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Movement of Bromacil and Norflurazon in a Sandy Soil in Florida

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Bromacil (5-bromo-3-sec-butyl-6-methyluracil) and norflurazon [4-chloro-5-(methylamino)-2-(α,α,α-trifluro-m-tolyl)-3(2H)-pyridazinone] are commonly used for weed control in Florida citrus groves at rates which vary from 1.8 to 7.2 kg/ha for bromacil and from 4.5 to 9.0 kg/ha per year for norflurazon, depending upon tree age, soil type, and the weed population and density. These herbicides may be subject to considerable leaching in the porous (90% or more sand) soils of Florida which also have low organic matter contents. Leaching is further enhanced by rainfall or irrigation particularly for compounds that are highly water soluble. As a result, some sources of ground and well water have been found to be contaminated in Florida with pesticides. Herbicides may be contributing to this problem, but studies which have included bromacil and norflurazon have focused on their efficacy regarding weed control in citrus (Ryan 1966; Singh and Tucker 1984). A limited amount of work has been devoted to quantifying soil residues and their movement (Tucker and Phillips 1969; Tucker 1978). Baumann et al. (1981) have reported that norflurazon was more mobile than fluridon and the mobility increased with decreased clay content. Lo and Merkle (1984) reported that norflurazon was more phytotoxic in soils having higher sand and low organic matter contents. Similar results have been reported by Houge et al. (1981) and Gerstl and Yaron (1983). Weber and Whitacre (1982) reported higher mobility of bromacil than buthidazole and both were more mobile than less water-soluble herbicides such as atrazine, prometon, and diuron. Mobility of five thiocarbamate herbicides in soil was found to be directly correlated with water solubility (Gray and Weirich 1968; Koren et al. 1967). Similar correlations between solubility and leaching of herbicides have been reported by Baker et al. (1966). Horowitz (1968) reported greater amount of bromacil leaching with increased amount of water.

One method of following herbicide movement in soil is by bioassay utilizing a plant indicator (Crafts 1935). The bioassay method has also been used to develop standard curves

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for converting indicator plant dry weight to herbicide concentrations. Rodriguez (1984) and Leela (1984) have used rice and cucumber plants in bioassay for detecting bromacil and other herbicides in soil. The objective of this investigation was to follow by bioassay, movement of bromacil and norflurazon in a sandy soil that is widely planted to citrus in Florida.

MATERIALS AND METHODS

Astatula fine sand soil (96.5% sand, 2.0% silt, 1.5% clay, and 0.6% organic matter) free of herbicide residues was collected from a citrus grove near the experiment station and placed in metal pots (35 cm diameter, 50 cm deep) so that the original profile is established. The soil was saturated with water for compaction. Bromacil at 3.36 and 6.72 kg/ha and norflurazon at 4.48 and 8.96 kg/ha were applied to the saturated soil surface. An untreated pot was maintained as control. Each treatment was applied to a single pot. Treatments and the control were replicated four times and arranged randomly in four blocks. These rates are equivalent to one and two times the recommended rate for weed control in citrus groves. The herbicides were applied in water at a volume equal to 1000 ℓ/ha. The pots were maintained outdoors. Samples were collected during June and July of 1983. Rainfall during this period was 36 cm. An additional 60 cm of water was applied to each pot during the same period.

Soil samples from each pot were collected at 2, 4, 6, and 8 weeks after application using a tube type soil sampling auger. A 30 cm acetate tube (2.2 cm diameter) was placed in the sampling tube to obtain undisturbed soil sample to a depth of 30 cm. This 30 cm soil sample was then cut into 7.5 cm subsections. Each subsection was placed in a petri dish for bioassays, using ryegrass (Lolium multiflorum Lam.) as the indicator plant. Twenty-five ryegrass seeds were placed in each petri dish and incubated at 25°C with a 14 hr, 100 $\mu E \cdot m^{-2} \cdot s^{-1}$ photoperiod. Water was added to the soil as needed. Ryegrass seeds were allowed to germinate and grow for 2 weeks. Upon harvesting, the seedlings were dried at 70°C for 48 hr and weighed. The weights were converted as percent of untreated control. All treatments were replicated four times and the results were subjected to analysis of variance with mean separation by a least significant difference comparison.

In order to relate ryegrass dry weight to herbicide concentration, a standard curve was generated by germinating and growing ryegrass seeds in Astatula soil containing various amounts of the herbicide for 2 weeks under the same conditions as described above. Each petri dish in these experiments contained 100 g of soil and appropriate amounts of herbicide solutions were added to the soil to give final concentrations of up to 10 ppm. Control dishes received no herbicide (Fig. 1). The relationship was developed between the dry weight of

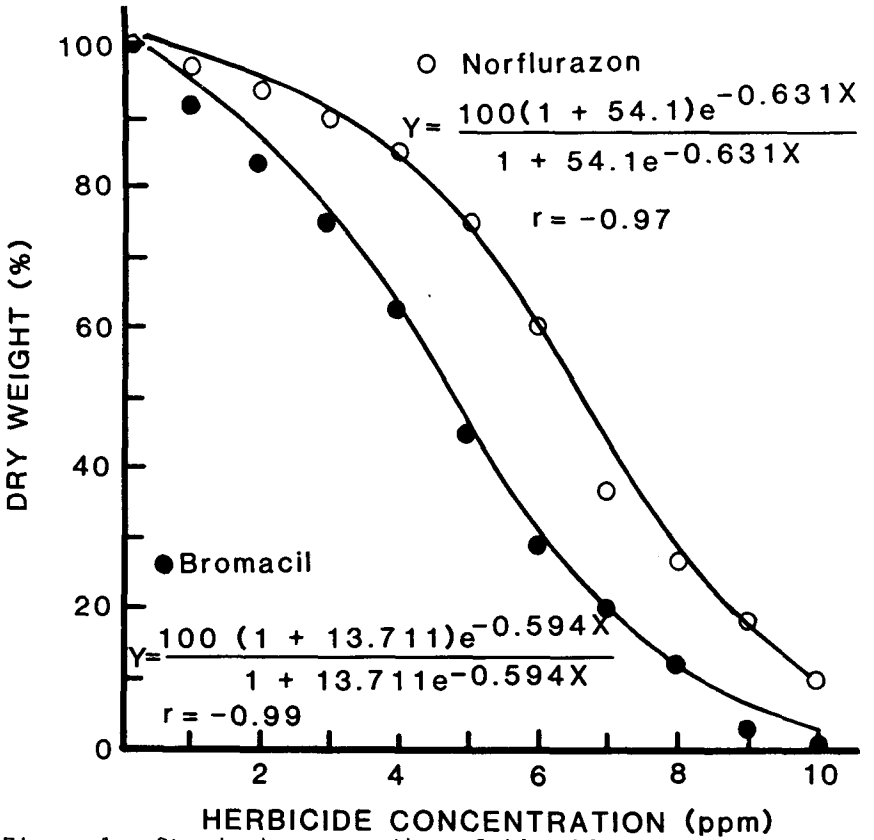

Figure 1. Standard curve: the relationship between dry weight of ryegrass and herbicide concentration.

ryegrass as percent of untreated control and herbicide concentration.

RESULTS AND DISCUSSION

The results are presented on the basis of ryegrass dry matter production in herbicide treatments as percent of untreated control. Herbicide concentrations are estimated by extrapolating the dry matter on standard curve which was developed with known herbicide concentrations (Fig. 1).

Ryegrass seedling dry weight was 24% (of control) when germinated and grown in sandy soil collected from 0 to 7.5 cm depth that had been previously treated with bromacil at 3.36 kg/ha. This 24% dry weight accumulation by ryegrass reflects about 7 ppm bromacil present in the soil 2 weeks after application. Over the next 6 weeks, the decline in growth due to the herbicide in this 0 to 7.5 cm deep soil steadily dropped and by the eighth week, the seedling growth was restored to 90% of the control (equivalent to 1 ppm; Fig. 2a). This coincides with the further downward movement of bromacil in the soil. Two

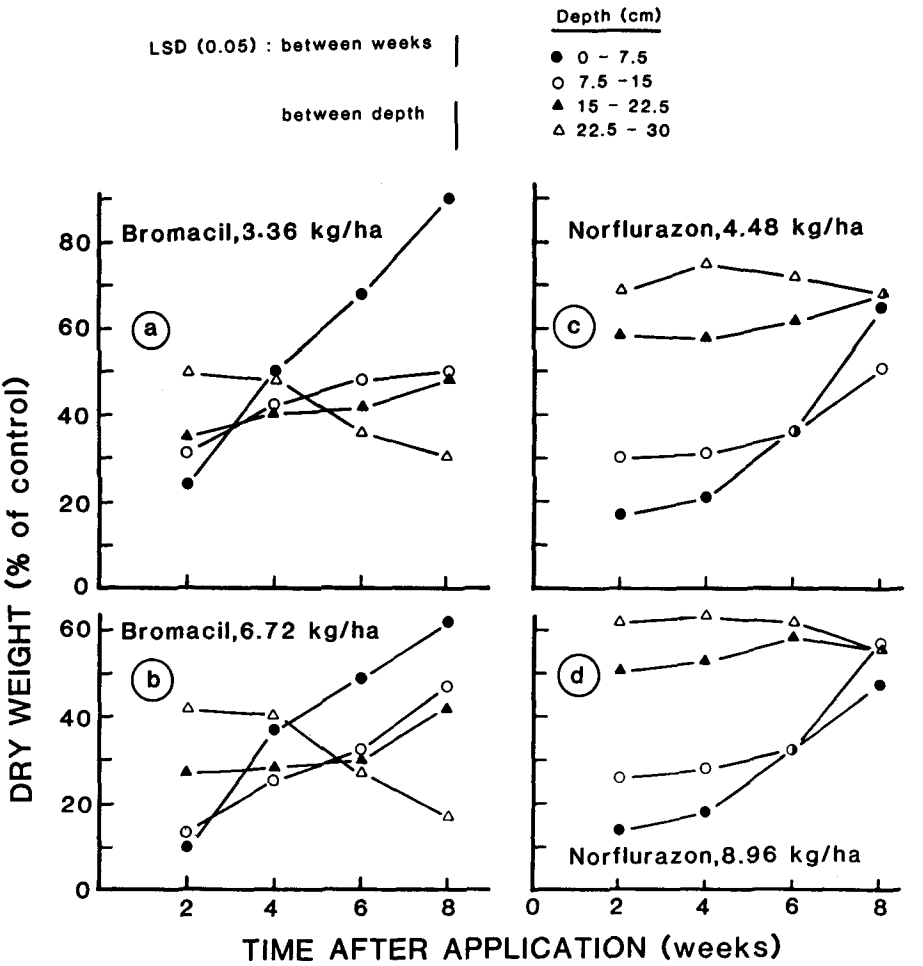

Figure 2. Dry weight of ryegrass as influenced by bromacil and norflurazon at various depths and time after application.

and 4 week soil samples obtained at depths of 22.5 to 30 cm had about 5 ppm (50% growth) and thereafter the herbicide accumulated in greater amounts. By the eighth week, about 6.5 ppm (30% growth) was detected at this depth. Both 7.5 to 15.0 cm and 15 to 22.5 cm deep soil samples contained about 6.5 ppm (about 33% growth) 2 weeks after application, and by the end of 8 weeks, the amount fell to about 5 ppm (50% of growth) in these soils. This general pattern of bromacil movement was unchanged when the application rate was doubled (6.72 kg/ha). Because of high herbicide concentration applied to the soil, the herbicide detected at various soil depths was accordingly greater, as revealed by ryegrass growth inhibition (Fig. 2b). Soil collected at 7.5 to 15.0 and 15 to 22.5 cm depths 4 and 6 weeks after application contained 6.5 ppm and at 8 weeks after application, the amount dropped to 5 ppm.

Most of norflurazon activity was located in the top few centimeters of the soil (Fig. 2c and 2d). For example, the top 15 cm of soil contained 8 to 9 ppm norflurazon 4 weeks after application. By the end of 6 weeks, the amount was still about 7.5 ppm. By the end of 8 weeks, norflurazon detected was 5 ppm in the 0 to 7.5 cm deep soil as compared to 6.5 ppm in the 7.5 to 15 cm deep soil (Fig. 2c). This pattern of norflurazon distribution at various depths vs. time was similar when the herbicide rate was doubled (Fig. 2d). Soil samples collected from both low and high norflurazon rate treated soils at greater depths (22.5 to 30 cm) did not reveal significant changes in phytotoxicity between 2 and 8 week periods. The activity, however, appeared to increase in this deep soil 4 weeks after application with a concomitant decrease in 15 to 22.5 cm deep soil.

Both bromacil and norflurazon activities detected were similar in soils collected 2 weeks after application. Subsequently, the movement of bromacil was faster than norflurazon. In the top 0 to 7.5 cm deep soil, norflurazon detected was about 5 ppm (65% growth) at 4.48 kg/ha and 6.5 ppm (50% growth) at 8.96 kg/ha, as compared to about 1 ppm (90% growth) at 3.36 kg/ha and 4 ppm (60% growth) at 6.72 kg/ha bromacil 8 weeks after application.

This study shows that norfluorazon remained in the top layers of soil considerably longer than did bromacil. This is a reflection of much lower water solubility of norflurazon and hence its slower movement by leaching. Water solubilities of bromacil and norflurazon are 815 and 28 ppm, respectively. Tucker (1978) reported that under field conditions in Florida citrus groves, bromacil was more evenly distributed throughout the profile depth as compared with diuron. High concentrations of diuron were consistently found in the surface layers because diuron is less soluble (42 ppm) in water and did not leach as rapidly as bromacil. The fact that norflurazon remained in the surface of the soil profile for longer periods would allow for greater volatilization and photodecomposition. Volatilization and photodecomposition have been shown to be factors responsible for norflurazon dissipation when the compound is exposed on the surface of the soil (Anonymous 1983). In the case of bromacil, such losses from soil are negligible and leaching may be a main cause and microbial degradation may be a secondary cause of its disappearence from soils.

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