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EFFECT OF PREEMERGENCE HERBICIDES ON CITRUS ROOTSTOCK AND LIVE OAK SEEDLINGS

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Abstract. **Greenhouse studies were conducted to evaluate the response of citrus rootstocks and live oak seedlings to a single soil application of herbicides. Herbicides included in these studies were: Hyvar-X (bromacil), Direx (diuron), Surflan (oryzalin), Solicam (norflurazon), Princep (simazine), Mandate (thiazopyr), and Goal (oxyfluorfen).**
High rates of herbicides reduced shoot and root growth of citrus seedlings, especially for bromacil. Mild toxicity symptoms do not result in permanent growth reduction. Seedlings exhibited greater phytotoxicity symptoms for bromacil than diuron. Rootstock differences were also noted with Carrizo citrange being more sensitive to bromacil than Swingle citrumelo.
Seedling growth and survival of live oak were effected by bromacil, diuron, and norflurazon.

Various studies have been conducted to determine the effects of herbicide application on the growth of citrus seedlings (Currey et al., 1977; Castle and Tucker, 1978; Tucker and Youtsey, 1980; Singh and Tucker, 1983, 1984; Singh and Achhireddy 1984; Reddy and Singh, 1993). Most nurseries use some form of chemical weed control due to the unavailability and high cost of hand labor for weeding operations. Many of the herbicides currently registered for use in citrus groves lack recommendations for nurseries. Weed control in Florida's citrus nurseries accounts for a significant portion of the annual production cost. Weeds compete with the citrus nursery stock for water, nutrients, and light and influence environmental conditions and ease to provide horticultural task to the young citrus seedling. Trees damaged with herbicides will remain smaller than uninjured trees (Jordan et al., 1992).

Three studies (beginning in July 1995) were conducted in the greenhouse to examine the effects of herbicide applications on young citrus rootstock seedlings over a period of 18 months. While all the herbicides used in this study were registered for use in commercial citrus groves, not all products contain information about the safety of product use on young citrus rootstock seedlings and budded trees or the herbicide use in citrus nurseries. Safety information concerning the use of herbicide products near oak trees is also important, since their roots may extend into properties that contain citrus groves treated with herbicides.

The objective of the studies was to evaluate the effect of each preemergence herbicide on growth of citrus and live oak seedlings.

Materials and Methods

Study 1. Rootstock/Herbicide Interaction

The seven rootstocks evaluated for phytotoxicity were Carrizo citrange (*Citrus sinensis* (L.) Osbeck × *Poncirus trifoliata* (L.) Raf.), Swingle citrumelo (*Citrus paradisi* × *Poncirus trifoliata*), Cleopatra mandarin (*Citrus reticulata* Blanco), Benton citrange (*Citrus sinensis* (L.) Osbeck × *Poncirus trifoliata* (L.) Raf.), Smooth Flat Seville (putative hybrid), Sun Chu Sha mandarin (*Citrus reticulata*) and Volkamer lemon (*Citrus volkameriana* Ten. and Pasq.). The herbicides and rates used in the study were: bromacil, diuron, norflurazon, oryzalin at 0.8, 1.2, 1.6 lb a.i./acre; oxyfluorfen at 0.4, 0.6, 0.8 lb a.i./acre; simazine at 0.9, 1.35, 1.8 lb a.i./acre; and thiazopyr at 0.163, 0.244, 0.325 lb a.i./acre.

Study 2. Rootstock/Herbicide Interaction

This study was conducted to determine the herbicide effects on Carrizo citrange and Swingle citrumelo rootstocks, which currently represent about 75% of the rootstock propagations in Florida citrus nurseries. The herbicides used were: bromacil, diuron, norflurazon, oryzalin at 1.6, 3.2, 6.4 lb a.i./acre; oxyfluorfen at 0.8, 1.6, 3.2 lb a.i./acre; simazine at 1.8, 3.6, 7.2 lb a.i./acre; and thiazopyr at 0.325, 0.65, 1.3 lb a.i./acre. Higher herbicide rates were used since no herbicidal effects on rootstocks were detected in the previous study.

Live oak (*Quercus virginiana*) seedlings were also included in the study. Statements currently appear on the bromacil label about injury to or loss of desirable trees that can result when the material is either applied or moved into contact with desirable tree roots (du Pont, 1995).

Study 3. Rootstock/Herbicide Interaction

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A third study was conducted to determine the effect of bromacil or diuron on five citrus rootstocks since Carrizo and Swingle exhibited different responses to these herbicides in Study 2. The five rootstocks in Study 3 were Carrizo citrange, Swingle citrumelo, Cleopatra mandarin, Sun Chu Sha mandarin (SCS), and Smooth Flat Seville (SFS). Bromacil or diuron were applied at 1.6, 3.2, 4.8 or 6.4 lb a.i./acre rates.

In all three studies seedlings were grown in the greenhouse for 45 days prior to the herbicide treatment. The surface area of the container was measured to calculate the amount of herbicide to apply to provide the required active ingredient per acre (a.i./acre). A stock solution was made that allowed the required amount of herbicide to be applied in a solution of 1.7 fluid ounce (fl oz) (50 ml) per container and poured on the soil in a single application, thus providing an even distribution of the required herbicide material. Plants were watered and fertilized as needed to maintain adequate seedling growth.

In Study 1, seedlings of each rootstock were individually potted into one quart (0.946 liter) styrofoam cups containing unsterilized Candler sand (Hyperthermic, uncoated Typic Quartzipsamments). The study was conducted in a randomized block design replicated four times. In Studies 2 and 3, seedlings were planted in 1 gallon (3.8 liter) black plastic pots with a diameter of 6.5 inches (16.5 cm) and a depth of 6.5 inches. The pots contained a drain hole in the bottom as well as four holes located around the sides. Prior to adding the soil approximately 1 inch (2.5 cm) of river rock was added to the bottom of the pots. The unsterilized potting soil was an Apopka fine sand (Loamy, siliceous, hyperthermic Grossarenic Paleudults) collected from an area next to a citrus grove at the Citrus Research and Education Center (CREC) in Lake Alfred Florida, in Study 2 and a Chandler sand in Study 3. The experimental design was a randomized block design replicated four times for each seedling type.

In Study 2, after 45 days and prior to herbicides being applied to the soil surface, individual seedlings were randomly assigned to each treatment with each treatment rate (low, medium, or high) being placed on a given bench containing the two types of citrus and the live oak seedlings. Study 3 improved the blocking design to place one of each treatment on a given bench to improve design and results obtained.

Results and Discussion

In Study 1, at 70 days after treatment (DAT) no clear trends in plant growth differences or phytotoxicity symptoms were noted, hence results are not presented as the herbicide rates were not high enough to be a limiting factor for plant growth.

Due to the design of Study 2, results reported for that experiment showed differences that are attributed to both replication and herbicide effects; i.e., all treatments for a given rate were placed on a single bench in the greenhouse. However, it is felt that in most cases the major difference resulted from the herbicide because the benches are quite close together in this greenhouse, thus minimizing the differences due to replication. At 70 DAT none of the seven herbicides decreased seedling fresh shoot weights of Carrizo citrange significantly (Table 1). However, bromacil at the medium and high rates and diuron at the high rate caused veinal chlorosis. Bromacil at the high rate had 24% of the foliage of Carrizo with slight to moderate veinal pattern and 7% at the medium rate with slight veinal patterns (Table 1). Diuron at the high rate had 20% of

Table 1. Effect of preemergence herbicide on the growth and foliage conditions of Carrizo citrange rootstock seedlings in Study 2.

		Fresh wt. (grams)[z]		Foliage conditions
Herbicide	lb a.i./acre	Shoot	Root	70 DAT with % veinal pattern noted
bromacil	1.60	32.98 a	24.49 b-f	All normal
	3.20	34.57 a	27.55 abc	7% slight
	6.40	28.74 a	20.42 ef	24% slight to moderate pattern
diuron	1.60	35.72 a	27.50 abc	All normal
	3.20	33.14 a	25.24 b-f	All normal
	6.40	37.11 a	24.32 b-f	19.5% slight to moderate pattern
oryzalin	1.60	32.68 a	21.50 def	All normal
	3.20	33.75 a	28.00 ab	All normal
	6.40	34.10 a	23.81 b-f	All normal
thiazopyr	0.33	33.83 a	21.19 def	All normal
	0.65	26.69 a	26.72 bcd	All normal
	1.30	35.82 a	23.27 b-f	All normal
norflurazon	1.60	32.61 a	21.97 c-f	All normal
	3.20	37.77 a	22.72 b-f	All normal
	6.40	35.84 a	19.93 f	All normal
simazine	1.80	34.48 a	27.44 abc	All normal
	3.60	31.18 a	25.96 b-e	All normal
	7.20	31.95 a	24.51 b-f	All normal
oxyfluorfen	0.80	32.55 a	28.43 ab	All normal
	1.60	33.23 a	33.20 a	All normal
	3.20	34.63 a	25.00 b-f	All normal
control		31.47	28.63	All normal

[z]Within a column, mean followed by the same letter do not significantly differ (Waller-Duncan, 5% level of significance).

Table 2. Effect of preemergence herbicide on the growth and foliage conditions of Swingle citrumelo rootstock seedlings in Study 2.

Herbicide	lb a.i./acre	Fresh wt. (grams)[z] Shoot	Fresh wt. (grams)[z] Root	Foliage conditions 70 DAT
bromacil	1.60	41.32 abc	26.46 b-e	All normal
	3.20	41.92 abc	28.89 bc	All normal
	6.40	39.89 abc	22.31 e	7% leaves with veinal patterns
diuron	1.60	43.64 ab	30.40 b	All normal
	3.20	38.11 bc	26.23 b-e	All normal
	6.40	46.39 a	27.62 bcd	All normal
oryzalin	1.60	41.56 abc	26.69 b-e	All normal
	3.20	39.08 abc	40.25 a	All normal
	6.40	43.76 ab	26.69 b-e	All normal
thiazopyr	0.33	41.64 abc	25.28 cde	All normal
	0.65	43.19 ab	36.64 a	All normal
	1.30	41.63 abc	28.97 bc	All normal
norflurazon	1.60	36.12 bc	25.08 cde	All normal
	3.20	38.17 bc	27.02 b-e	All normal
	6.40	40.75 abc	23.41 de	All normal
simazine	1.80	41.91 abc	28.51 bc	All normal
	3.60	40.91 abc	24.99 cde	All normal
	7.20	43.73 ab	28.19 bcd	All normal
oxyfluorfen	0.80	40.17 abc	30.87 b	All normal
	1.60	35.28 c	30.29 b	All normal
	3.20	46.53 a	28.70 bc	All normal
control		40.82	32.40	All normal

[z]Within a column, mean followed by the same letter do not significantly differ (Waller-Duncan, 5% level of significance).

the foliage exhibiting slight to moderate veinal patterns on Carrizo seedlings. Increasing rates of both bromacil and diuron, increased the incidence of foliar patterns. Carrizo has been previously reported to be more sensitive to herbicides than Swingle (Singh and Achhireddy, 1984). However, 70 DAT the products did not cause decreases in seedling growth as measured by fresh shoot weight. Additionally, as new growth emerged on the seedlings toward the end of the treatment period, evidence of foliar patterns was less than had been noted on earlier flushes.

As with Carrizo citrange rootstock, the seven herbicides had little negative effect on the fresh shoot or root weights of Swingle citrumelo at 70 DAT (Table 2). The only herbicide that produced visible phytotoxicity symptoms was bromacil at the high rate on 7% of the leaves.

Carrizo had a greater number of leaves with veinal patterns than Swingle at the high and medium rates of bromacil and at the high rate of diuron. This difference between Carrizo and Swingle has been previously reported (Castle and Tucker, 1978). Those findings indicated a higher numerical mean injury score rating for Carrizo than for Swingle at first rating, however, the scores were not statistically different. That data also agreed with this study in that bromacil produced greater injury to citrus nursery trees than diuron when used at the same lb a.i./acre.

The herbicide effects on the growth of live oak seedlings (Table 3) were quite different from those for the citrus seedlings (Tables 1 and 2). Bromacil, norflurazon and diuron had the greatest negative effect on both fresh shoot and root weight and on the foliage appearance of the live oak seedlings. The high rates of bromacil, norflurazon, and diuron resulted in some seedling mortality. At the low rate of bromacil, 50% of the seedlings died with the remaining 50% severely necrotic; at the medium rate, 75% died and 25% were severely necrotic; and at the high rate, 50% died and 50% were severely necrotic. For norflurazon, at the low rate and

Table 3. Effect of preemergence herbicide on the growth and foliage conditions of live oak seedlings in Study 2.

Herbicide	lb a.i./acre	Fresh wt. (grams)[z] Shoot	Fresh wt. (grams)[z] Root	Foliage conditions[y] 70 DAT
bromacil	1.60	2.09 ghi	6.78 f-i	D-2 E-2
	3.20	0.37 i	4.90 hi	D-1 E-3
	6.40	0.44 i	3.99 i	D-2 E-2
diuron	1.60	5.59 a-e	10.73 b-e	A-1
	3.20	4.81 c-g	7.57 d-h	A-2
	6.40	2.04 hi	6.51 f-i	C-3 E-1
oryzalin	1.60	5.88 a-e	7.51 d-h	All normal
	3.20	4.39 c-h	7.34 e-i	All normal
	6.40	4.92 b-f	8.06 c-h	All normal
thiazopyr	0.33	6.43 a-d	10.94 bcd	All normal
	0.65	6.20 a-e	12.09 b	All normal
	1.30	3.60 e-h	7.12 f-i	All normal
norflurazon	1.60	4.75 c-h	7.86 d-h	B-1 B & C-2
	3.20	3.56 e-h	6.66 f-i	B-1 B & C-2
	6.40	2.31 f-i	5.60 ghi	D-2 E-1
simazine	1.80	7.60 ab	16.68 a	All normal
	3.60	4.86 b-g	7.30 e-i	All normal
	7.20	4.14 d-h	8.98 b-g	All normal
oxyfluorfen	0.80	6.38 a-d	11.45 b-e	All normal
	1.60	8.25 a	16.29 a	All normal
	3.20	6.98 abc	9.96 b-f	All normal
control		7.00	11.32	

[z]Within a column, mean followed by the same letter do not significantly differ (Waller-Duncan, 5% level of significance).

[y]Foliage conditions: A = veinal pattern, B = white, bleached appearance, C = mild necrosis, D = severe necrosis, E = seedling death, number after letter indicates number of seedlings effected.

medium rate 25% of the seedlings had leaves that were white with bleached in appearance, and 50% of the seedlings had leaves that were white with bleached appearance and mild necrosis. For norflurazon at the higher rate, 50% of the seedlings had severe necrosis and 25% died. For diuron at the low rate, 25% of the seedlings had veinal patterns and the remaining 75% were symptom-free; at the medium rate 50% of the seedlings showed veinal patterns; and at the high rate 75% of the seedlings had mild necrosis and the remaining 25% died.

Foliar patterns were noted in both bromacil- and diuron-treated Carrizo seedlings, with foliar patterns caused by bromacil more evident (Table 1). As for Carrizo citrange, foliar patterns were noted only on 7% of the leaves of Swingle citrumelo seedlings treated with bromacil at the 6.4 lb a.i./acre rate (Table 2).

With live oak seedlings, bromacil, norflurazon, and diuron at increasing rates had significant effects on both shoot and root weights of oaks seedlings. Bromacil, norflurazon, and diuron caused seedling mortality.

Studies evaluating the effects of herbicides on the growth of seedlings should be longer in duration than was conducted in the

Table 4. Mean fresh shoot weight, fresh root weight, and dry root weight for each rootstock and herbicide application rate at 150 DAT in Study 3.

		Herb. rate	Fresh shoot wt.[z]	Fresh root wt.	Dry root wt.	Seedlings with foliar patterns	Percent leaves injured
Rootstock	Herbicide	lb a.i./acre	grams	grams	grams	#	%
Swingle	bromacil	1.60	35.36 h-n	42.06 cde	9.55 e-j	2	10
	bromacil	3.20	24.73 l-p	22.08 l-p	5.15 l-p	4	25
	bromacil	4.80	27.78 k-o	23.67 j-p	6.23 j-p	3	18
	bromacil	6.40	22.68 m-p	21.65 l-p	4.97 l-p	4	28
	diuron	1.60	34.58 h-n	37.38 d-g	9.11 e-j	0	0
	diuron	3.20	37.44 g-l	35.75 d-h	9.21 e-j	0	0
	diuron	4.80	42.02 d-k	35.14 d-i	9.07 e-j	0	0
	diuron	6.40	41.41 e-k	31.39 e-m	8.96 e-j	1	6
	control	0.00	37.38 g-l	42.33 cd	10.15 e-i	0	0
Carrizo	bromacil	1.60	25.47 l-p	20.59 m-p	4.57 m-p	2	6
	bromacil	3.20	21.53 nop	19.81 nop	4.30 nop	3	27
	bromacil	4.80	13.86 op	15.66 op	3.85 op	4	53
	bromacil	6.40	12.00 p	13.84 p	3.16 p	4	33
	diuron	1.60	30.04 j-n	28.54 f-n	7.53 h-n	0	0
	diuron	3.20	35.52 h-n	32.23 d-l	8.48 f-l	0	0
	diuron	4.80	29.99 j-n	26.58 g-n	7.07 h-o	0	0
	diuron	6.40	34.00 h-n	33.27 d-k	9.04 e-j	0	0
	control	0.00	30.36 i-n	25.76 h-o	6.79 h-p	0	0
Cleo	bromacil	1.60	38.64 f-l	25.02 h-o	6.91 h-o	0	0
	bromacil	3.20	32.75 h-n	19.81 nop	5.24 k-p	1	9
	bromacil	4.80	44.73 b-i	28.88 f-n	7.80 g-n	1	23
	bromacil	6.40	36.21 g-m	23.36 k-p	6.02 j-p	4	20
	diuron	1.60	52.49 b-f	26.66 g-n	8.03 f-m	0	0
	diuron	3.20	50.57 b-g	34.28 d-j	10.38 e-h	0	0
	diuron	4.80	45.24 b-h	29.92 f-n	8.84 e-k	0	0
	diuron	6.40	40.32 e-k	30.59 f-n	8.90 e-k	1	10
	control	0.00	41.54 d-k	24.42 i-p	7.05 h-o	0	0
SCS	bromacil	1.60	34.38 h-n	29.75 f-n	8.99 e-j	0	0
	bromacil	3.20	37.75 g-l	29.38 f-n	8.95 e-j	0	0
	bromacil	4.80	31.96 h-n	25.32 h-o	7.17 h-o	0	0
	bromacil	6.40	34.84 h-n	26.55 g-o	7.56 h-n	2	16
	diuron	1.60	38.80 f-l	30.65 f-n	9.15 e-j	0	0
	diuron	3.20	31.94 h-n	22.88 k-p	6.53 i-p	0	0
	diuron	4.80	44.01 c-j	38.03 def	11.56 def	0	0
	diuron	6.40	31.11 h-n	27.14 f-n	7.87 g-n	0	0
	control	0.00	34.87 h-n	27.00 g-n	7.47 h-o	0	0
SFS	bromacil	1.60	56.01 bcd	27.53 f-n	11.27 d-g	3	13
	bromacil	3.20	43.80 c-j	28.58 f-n	10.18 e-i	3	34
	bromacil	4.80	41.87 d-k	23.91 j-p	8.23 f-m	4	40
	bromacil	6.40	*	*	*		
	diuron	1.60	58.59 b	69.91 a	16.49 ab	0	0
	diuron	3.20	73.33 a	78.33 a	19.49 a	1	5
	diuron	4.80	59.03 ab	56.96 b	14.19 bcd	0	0
	diuron	6.40	53.08 b-e	49.44 bc	12.18 cde	2	17
	control	0.00	58.24 bc	51.59 bc	15.81 bc	0	0

[z]Means followed by same letter do not significantly differ (P = .05, Waller-Duncan).
[y]* = seedlings discarded due to treatment error.

second study, 70 days may not allow time to develop differences in plant growth, especially if the materials are applied during months of reduced plant growth (Castle and Tucker, 1978).

Different results may occur in field situations if materials are applied in a manner which allows herbicide materials to contact citrus foliage, especially if applied through overhead irrigation systems. Phytotoxic symptoms of oxyfluorfen and norflurazon have been reported at rates of 1 and 2 lb/acre (Singh and Achhireddy, 1984: Singh and Tucker, 1984), whereas in this study even higher rates did not produce phytotoxic symptoms. If materials are applied via overhead irrigation, herbicide materials should be washed off with additional irrigation to reduce foliar damage (Singh and Achhireddy, 1984).

In Study 3, for each herbicide treatment, means were calculated for the fresh shoot weight, fresh root weight, and dry root weight for each of the five rootstocks at 150 DAT (Table 4). Data were analyzed as a factorial for rootstock and herbicide. Of the five rootstocks, only Swingle citrumelo and Carrizo citrange showed major statistical differences determined using the Waller-Duncan statistical test at the P = .05 level (Table 4).

From the data presented for Swingle citrumelo rootstock, significant differences were found for fresh shoot weight (4.8 and 6.4 lb a.i./acre) and fresh root (4.8 and 6.4 lb a.i./acre), and dry root (3.2, 4.8, and 6.4 lb a.i./acre) weight for bromacil. It should also be noted that the 3.2, 4.8 and 6.4 lb a.i./acre rates are at levels that exceed the normal use rates for young trees. Bromacil current use rates for trees less than one year of age is 1.6 to 2.4 lb a.i./acre (Knapp, 1997). No major differences were determined for diuron at the four rates when the material was applied to the Swingle seedlings. There are clear reductions in weights of fresh shoot, fresh root, and dry root; 39%, 49%, and 51%, respectively, as you increase herbicide application rates of bromacil.

In Study 3 for Carrizo seedlings, statistical differences were determined for fresh shoot weight and for fresh root weight when bromacil was applied to seedlings at rates of 4.8 and 6.4 lb a.i./acre and at the 6.4 lb a.i./acre, respectively. No statistical differences were determined for dry root weight at any application rate of bromacil. No major differences were determined for diuron at the four rates. When comparing the means to the control for Carrizo, there were clear reductions in weights for fresh shoot, fresh root, and dry root of 61%, 46%, and 53%, respectively, as you increase the herbicide application rates of bromacil. No statistical differences were noted for Cleo or Sun Chu Sha seedlings treated with bromacil or diuron.

Statistical differences in fresh shoot weight were noted when Smooth Flat Seville seedlings were treated with bromacil at the 4.8 lb a.i./acre and for fresh and dry root weight at the 1.6, 3.2, and 4.8 lb a.i./acre. No clear trends were noted for the diuron-treated Smooth Flat Seville seedlings. The Smooth Flat Seville seedling at the 6.4 lb a.i./acre were discarded due to treatment error.

Bromacil applications caused foliar toxicity patterns in greater numbers of seedlings (58%) than did diuron (6%) (Table 4). For the bromacil-treated seedlings, foliar patterns were noted on the following rootstocks: Swingle citrumelo, 81%; Carrizo citrange, 81%; Cleopatra mandarin, 38%; Sun Chu Sha, 13%; and Smooth Flat Seville, 83%. For the diuron-treated trees, foliar patterns were noted on the following rootstocks: Swingle citrumelo, 6%; Carrizo citrange, 0%; Cleopatra mandarin, 6%; Sun Chu Sha, 0%; and Smooth Flat Seville, 19%. As new growth emerged on the seedlings toward the end of the treatment period evidence of foliar patterns was less than had been noted on earlier flushes.

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