cally. Use of arsenical compounds on citrus other than grapefruit could complicate the enforcement of the arsenical and maturity laws by the Florida Department of Agriculture.

ACKNOWLEDGMENTS

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A COMPARISON OF HERBICIDE, MECHANICAL TREE HOE, AND FLAMING TREATMENTS IN A 2-YEAR WEED CONTROL EXPERIMENT

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ABSTRACT

A weed control experiment was conducted for 2 years on 3-year-old 'Duncan' grapefruit trees growing on Lakeland fine sand. The methods compared were flaming, mechanical tree hoeing, and herbicide treatments including different rates of diuron, terbacil, paraquat, dichlobenil, and trifluralin.

There were no significant differences in trunk circumference growth between treatments even though the range of average weed control varied from 29% for the mechanical tree hoe to 84% for dichlobenil at 3 lb/A. No significant differences between treatments existed in fruit yield and juice quality.

Generally, flaming was the most expensive method of weed control while the mechanical tree hoe was the least expensive. Estimated cost per treated acre per year (excluding supervisory and intergrove transportation costs) ranged from $21.00 for the mechanical tree hoe to $152.00 for the flame hoe at 2 mph.

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INTRODUCTION

The first herbicides evaluated and recommended for use in Florida citrus were diuron and simazine for the preemergence control of broadleaf weeds and annual grasses and dalapon for the control of perennial grasses (1, 2). The substituted uracils, terbacil, and bromacil were evaluated by Ryan (3) and were found to give satisfactory control of perennial grasses. At present, there are 6 preemergence herbicides recommended for use. These are diuron, simazine, terbacil, bromacil, dichlobenil, and trifluralin.

The 2-year experiment reported here was designed to evaluate 4 of the above herbicides, namely, diuron, terbacil, dichlobinil, and trifluralin and 2 other weed control methods, mechanical hoeing and flame hoeing, the latter described by Whitney (5). The objective of this study was to compare the effectiveness of different chemical and nonchemical methods of weed control as determined by:

1. The frequency of application necessary to maintain a satisfactory level of weed control.
2. The tolerance of the various weed species present.
3. The existence of any toxicity effects or physical damage to the tree.
4. Effects on tree growth, fruit yield, and quality.
5. The estimated cost of each treatment.
6. The overall feasibility of each treatment in terms of a commercial weed control program.

Materials and Methods

The experiment was initiated in 1968 in a grove of 3-year-old 'Duncan' grapefruit trees on rough lemon rootstock planted in a 25 foot by 25 foot spacing on Lakeland fine sand. Fourteen treatments were replicated 4 times with 4 trees per plot and one buffer tree between plots.

The treatments (Table 1) compared were flame hoeing at 2 and 3 mph at 2 application frequencies; diuron at 6 lb./A and 3 lb./A; diuron at 3 lb./A + paraquat at 0.5 lb/A; terbacil at 4 lb/A and 2 lb./A; terbacil at 2 lb./A + paraquat at 0.5 lb./A; dichlobenil at 6 lb./A and 3 lb./A; and trifluralin at 1 lb./A and 0.5 lb./A. The trifluralin rates were increased to 1 and 2 lb./A after the second application. Both dichlobenil and trifluralin were mechanically incorporate into the soil. Treatments were applied in continuous strips 5 feet wide on both sides of the trees.

Equipment used included a 5 foot in-and-out mechanical hoe, a flame hoe, and a commercial Myers applicator delivering 114 gpa at 2 mph and 40 psi nozzle pressure.

Plots were evaluated at 1-month intervals for weed control on the basis of percent of bare ground present (0=no bare ground; 50—50% bare ground; and 100=100% bare ground). At monthly intervals, a check was made on the weed species present, noting particularly any changes in the prevalence of particular species following treatment. In general, treatments were reapplied whenever bare ground ratings fell below 70%.

Tree trunk circumferences were measured 4 inches above the ground at the start of the experiment and then after the first and second year as a record of tree growth.

Tree foliage was observed periodically for signs of herbicide toxicity symptoms and the trunks were examined for any physical damage caused by the equipment.

In the final year of the experiment, limited data were recorded on fruit yield, percent Brix, percent acid, and Brix/acid ratio.

Costs of each treatment were estimated by using the present cost of the materials, the fixed and variable costs of the equipment, and the current labor charges.

The following species were recorded in the experimental area during the period of the experiment: common ragweed (*Ambrosia artemisifolia*); Spanish needles (*Bidens bipinnata*); horseweed (*Erigeron canadensis*); cudweed (*Gnaphalium* sp.); camphorweed (*Heterotheca subaxillaris*); pepperweed (*Lepidium virginicum*); nutsedge (*Cyperus* sp.); spurge (*Euphorbia* sp.); bermudagrass (*Cynodon dactylon*); crabgrass (*Digitaria* sp.); Florida beggarweed (*Desmodium tortuosum*); evening primrose (*Denothera* sp.); Florida pusley (*Richardia scabra*); black nightshade (*Solanum nigrum*); blue toad flax (*Linaria canadensis*); jerusalemoak (*Chenopodium botrys*); lambsquarters (*Chenopodium album*); pigweed (*Amaranthus* sp.); and teaweed (*Sida acuta*).

Results and Discussion

Weed control and tree growth.—Effects of the treatments on weed control and on tree growth are shown in Table 1. Based on the F test (.05 level) from a statistical analysis, there were significant differences in percent weed control between treatments. However, no significant differences (.05 level) in percent tree growth existed between treatments.

Comparisons in weed control between the flame hoe (Treatment 1) and the mechanical hoe (Treatment 3) are shown in Figure 1. A total of 36 applications was made with a flame hoe, while the mechanical hoe was used only 6 times, which was less than the number actually desired because of the difficulties encountered in securing the equipment. The mechanical hoe applications produced drastic reductions in weed population for a short period, whereas the flame hoe applications held the weed population at a more constant level. The average percent weed control with the mechanical hoe was significantly less than that for all other treatments (Table 1). The flame hoe provided satisfactory weed control

Table 1. Treatments, weed control, and tree growth in 2-year study.

Treatment No. and description*	Total No. of applications	1st year % weed control**	1st year % growth+	2nd year % weed control**	2nd year % growth+	2-year average % weed control**,++	2-year average % growth+
1. Flame hoe, 2 mph, 60 psi	36	78.8	37.8	65.9	24.4	73.5 ab	31.1
2. Flame hoe, 3 mph, 60 psi	37	76.6	33.7	51.2	23.5	68.0 abc	28.6
3. Mechanical hoe, 1.5 mph	5	33.4	31.8	22.8	22.5	29.0 d	27.1
4. Mechanical hoe, 1.5 mph	4	33.6	37.7	22.7	17.5	30.0 d	27.6
5. Diuron, 6 lb/A	3	83.4	35.8	76.0	21.5	80.3 ab	28.7
6. Diuron, 3 lb/A	4	70.8	30.5	53.8	23.3	63.7 bc	26.9
7. Diuron, 3 lb/A + paraquat, 0.5 lb/A	4	70.4	34.6	64.9	24.7	68.1 abc	29.7
8. Terbacil, 4 lb/A	4	75.8	33.5	75.2	23.8	75.6 ab	28.7
9. Terbacil, 2 lb/A	4	74.4	31.0	66.3	26.1	71.1 ab	28.6
10. Terbacil, 2 lb/A + paraquat, 0.5 lb/A	4	73.6	30.4	71.5	25.8	72.3 ab	28.1
11. Dichlobenil, 6 lb/A	3	77.8	30.9	73.6	20.8	76.1 ab	25.9
12. Dichlobenil, 3 lb/A	3	85.8	34.1	80.9	23.3	83.8 a	28.7
13. Trifluralin, 2 lb/A	4	66.1	33.4	30.8	24.3	52.2 c	28.9
14. Trifluralin, 1 lb/A	4	59.6	37.0	40.8	22.9	51.6 c	30.0
Average						64.0	28.5

*All herbicides applied at 2 mph.

**Average of monthly ratings where percent weed control = percent bare ground.

+Based on initial trunk circumference (4/68).

++All averages in this column which are not followed by the same letter are statistically different (.05 level) by Duncan's New Multiple Range Test.

and tree growth, being slightly better at 2 mph for both. On the average, the flame hoe treatments were applied every 10 to 12 days between May and November. They provided satisfactory weed control if the weeds were flamed at an early stage of growth (less than 3 or 4 inches high) and before the weeds became too luxuriant or became too dry and created a fire hazard.

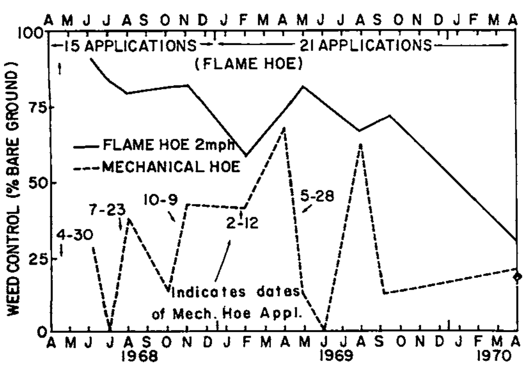

Figure 1.--Weed control with flame hoe and mechanical hoe.

Better weed control was maintained with diuron at 6 lb than at 3 lb, although the lower rate also gave satisfactory control in the first year (Table 1). As seen in Figure 2, diuron achieved a higher degree of control than did terbacil during much of the experimental period. This was mainly due to better control of a high population of Spanish needles (*Bidens bipinnata*). The addition of paraquat (Treatment 7) improved weed control at the lower rate. This was probably due to the "burn down" action of the paraquat, especially when the weed growth was vigorous at the time of application.

Weed control with terbacil followed a similar pattern to that with diuron (Figure 2). The 4 lb rate of terbacil gave better weed control than the 2 lb rate and both rates gave better control than the 3 lb diuron treatment but were not as good as diuron at 6 lb. There were no marked differences in weed control or tree growth among the 3 terbacil treatments (Treatments 8, 9, 10). The addition of paraquat to terbacil showed no advantage over using terbacil

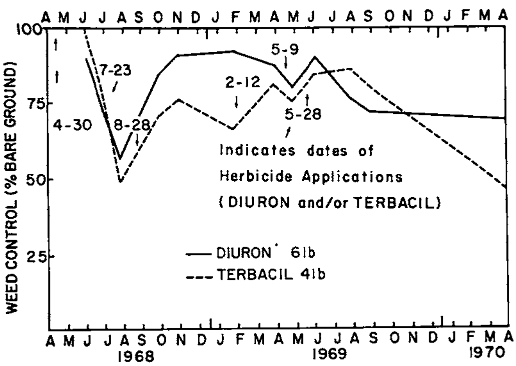

Figure 2.--Weed control with diuron and terbacil.

alone.

Dichlobenil and trifluralin, the 2 herbicides requiring incorporation in the soil, are compared in Figure 3. The main difference in the control by these 2 herbicides was the broad spectrum of weeds controlled by dichlobenil as compared to the narrow spectrum controlled by trifluralin. Many tolerant species appeared in the trifluralin plots. Both dichlobenil treatments gave good overall weed control for up to 5 months. The lower rate gave better overall weed control than did the 6 lb rate. There are 2 possible explanations for this result. In one 6 lb plot, the presence of charcoal, probably from a wood fire in the past, was thought to have reduced the effectiveness of the chemical; and in another plot, a localized patch of bermudagrass resulted in a poor weed control rating. The tree growth in the 3 lb treatments was better than average. Of the herbicides tested, trifluralin performed the poorest, especially at the initial rates. Weed control improved at the 1 and 2 lb rates but was poor. In spite of the poor weed control, tree growth was as good as in other treatments, so weed competition, at least from the species present, was not a factor. In 1968, a permanent overhead irrigation system was installed in the grove, so from that time onward, competition for moisture was not a major factor.

Tolerant weed species.—A build up of certain weed species following certain herbicide treatments was observed throughout the experiment, becoming more evident with time. Weed species tolerant to a particular herbicide tended to build up in some plots due to reduced competition by other weeds, resulting in a poor rating even though most other species were satisfactorily controlled.

Florida pusley, and to a lesser extent cudweed, crabgrass, and spurge, showed some degree of tolerance to the flaming treatments. A build up of crabgrass occurred in some of the diuron plots, particularly at the lower rate of application. Cudweed, bermudagrass, blue toad flax, and spurge also showed some tolerance to diuron. Spanish needles was the prevalent weed found in most of the terbacil plots, and the build up of this species necessitated a special application of paraquat to achieve satisfactory control. High populations of blue toad flax, cudweed, and evening primrose were also found. Pigweed was also tolerant to terbacil; however, a low initial population in the experimental area prevented it from becoming a serious problem in this experiment. Since different weed species are tolerant to diuron and terbacil, a mixture of the 2 herbicides would provide more complete control except for blue toad flax and cudweed which are usually not serious weed pests.

With the exception of bermudagrass, none of the species in the experimental area could be considered tolerant to dichlobenil. Crabgrass was usually the first to reappear and this was predominantly in the center area (tree trunk line) of the plots where the mechanical hoe did not adequately incorporate the herbicide.

The early breakdown of control in the trifluralin plots resulted from a high degree of tolerance of several weed species to this material. Beggarweed was particularly tolerant. Other tolerant species were Spanish needles, spurge, cudweed, pepperweed, nutsedge, and bermudagrass. Crabgrass, pigweed, Florida pusley, blue toad flax, and evening primrose were controlled by trifluralin at the higher rates.

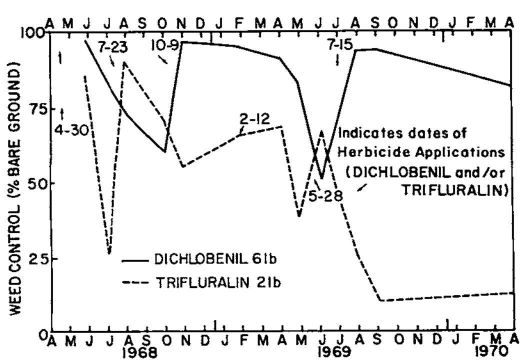

Figure 3.--Weed control with dichlobenil and trifluralin.

Toxicity symptoms.—Throughout the experiment, no signs of herbicide toxicity symptoms on the tree foliage were observed. From previous work (2, 3), symptoms were not expected to occur at the rates used. Some damage to the trees resulted from the flame hoe due to scorching of the lower limbs and equipment contact with the trunks due to inexperience of the operator. No damage to trunks was caused by the mechanical hoe. Feeder root pruning was not considered an important factor as most of the roots were growing below the working depth of the hoe.

Yield.—Yield records from only one replication were obtained at the end of the second year as several of the plots had been picked before they could be checked. The data were statistically analyzed by using individual tree data. Ryan (2), working with young trees, found that yields were higher from trees receiving herbicide treatments than from those receiving mechanical weed control treatments except in cases where severe herbicide symptoms occurred. In this experiment, there were no significant differences in yield between treatments. The overall average fruit yield was 129 lb/tree. There appeared to be yield differences but these were not significant, possibly due to considerable within plot variation. The trees appeared to be quite uniform at the start of the experiment; however, pre-experimental yields were not obtained and yields of young trees are known to be quite variable.

Fruit quality.—Early work by Ryan (4) showed that in oranges, herbicides at the recommended rates had no effect on fruit quality. Fruit quality data in this study were also incomplete at the end of the second year because of plots harvested before samples were obtained. There were no significant differences in fruit quality parameters between treatments. Those parameters measured and their overall averages were as follows: percent juice by weight, 51.39; percent soluble solids, 8.56; percent acid, 1.21; and solids/acid ratio, 7.11.

Estimated costs.—Whitney (5, 6) has estimated the costs of weed control by chemical and nonchemical methods. His estimates include machine, labor, and material costs in the grove, but do not include supervisory or intergrove transportation costs.

Table 2 shows the estimated costs for the various treatments in this study. Note that all costs are on a treated acre basis. Generally, treatment methods ranked in descending order of cost were: flame hoe, herbicides, and mechanical hoe. It would appear that the cost of the flame hoe at 2 mph is impractical. At 3 mph, the flame hoe cost was comparable to the more expensive herbicide treatments; but the number of applications required with the flame hoe makes its feasibility questionable.

The costs of several herbicide treatments (Nos. 5, 6, 7, 12, 13, 14) were moderate. Of these treatments, diuron at 6 lb and dichlobenil at 3 lb offered the best weed control.

The costs of the mechanical hoe treatments were quite low since these treatments were not applied as often as intended. In some commercial operations, the number of applications would be twice those applied in this study.

The weed control, tree growth, and cost information given in this paper poses a very practical question—what degree and method of weed control is most desirable to maximize returns from young citrus trees? In this study, 80% weed control offered little if any faster tree growth than did 30% weed control. The cost of 30% weed control is certainly less. The results of this study suggest that the attainment of a high degree of weed control may not be economically sound under the following conditions: (a) after trees have been established in the grove for a period of 3 to 5 years, (b) when trees are growing on a well-drained Lakeland fine sand, and (c) when trees are not subjected to moisture stress at any time during the growing season due to the presence of a permanent overhead irrigation system. Any one of the three methods in this study can be used for weed control; however, the mechanical hoe and herbicides can generally be used at a lower cost and with a greatly reduced number of applications.

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Table 2. Estimated costs* per treated acre for weed control treatments in 2-year study.

Treatment No.	Estimated cost/ treated acre/ application	No. of appli- cations in study	Estimated total cost/ treated acre for 2-year study**	Estimated cost/treated acre/ year**
1. Flame hoe, 2 mph	$ 8.23+	36	$304.53	$152.26
2. Flame hoe, 3 mph	5.49+	37	211.38	105.69
3. Mechanical hoe	8.25	5	49.50	29.75
4. Mechanical hoe	8.25	4	41.25	20.62
5. Diuron, 6 lb	26.36	3	87.33	43.66
6. Diuron, 3 lb	15.11	4	74.69	37.34
7. Diuron, 3 lb Paraquat, .5 lb	22.11	4	96.69	48.34
8. Terbacil, 4 lb	53.36	4	221.69	110.84
9. Terbacil, 2 lb	33.61	4	142.69	71.34
10. Terbacil, 2 lb Paraquat, .5 lb	40.61	4	170.69	85.34
11. Dichlobenil, 6 lb	64.91	3	194.73	97.36
12. Dichlobenil, 3 lb	38.51	3	115.53	57.76
13. Trifluralin, 2 lb	26.81	4	107.24	53.62
14. Trifluralin, 1 lb	19.46	4	77.84	38.92

*Assumed herbicide costs--diuron, $3.75/lb; paraquat (CL), $14.00/lb; terbacil, $12.37/lb; dichlobenil, $8.80/lb; and trifluralin, $7.35/lb.
Assumed machine and labor costs/treated acre--flame hoe, 2 mph, $4.05; flame hoe, 3 mph, $2.70; mechanical hoe, $8.25; and herbicide applicator, $3.86.

**Includes cost of initial mechanical hoeing.

+Flame hoe fuel cost--27 gal/hr x $.15/gal.