so, they are named as agricultural pests.

When the wild plants interfere with cultivated plants, specifically, they become weeds, which unlike others agricultural pests, they are by nature always present in agroecosystems, they are difficult to control and are directly (competition, allelopathy, etc.) or indirectly (reservoir of pathogens, insects and nematodes) responsible for the drastic decrease in economic production of crops.

For a long time, agricultural researches have demonstrated that the control of weeds in various agroecosystems is a key factor for the success of crop production. All the technological development in crop science, nutrition, or breeding, can be compromised if the weeds were not controlled. The weed control is done by combining several methods, such as preventive, cultural, and chemical weeding, this, by the use of herbicides.

Herbicides are chemicals used to eliminate plants. They are applied in suitable doses directly on the vegetation for foliar absorption (post-emergence treatment), or on the soil for absorption by the plant tissues formed after the seed germination, before the plant emergence from the soil surface (pre-emergence treatment). They are generally used to control of weeds in different agro-ecosystems, or in any other favorable ecological niches of these organisms: wasteland, margins of highways, railroad beds, parking lots, and aquatic environments.

To selection of which herbicide will by used to weed control, you should always have an ecological focus using this agronomic technique aiming the maximum production. This

duality, choice, besides the type, dose, number and mode of application, should always seek the dichotomy of maximum efficiency and minimum environmental impact, thus maximizing the benefits of their use and minimizing their environmental and toxicological risks

Even so, the use of these chemicals is not without risks, with possible presence of residues in agroecosystems that can cause toxicity to susceptible plants used in rotation with the crops originally treated with the herbicides.

Brazil is a country where agricultural production is has world importance, notably in the growing of sugarcane and soybean, which since the end of the last century, with the implementation of the program using ethanol to replace gasoline, and the cultivation of soybeans in the Brazilian Cerrado (savanna), their productions and productivities have increased significantly each year.

These two crops are cultivated in extensive areas, because of their ease of use and performance; and the use of herbicides in these crops is intensive and in many cases, especially in sugarcane, in that most herbicides have long residual power, persisting in soil for a very long time. Thus, these two crops, sugar cane and soybeans, must be those with the greatest potential risk of occurrence of problems related to the persistence of herbicide molecules in the soil for a longer period than it is desirable, with the possibility of causing environmental contamination and phytotoxicity to sensitive crops used in rotation, especially with soybean that has a shorter cycle.

These themes are linked with the herbicide ecotoxicology, and only in 1960 began the interest in studies on the ecological effects of chemicals, when then the society begins to worry about their effects on environmental contamination due to, primarily, the world press reports on the effects of insecticides for agricultural use on the wildlife. A classic example occurred in the 60's in Mississippi and Atchafalaya rivers, United States, resulting in the deaths of ten millions fishes from water polluted with the insecticide endrin (Madhun & Freed, 1990). In 1962, there was a great repercussion around the world, with the release of the book "Silent Spring", written by Rachel Carson (1964), which projected an obscure future for planet Earth, if the man did not stop using pesticides in an indiscriminate way.

Soon after this season, in 1975, it was started the development of Ecotoxicology, a branch of science created by Rene Thruhaut in Paris (Astolfi et al, 1984), studying the mechanisms of environmental contamination by natural and artificial chemicals (xenobiotics) as well as the action   such substances and their effects on living beings that inhabit the biosphere. Ecotoxicology is a natural extension of Toxicology.

One test that has contributed to understanding the behavior of pesticides are the ecotoxicological field tests to verify and monitor the persistence, accumulation, degradation and leaching of these products in soil.

2. Behaviour of herbicides in soils, especially sulfentrazone

The agricultural soil is the final destination of a large number of herbicides, either when they are applied directly to the soil or on the shoots of plants (Walker, 1987). When the herbicides, reach the ground, interacting with the environment, their fate is governed by three general types of processes: physical (sorption-desorption, volatilization, leaching by

water erosion and transportation along the ground by wind and water); chemicals (photodecomposition, sorption, chemical reactions with the soil constituents) and biological (represented by the microbial decomposition of the molecule and removal of soil by plants), Sheets, 1970, Blanco, 1979.

All these processes are described in the opinion of Briggs (1969, 1976, 1981), Blanco (1979), Walker (1983), Walker & Allen (1984) and Velini (1992), dependent on the chemical and physical soil nature and climatic conditions, particularly temperature and soil moisture, and soil characteristics (texture, structure, content and nature of colloid, pH, temperature, humidity, and others). The chemical nature of each herbicide, in turn, is a function of its molecular structure, molecule ionization, water solubility, lipid solubility, polarity and volatilization of the molecule. On the other hand, several external factors may play an important role in herbicide-soil interactions, such as dose and application mode, the herbicide formulation and soil microbial community

It is understood by adsorption to the accession of a molecule, ion or particle of the surface in any other particle, resulting from the interaction of a force field emanating from the adsorbent surface (clay and organic matter) and the surface of the adsorbate (in this case a herbicide). Herbicide Particles can also be absorbed by soil colloids. In 1994, Harper pondered the difficulty of distinguishing between the phenomena of absorption and adsorption, suggesting the use of the term sorption, which refers both cases.

Briggs (1969, 1976) reported that the extent and intensity of the processes involved in the phenomenon of sorption / desorption depend largely on molecular properties (physical and chemical) of the herbicide and the temperature, humidity, and soil pH and colloids. Herbicides can be molecular, weak acids or bases with their ionization depending on the soil pH, when the herbicide is the value of its ionization constant (pK), near the soil pH, the predominant form (molecular or ionic) , can vary greatly with a slight change in soil pH, Figure 1 illustrates it for sulfentrazone (pk = 6.56), characterized with weak acid.

Figure 1 shows the effect of soil pH rate on the percentage of the herbicide shape, ionized (anion) or molecular, and helps to understand the article of Grey et al. (1997), who analyzed the sorption of sulfentrazone when applied in multiple doses, varying the soil pH index, note that this characteristic has very significantly influence on the phenomenon of herbicide sorption to soil colloids, that decreases in response to a increasing pH, especially when this increase occurs above the pK of the herbicide (6.56), that because of the increased concentration of ionized form (anion) and a decrease in molecular form, in reverse, there is increased sorption to colloids when the index decreases, especially when this value below the pK of sulfentrazone.

It should be noted that this proportionality has a logarithmic behavior, so that a small variation in pH values leads to a major shift in the predominant form of the herbicide (molecular or ion).

This is a reality for Brazilian soils that have a pH range that include the pK of sulfentrazone (6.56), theoretically in two soils in the same climatic region with soil texture and organic matter equal but with the soil pH ranging from 5.5 to 7.2, the percentage of ionization would vary from 8.01 and 81.32% respectively, and may thus influence significantly the sorption of herbicides to soil colloids and in consequence, there are different persistence just for this variation in soil pH.
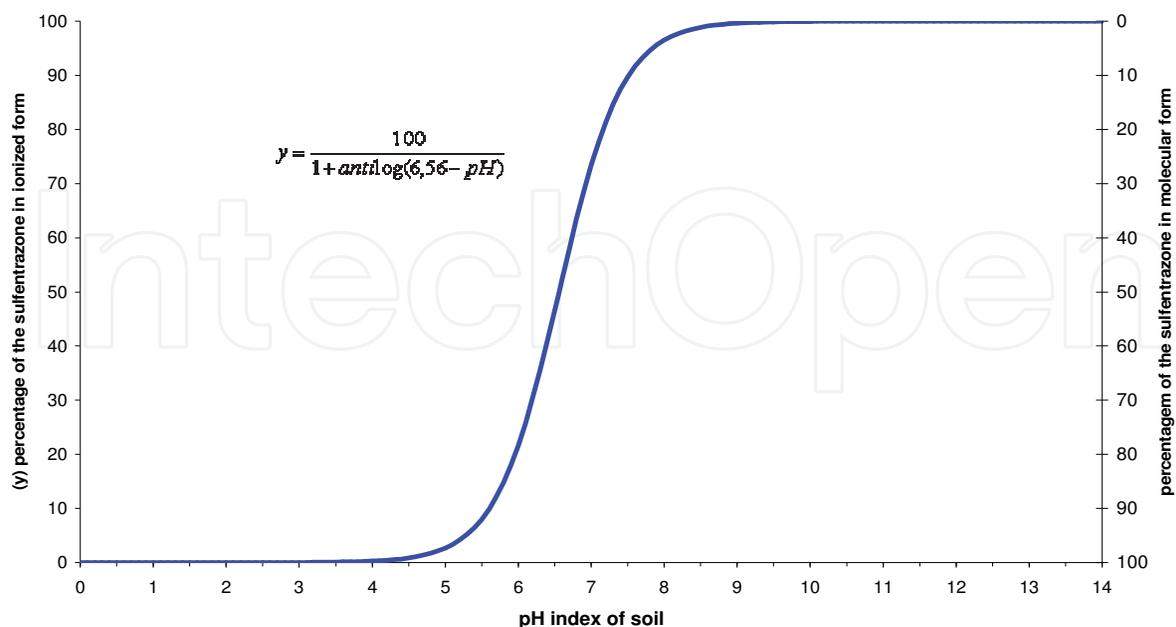
The chart shows the curve with the equation:

$$y = \frac{100}{1 + antilog(6,56 - pH)}$$

Fig. 1. Logistic model showing the ionization variation and molecular percentage of sulfentrazone (pk = 6.56), depending the content of the soil pH.

It should be noted that at low pH, even with a higher proportion of ionized form in the proton hydrogen (H^+) in soil solution competes with the ionized form of the herbicide by the site of sorption to soil colloids, so in many cases there is a greater sorption when soil pH is equal to the pK of the acid herbicide.

Reddy & Locke (1998), studying the sulfentrazone interaction on soil microorganisms using the labeled carbon method in the radical of the phenol molecule, found that after 77 incubation days, only 2.1% of 14 C-sulfentrazone were degraded by respiration edaphic to 14 CO_2, concluding that the native population of microorganisms edaphic had a small adaptation to the herbicide, could not dispel and degrade it, suggesting that this pathway is not the most efficient for their removal of the environment.

Chemical dissipation of the herbicide sulfentrazone is not yet fully understood, we know that does not show hydrolysis, photolysis are stable when applied to the soil, but extremely sensitive to this process in the water (EPA, 2011, Reddy & Locke 1998). All of these processes and factors influencing the sulfentrazone soil persistence.

3. Herbicides persistence in soils

Seeds of agricultural crops, when thrown to the ground, germinate at once and have slow initial growth in relation to the weeds. Herbicides applied directly on the ground need to persist in action on the ground with multiple streams of weed emergence (residual power) until the final limit of the critical competition period that for some crops is relatively long in Brazil.

For example, for the soybean crop in Brazilian conditions, this period is 30 to 50 days after emergence, while the sugarcane is planted in southeastern Brazil, at different periods during the year, the critical competition periods of varies according to these periods, a shorter period for spring and summer plantings, 15 to 60 days, and a longer, 60 to 90 days after emergence of seedlings, for autumn / winter planting because of drought that halts the growth of the plants until the next rain season (Blanco et. al 1978, 1979, 1981), so the herbicides used in this condition will persist for a long time with residual action to weeds in order to control their first flows allowing the plant to grow and expanding their leaves from parallel planting lines, shading the spacing of planting, controlling these plants through of light competition.

By definition, the persistence of herbicides in soil can be of three types, according to the method and objective of its biological, agronomic and chemical persistence determination. The biological persistence is determined by biological methods (bioassays) the time of the residue effect on living beings (bioactivity), in which case the agronomic persistence is determined using plant test, a biological persistence is individualized, therefore, measurements of the time that the herbicide residue with activity remains in soil can affect plants grown in a system of succession or rotation of crops. The chemical persistence concerns at time of the residue remains in soil that can be detected by chemical or radiometric methods.

The chemical methods (residues analysis) quantify the level of the herbicide while the biological (bioassay) qualify the presence of this, and in many cases this method is more sensitive, as all methodologies, advantages and limitations, and their use depend on the purpose of each test. Figure 2, show inferences about the persistence of herbicides in soil and their action.
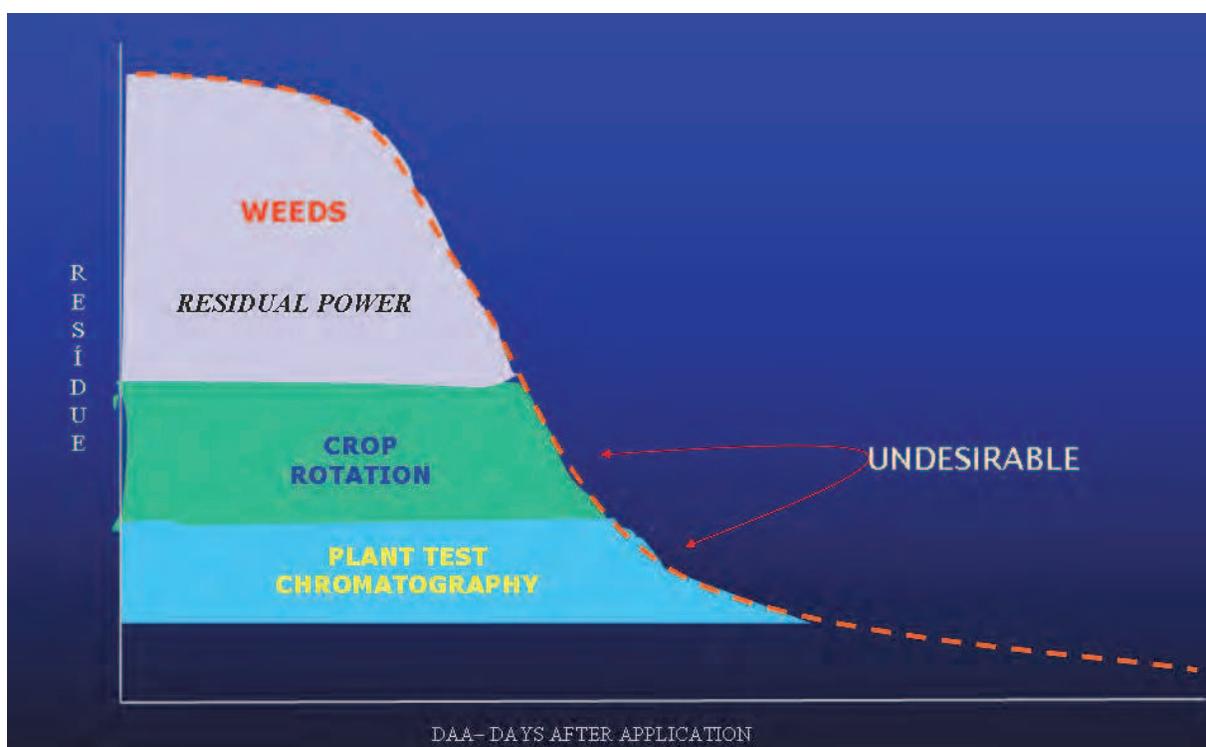

Fig. 2. Show a theoretical model by a logistic function, emphasis areas for action or method capable of detecting the herbicide, thus illustrating the decreasing variation of the residual herbicide in soil in time function (persistence).

We observe that the highest concentrations of the herbicide residues in soil correspond to the desirable effect of weed control (residual power). Over time, the herbicide concentration in soil decreases to levels that no weed control, but its concentration can affect crops in succession to that in which the herbicide was applied originally; their presence can be detected by symptoms of phytotoxicity expressed in these crops when they are sensitive. From this time, the residual level of the herbicide is very low, being detected only by plants with extremely susceptibility to the herbicide (plant test) or by analytical methods (eg chromatography). From this point, the concentration of herbicide in the soil is so low that current technology can not detect its presence on the ground.

Thus, the ideal herbicide would be that for which there is a coincidence of the final period of their persistence with the final period of the critical competition period the crop, a situation that unfortunately does not occur for current herbicides.
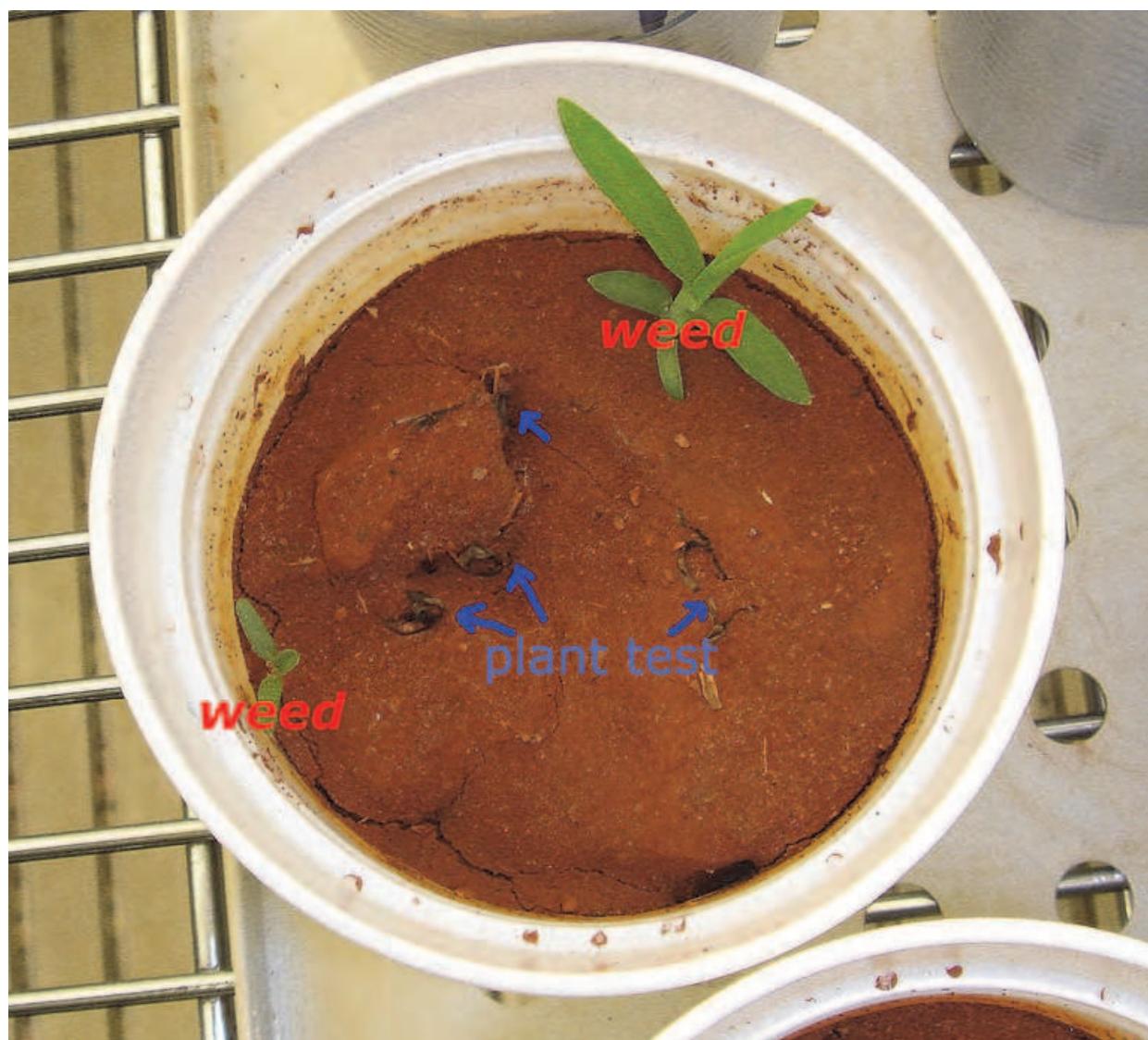

Fig. 3. Bioassay showing different action of the herbicide. Photo: Flávio M. G. Blanco.

Figure 3 explains the difference between persistence and residual power of the herbicide. Although the herbicide is present (persistent) in the soil, because it affects the plant test, does not affect the weeds, in this case the herbicide persists in the soil, but without power or residual effect on weeds.

Aiming aspects of selectivity for crops in succession to determine the persistence using the methodology to plant test is more efficient because the residual level in the soil did not affect the plant test, the more sensitive and also not cause injury to succession crops.

It should be emphasized that the use of results from ecotoxicological research, with aim to study the persistence of herbicides in soils in other countries (not Brazil) should be used with reservation, since different soil and climatic conditions often change the action of herbicides in soil, moreover, even when considering the Brazilian territory, it is difficult to extrapolate, for example, the results obtained in the Southeast to the Northeast Region.

In Brazil, the research works of herbicides in soils in agroecosystems are still few, especially when obtained under natural conditions of cultivation, such as the determination of persistence in the soil sulfentrazone, as well as its effects on cultures in a system of succession

3.1 Soil persistence of sulfentrazone in Brazilian conditions

3.1.1 Persistence determination by bioassays

Sulfentrazone herbicide is registered in Brazil for soybean, sugarcane, coffee and citrus. Belongs to the aryl-triazolinonas herbicide group, solubility of 780 mg L $^{-1}$ (pH $_7$), vapor pressure 1.10 $^{-9}$ mmHg (25 C^o), dissociation constant (pK) 6.56 and partition coefficient (Kow $_{(pH7)}$ 9.8), belongs to group aryl triazolinonas chemical, mode of action is to the destruction of cell membranes by inhibiting the enzyme Protox is the accumulation of protoporphyrin IX causing peroxidation of O_2 and consequently the destruction of cell membranes.

Rossi et al. (2003) using bioassays, evaluated the leaching of sulfentrazone (0.86 kg ha^{-1}), in two Brazilian soils (Red Nitosol and Neosoil Quartzarênico), in PVC columns; 0.10 and 0.50 m (diameter and length) using sorghum (*Sorghum bicolor*) under different rainfall regimes for 15 days, determined that over rainfall of 90 mm, the herbicide was detected by 7.5 and 12.5 respectively in Red Nitosol and Neosoil Quartzarênico soil.

These data are consistent with Vivian et al. (2006), also in brazilian conditions, investigating the actions of sulfentrazone, up to 20 cm deep, applied at the dosage of 0.9 kg ha^{-1} in sugarcane crop, determined with bioassays using sorghum as plant test, the leaching of herbicide was significant only on 0-10 cm layer of soil and persisted up to 467 days. However, when reapplying the herbicide in sugarcane crop, the order of persistence could not be determined, because until the last evaluation (640 days) the herbicide still persisted in the soil. In the same work, it was given the relationship of sorption (RA) in 3.6, indicating that this herbicide, when sorbed onto colloids, has a tendency for slow release into soil solution.

For new herbicides the difficulty is to determine which plant test should be used, especially when the group is composed of a few chemical elements. To determine the sensitivity, several mathematical models can be tested, to quantify and explain the phenomenon:

exponential, reciprocal, logistic, quadratic, cubic, Gompertz, exponential, quadratic and cubic, and others. The important aspect is not to analyze only the mathematical aspect of the model, such as the coefficient of determination that reflects the goodness of fit, but also the logic of biological phenomena, thus the choice of model will have a higher probability of success.

For Streibig et al. (1988, 1995), when compared with other methods for the detection of residues in agroecosystems, such as chromatography, the mathematical modeling studies using bioassay methods, is not fully standardized yet. There are several types of models, in the literature, to estimate the phenomenon, however, the authors indicate the logistic or log-logistic model as the most appropriate to explain the dependence of plant development with herbicide dose variation, and especially for calculating the RG 50 (herbicide dose that reduces growth by 50% of the plant). The same opinion is shared by Seefeldt et al. (1995).

Thus, Blanco (2002), using the bioassay method, tested two plant species, candidates as test plant for sulfentrazone herbicide, evaluating the biological responses of sorghum (*Sorghum bicolor*), cv AG 2002 and sugar beet (*Beta vulgaris*), cv. Early Wonder, exposed to a series of herbicide dilutions, growing for 14 days in 300 ml plastic cups, without percolation, with 250 g of soil with medium texture, kept at 80% of field capacity by daily watering in a fitotron Conviron® model PVG386, at 20° C, 70-80% relative humidity and photoperiod of 16 hours, light intensity of 35,400 lumens m^{-2}, to determine the dose that reduces 50% of their fresh weight of the epigeal part (RG 50%), using logistic function as the mathematical model (Fig. 4).
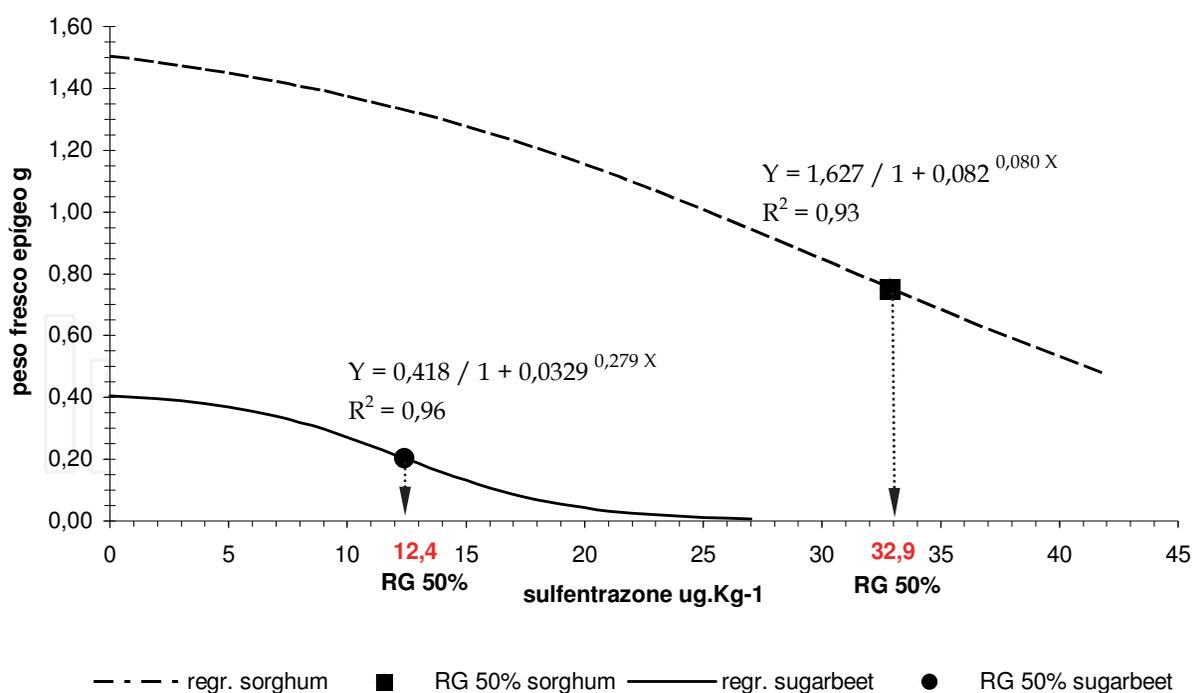

Fig. 4. Effect of increasing doses of sulfentrazone on epigeal fresh weight of sugar beet and sorghum and determination of the RG (50%) of each plant by logistic regression models, mean values of 10 replicates. (Blanco, 2002).

The analysis of the sensitivity of the plant test, using the methodology to evaluating the "fresh epigeal mass" instead of "epigeal dry mass," is due to feature of the herbicide, which belongs to the family of aryl triazolynonas, and is a desiccant, so, the methodology of evaluating the "epigeal dry mass," would tend to remove all differences between treatments, making all of them similar to the control, considering that a turgid leaf, when dried, can present the same symptoms (chlorosis, necrosis and desiccation) as a leaf treated with herbicide. Drying the plant material, it decreases the variability between treatments and, consequently, increasing the difficulty in finding significant differences between them, either by treatments analysis of variance (F test) or by an independent medium test

As observed in Figure 4, the logistic model adapts well to explaining the phenomenon, either by their biological logic - gradual reduction in mass with the increase of doses tested, as well as mathematical logic - high coefficients of determination, 0.93 and 0.96, showing excellent fit of the data to the chosen model. It should be noticed that to obtain the mathematical models, we used an appropriate number of observations, depending upon the extent of the analyzed data, fifteen and ten grain sorghum and sugar beet, respectively with a spacing between them of 3 µg of sulfentrazone, contributing to good accuracy of the obtained models

It is emphasized that the high light intensity, 35,400 lumens m^{-2}, and the photoperiod of 16 hours, for the bioassay, increased the sensitivity of the test plant, because sulfentrazone has its mode of action activated by the light intensity.

In figure 4, it is shown that both plants were very sensitive to the herbicide, notably beets with the highest sensitivity with RG (50%) equal to 12.4 µg.kg^{-1}, less than the half of the value observed to sorghum. Thus, the beet was used as the test plant for biological assays to determine the persistence of sulfentrazone in sugarcane and soybean crops in the proceedings of Blanco & Velini, 2005 and Blanco et al. 2010, described below.

3.1.2 Soil persistence of sulfentrazone applied in sugarcane crops.

Blanco et al. 2010, studying the sulfentrazone (0.6 and 1.2 kg ha^{-1}) in Brazilian conditions, soil pH 6.4 and organic matter, 11 g dm-3, using the bioassay method evaluating herbicide persistence under field conditions, the sugarcane crop until 704 days after treatment application, obtained the following biological responses for the plant test, described in the Figure 5.

During the test period, the soil was sampled in 23 seasons, immediately after application (0), up to 704 DAT, where the soil was sampled to determine the persistence by bioassay method, using sugar beet as test plant, growing for 14 days in a phytotron set at 20 ° C, 70-80% relative humidity and photoperiod of 16 hours, with light intensity of 35,400 lumens m^{-2}.

The climatic condition during the test is represented by figure 6.

The doses evaluated had different behavior dose of 0.6 kg ha^{-1} increased gradually from fresh epigeal not deferred test t$_{(p <5\%)}$ from the control 601 DAT by the end of sampling at 704 DAT. The dose 1.2 kg ha^{-1}, the averages of fresh epigeal also increased and differed significantly from the control, until the end of sampling.

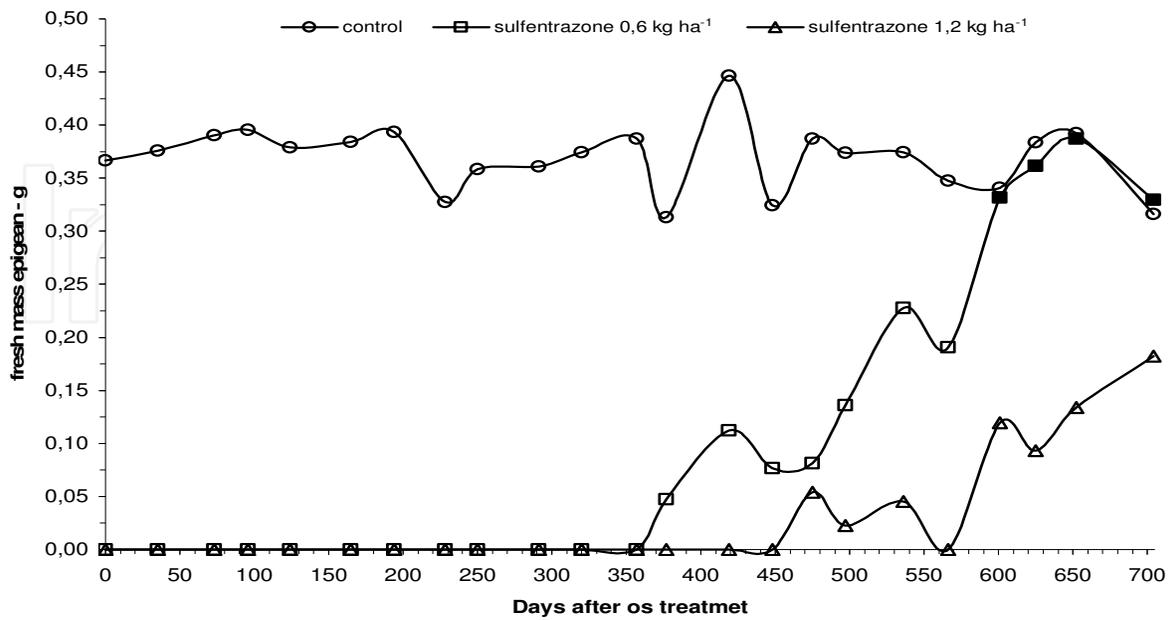Fig. 5. Temporal variation of fresh epigeal a function of days after treatment, ■ represents no significant difference (p> 0.005), compared with the control. Each symbol represents the mean value of 5 replicates (Blanco et al. 2010).
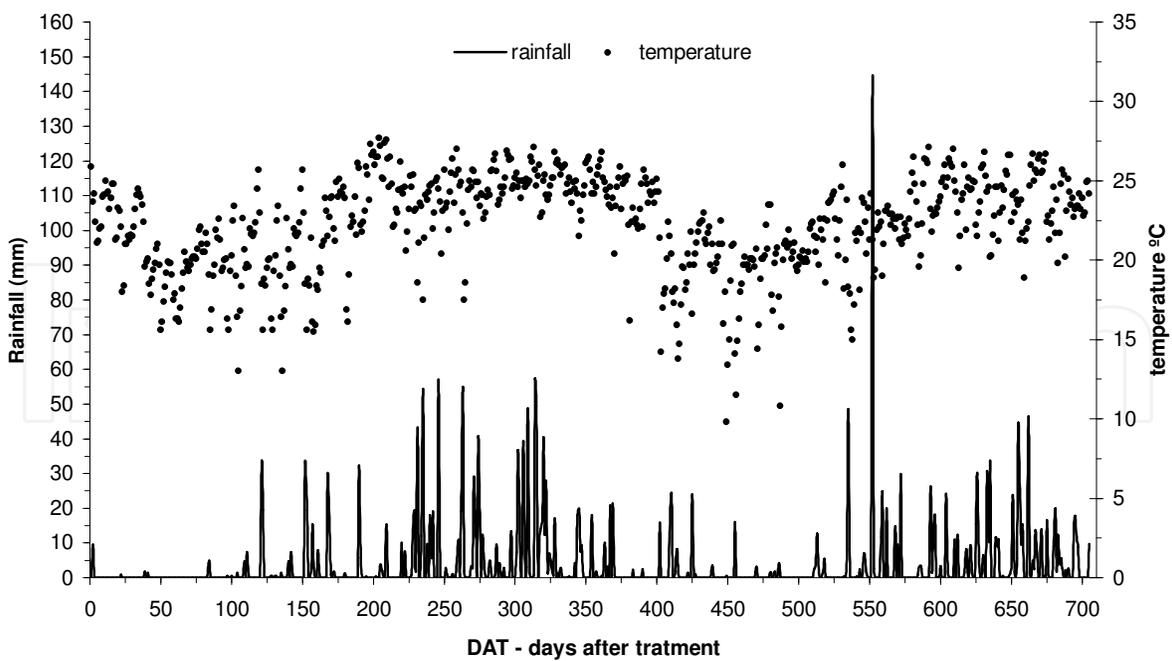

Fig. 6. Daily rainfall and average air temperature in the period from 30/03/2000 to 04/03/2002. (Blanco et al. 2010).

Through these values, we can determine the final limit of the persistence of the herbicide at 0.6 kg ha-1, 601 DAT, the highest dose was found this persistence has lasted over 103 days, signaling that the sulfentrazone persistence when applied at 1.2 kg ha-1, may exceed 704 DAT.

The timing of herbicide in early fall was characterized by a gradual decrease in rainfall and water content in soil, which benefited the herbicide sorption to soil colloids and discouraging the development of the microbial community, participatory processes dissipation herbicides (Alexander 1965; Weber 1970), it favored the retention of the herbicide in the soil, which would explain the lack of plant development in the first test ratings, which occurred only after 150 DAT, with the onset of rains and the increase in temperature, remaining until 450 DAT.

This condition favored the development of the microbial community and the desorption of the herbicide to the colloids, thus making it available to the dissipative processes (Blanco, 1979, Walker and Allen, 1984; Reddy and Locke, 1998), reducing its concentration in the soil and thus the beginning of the first plant test germination, the DAT 377 and 475 for treatments 0.6 and 1.2 kg ha-1, respectively (Figure 1).

However, the increase in temperature and precipitation was only sufficient to that the herbicide was dissipated partly because after the dry season (448-556 DAT) was necessary to even more a rainy season (550 until 704 DAT), so that there were further dissipation of the herbicide and progressive reduction of their concentration in the soil, notably for the dose of 0.6 kg ha-1, where it was possible to determine the end of the persistence of sulfentrazone, the highest dose was also detected by this plant test until the end of the evaluations, at 704 DAT.

3.1.3 Soil persistence of sulfentrazone applied in soybean and its effect on crops rotation

Blanco & Velini, 2005 studying the persistence of sulfentrazone applied in soybean cv. Embrapa 48, at the same doses of the test previously described , 0.6 and 1.2 kg ha-1, pH 5.8 and soil organic matter content of 43 g dm-3, using the same bioassay method, also evaluated the effect of this herbicide on five crops in succession: millet cv. Italian and oats cv. White, wheat cv. IAC 24, sunflower cv. Uruguay and kidney bean cv. Carioca, under field conditions for 539 days after the treatments. The biological response of the beet test plant for persistence of the herbicide is described in Figure 7.

The Figure 7 shows the results of the action of sulfentrazone on the beet plant test; it is observed that when the test was carried out with the soybean crop, there were six samples and from these, the growth of beet plants was observed only in the control treatment. After the soybean harvest, it was initiated the preparation of the area for planting crops in rotation, at 159 DAT. Despite all the procedures for preparing the soil for planting, it was found that the management was not sufficient to dissipate the herbicide. The results of the bioassays from samples collected from each culture, at the harvest 278 DAT (oats, beans and millet), 286 DAT (wheat) and 305 DAT (sunflower), demonstrated that the persistence of the herbicide was not influenced by crop type neither by specific cultivation practices that were undertaken for each crop.
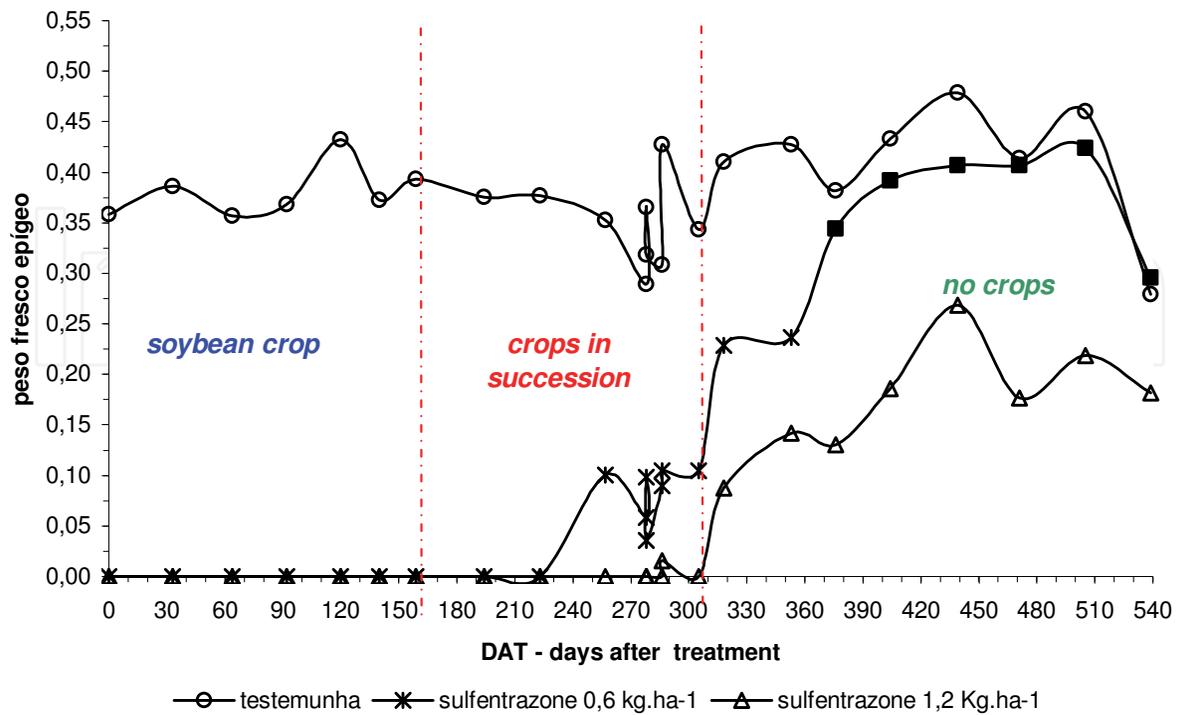
Fig. 7. Temporal variation of fresh epigeal a function of days after treatment, ■ represents no significant difference (p> 0.005), compared to control. Each symbol represents the mean of 5 repetitions (Blanco & Velini, 2005).

In all samplings, tests of means (*t* test at 5% probability) were carried out contrasting the control treatment with herbicide doses in each season. The results indicated that only for the lowest dose, from 376 DAT, there was no significant difference to the control until the end of the test (539 DAT). For this reason, 376 DAT can be defined as the final limit of sulfentrazone persistence at the dose of 0.6 kg ha⁻¹. At the highest dose used, the fresh weight of the plant test was significantly lower than that of the control, in all evaluated periods, indicating that, for the dose of 1.2 kg ha⁻¹, the final limit of persistence was not achieved, thereby; the persistence of sulfentrazone, in soil in this case, was longer than 539 days after herbicide application.

Figure 8 shows the rainfall and average temperature during the research work.

The soil where the assay was carried out showed a high content of organic matter (43 g dm3) and clay (46.3%), this fact combined with the predominant molecular form (85.2%) of the be herbicide, favored the sorption of the herbicide to soil colloids (Weber 1970, Grey et al., 1997). However, as the herbicide was sprayed in the summer, characterized by frequent rainfall and high temperatures (Figure 6), the conditions were not favorable for the herbicide sorption to the soil colloids, but tending to stay in the solution available for dissipative processes and leaching (Briggs, 1976; 1984; Weber, 1970; Walker & Allen, 1984).

This condition was maintained until 80 DAT, the period when due to the dry season, there was the most favorable condition for the herbicide sorption to the colloids, until 200 DAT, when a new rainy condition favored the persistence of the herbicide in the soil solution and subjected to the dissipative processes and leaching. This argument is strengthened by, the
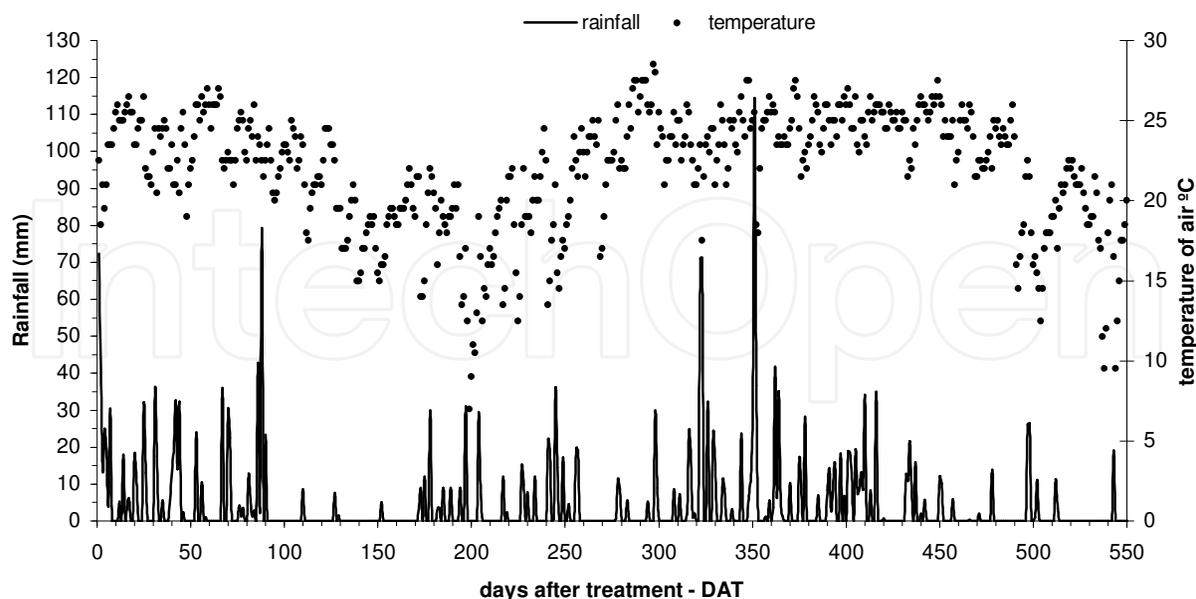
Fig. 8. Daily rainfall and average air temperature in the period from 13/01/2000 to 04/07/2001 (Blanco & Velini, 2005).

first occurrences of test plants in the bioassays at the initial phase of this period, indicating the beginning of the herbicide dissipation.

This condition of high intensity and abundance of rainfall and high temperatures was maintained until almost the end of the assay, at 500 DAT, was favorable to the dissipation of the herbicide, and it was possible to define the limit of the persistence of sulfentrazone in its lowest doses, at 376 DAT. After this period, the weather conditions changed to dry, with cool temperatures, characteristic of the end of the experiment (fall/winter). This phase was favorable to the herbicide sorption to the soil colloids, becoming not available to the processes of dissipation and thus the herbicide residue level in the soil was able to affect significantly the test plant,not being able to detect the final limit of the persistence of sulfentrazone at the highest dose, 1.2 kg ha-1.

For the persistence data obtained in this experiment, beyond the Ecotoxicological aspects, it is important to notice that after the harvest of soybean crop, there were still residues of the herbicide in a reasonable concentration in the soil, resulting in two immediate risks for the crops in succession to soybean: injuries to sensitive crops and when the crop is tolerant to the herbicide, if the same chemical is used for weed control, as it was already present in the soil, there may be an initial concentration higher than the tolerance threshold level and cause damage to the crop that would theoretically be tolerant to the herbicide. To evaluate the selectivity of sulfentrazone on soybean crops in succession, several development parameters of these crops were measured at different periods: visual symptoms of phytotoxicity, stand, height, leaf area, leaf number, fresh and dry weight and also production.

Analysis of the results showed that sulfentrazone, independent of the dose, affected the millet and oat development. On the other hand, for sunflower and bean crops, the variance

analysis showed that the treatments were not significant, thus demonstrating the selectivity of this herbicide for these crops. For wheat crop, the selectivity of the herbicide was variable according to the dose tested. It was selective for the lowest dose and not selective for the highest dose, 0.6 and 1.2 kg ha^{-1}, respectively

4. Conclusion

The methodology of bioassays for the detection of residues of sulfentrazone in soil is adequate.

The herbicide when applied in the cultivation of sugarcane cv. SP8018160 and soybean cv. Embrapa 48 shows long persistence in the soil and affects significantly the development of millet cv. Italiano and oats cv. White and wheat cv. IAC 24 (at 1.2 kg ha^{-1}) in soybean rotation, however, for sunflower cv.Uruguay and kidney bean cv . IAC Carioca and wheat cv. IAC 24 (dose 0.6 kg ha^{-1}), sulfentrazone does not affect the development of these plants.

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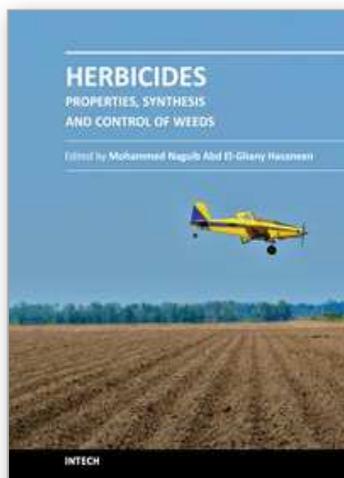
Herbicides - Properties, Synthesis and Control of Weeds

Edited by Dr. Mohammed Nagib Hasaneen

This book is divided into two sections namely: synthesis and properties of herbicides and herbicidal control of weeds. Chapters 1 to 11 deal with the study of different synthetic pathways of certain herbicides and the physical and chemical properties of other synthesized herbicides. The other 14 chapters (12-25) discussed the different methods by which each herbicide controls specific weed population. The overall purpose of the book, is to show properties and characterization of herbicides, the physical and chemical properties of selected types of herbicides, and the influence of certain herbicides on soil physical and chemical properties on microflora. In addition, an evaluation of the degree of contamination of either soils and/or crops by herbicides is discussed alongside an investigation into the performance and photochemistry of herbicides and the fate of excess herbicides in soils and field crops.

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