Pest Management Grants Final Report

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Determining Seed Bank Levels in Citrus Orchards:
A Basis for Designing a Weed Control Program

Principle Investigators:

Kurt Hembree, Fuhan Liu, and Neil O'Connell

UCCE, University of California

Kearney Agricultural Center, University of California,

Parlier, CA 93648

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Abstract

This study investigated seedbank levels and field weed emergence and species in citrus orchards related to 7 different tree classes based on the duration of herbicide use. The 7 classes were Class I (< 4 years), Class II (4 - 8 years), Class III (9 - 13 years), Class IV (14 - 18 years), Class V (19 - 23 years), Class VI (24 - 27 years), and Class VII (> 27 years). Soil core samples were taken from fields and viable seeds were extracted according to different tree classes. Results indicated that total viable seeds in citrus orchards decreased with increasing duration of herbicide application. Seedbank tended to be higher in the tree row than in the tree middle from Class I to Class IV. Older citrus orchards (> 19 years) that had longer duration of herbicide use had similar seed bank densities for tree rows and tree middles. Younger citrus orchards had larger variability in total seedbank density with coefficient of variance value > 130 % for Class I citrus orchards and > 70% for Class II and Class III citrus orchards. Weed emergence and density were evaluated in the field from plots receiving preemergent herbicide applications and plots not receiving preemergent herbicides. Five species were the most common detected: common groundsel (*Senecio vulgaris*), horseweed (*Conyza canadensis*), prickly lettuce (*Lactuca serriola*), annual sowthistle (*Sonchus oleraceus*), and panicle willowweed (*Epilobium paniculata*). All five of these species have pappus bearing seeds that allow for wind dispersal and could continually be invading citrus orchards.

EXECUTIVE SUMMARY

In citrus orchards, weeds are controlled primarily with preemergent herbicides during fall and winter months. Properly timed, postemergent herbicide applications efficiently prevent a large number of species from replenishing their respective seed banks. Over time, seed banks should diminish, but growers cannot evaluate seed bank depletion since the weeds are controlled prior to their emergence, preventing detection by the farmers. This project identifies long-term seed bank dynamics using easily obtained information on duration of herbicide use and size of citrus tree canopy. The results from this study should allow growers and private consultants to choose modifications to their weed management programs that balance risk of weed control failure with environmental or health risks. The specific objectives of this project were: 1) to determine viable seed density in citrus orchards, based on duration of herbicide use and classes of size of citrus tree canopy by diameter, and 2) to evaluate weed species emergence and density in citrus orchards based on duration of herbicide use and classes of size of citrus tree canopy by diameter. In object 1, soil samples were taken within each duration class from the middle of tree rows and along the tree row. Dried soil samples were washed using a hydroneumatic elutriator. Counts from the sieves were combined to determine the number of total seeds for each soil sample. In object 2, five tarps (size 10 x 12 ft) were put in each citrus field before herbicide application to keep area free from herbicide treatment in November 1999 and November 2000. After application, tarps were removed from the citrus fields. Weed emergence and density were evaluated by species in April 2000 and April 2001. The results showed total seeds in soil of citrus orchards decreased with increasing duration of herbicide application. Statistical analysis showed no significant difference ($P > 0.01$) of weed density between year 2000 and year 2001.

Field evaluations of weed emergence showed weed species were only found on the tree row in newly planted citrus in Class I.

Introduction

The overall goal of this proposed research is to manage weeds in citrus orchards effectively and economically while maintaining environmental and human health. Achieving this goal is aided by a decision support tool that identifies long-term seed bank dynamics using easily obtained information on duration of herbicide use and size of citrus tree canopy. This approach should allow farmers and private consultants to choose modifications to their weed management programs that balance risk of weed control failure with environmental or health risks. Economically, this decision support tool should help farmers and private consultants reduce inputs making their enterprise more profitable. The specific objectives of this project were: 1) to determine viable seed density based on duration of herbicide use and classes of size of citrus tree canopy by diameter in citrus orchards, and 2) to evaluate weed species emergence and density in citrus orchards based on duration of herbicide use and classes of size of citrus tree canopy by diameter.

It is widely recognized that seed dormancy and germination strategies contribute to the perpetuation of weeds as agricultural pests. Herbicide application can control weeds after germination but not dormant seeds. Seedbanks decline if the mortality of germinating and dormant seeds exceeds replenishment of the seed bank. Over time, these seedbank should diminish, but farmers cannot evaluate seed bank depletion since the weeds are controlled prior to their emergence and hence detection by the grower. Herbicides are applied in citrus orchards throughout the life of the orchard that usually exceeds 25 years. Weed management within an orchard possibly could change with orchard age if seed bank depletion in citrus orchards was understood. A better understanding of the risk of weed pressure in citrus should allow farmers to make changes to their weed control practices that reflect actual weed pressure.

The species composition and density of weed seed in soil varies greatly and are closely linked to management practices and environmental conditions of the cropping land and varies between fields and within fields. Citrus orchards are managed as a no-till system with no vegetative cover on the orchard floor. Continuous herbicide use should influence seed densities and species composition of the seedbank. Researchers have reported a steady decline in total seed bank densities in plots receiving continuous herbicide applications (Burnside et al., 1986; Schweizer and Zimdahl 1884). The seedbank was reduced 98% after atrazine was applied to corn for 6 years (Schweizer and Zimdahl, 1984). When triazines were applied consecutively to corn fields for 16 yr in England, the seed bank decreased 96% and number of species was reduced by half (Roberts and Neilson, 1981). Sub-lethal doses of herbicide reduced seed production of several weed species as much as 90 % (Biniak and Aldrich, 1986; Salzman et al., 1988).

Canopy size affects the amount of light reaching the soil surface. Reduced light to the soil surface reduces germination and growth of weeds.

Although seedbanks have been studied extensively, seedbanks have not been investigated in citrus orchards. Knowledge gained through this research will provide the foundation for development of new strategies and more efficient techniques, resulting in more economical weed management systems that reduce the risk of damage to the environment.

Material and Methods

Objective 1: To determine viable seed density in citrus orchards under different duration of herbicide use and size of citrus tree canopy.

Site Selection: Orchard sites for soil sampling were selected by first considering duration of herbicide use. Seven duration classes were selected at < 4 yr, 4 - 8 yr, 9 - 13 yr, 14 - 18 yr, 19 - 23 yr, 24 - 27 yr, and > 27 yr of clean floor management. Within each duration-class, we measured canopy size. A total of 42 citrus sites were selected from Fresno, Madera, Tulare, and Kern counties. In the San Joaquin Valley, citrus commonly is planted with 22 ft row spacing and 20 ft tree spacing.

Soil Sampling: Soil samples were taken within each duration class. Soil samples were taken using a W-shaped pattern imposed over the orchard with nine soil samples taken in the middles between tree rows and 9 samples taken on the tree rows. Each of the samples was a composite of five subsamples taken from the middle of tree rows and three subsamples taken along the tree row (Fig. 1). All samples were taken to a depth of 5 cm with an auger. The soil samples were air-dried.

Seedbank Determination: 100-gram samples of dried soil were washed using a hydroneumatic elutriator. Soil samples were placed in the elutriation chamber and washed for 15 - 20 minutes (dependent on clay content). Four sieves with mesh size of 2 mm, 500 µm, 250 µm, and 120 µm were used to collect seeds and other contents. After washing, sieves were removed and the collected contents dried. The sediment at the bottom of the elutriation chamber was washed into a 355 µm sieve of and dried. Viable seeds on each sieve were examined under a dissecting microscope. Seeds that did not collapse when pressured by fine-tipped forceps were considered viable. Counts from the sieves were combined to determine the total number of viable seeds for each soil sample. Viable seeds were identified and counted by species.

Data analysis. Statistical analysis was performed using the Statistical Analysis System (SAS 1985). The ANOVA procedure was conducted to perform analysis of variance on total viable seeds from each tree class. All statistical tests were performed at $\alpha = 0.05$.

Objective 2. To evaluate weed species emergence and density in citrus orchards based on duration of herbicide use and classes of size of citrus tree canopy by diameter.

Five tarps (size 10 ft x 12 ft) were put in each citrus field where soil core samples were taken before herbicide application to keep the area free from herbicide treatment in 1999 and 2000, respectively. After application, tarps were removed from the fields. Weed emergence and density were evaluated by species in April 2000 and April 2001, respectively for plots with preemergent herbicide application and without preemergent herbicide application (control treatment). The ANOVA procedure was conducted to perform analysis of variance on weed density between the two years and the REG procedure was used to determine the relationship between diameter of tree size and tree class. All statistical tests were performed at $\alpha = 0.05$.

Results

Objective 1

A total of 42 citrus sites with 378 soil samples were sampled. Results indicated that the youngest citrus orchard (Class I) had the largest seed density. Total viable seedbank density based on averages of cores from each tree class decreased with increasing duration of herbicide application (Table 2). Greater seed densities were counted in the tree row than were counted in the tree middle for younger citrus orchards. In citrus orchards with over 19 years of clean floor management and herbicide application, seed densities were similar for tree rows and tree middles (Table 2). The newly planted citrus in Class I (tree diameter < 1.0 m) indicated that only few seeds were found in seed density compared to older citrus orchards (Class V, class VI and Class VII). These two fields were replanted from previous citrus orchards. Crop rotation history as well as herbicide application history played a significant role in seed density.

The distribution ranges of viable seeds along the tree row and in the middle of tree rows are presented in Figures 2 & 3. Statistical analysis showed younger citrus orchard variability in total seedbank density was larger with CV value > 130 % for Class I citrus orchards and > 70% for Class II and Class III citrus orchards.

Objective 2

To effectively manage vegetation, it is important to know the weed species present, their abundance, and location in the orchard. The weed density should reflect seed bank densities that in turn, are affected by floor management activities. Weed species that receive wind-borne seed may continually invade orchards and may not be found at high densities in the soil seed bank. Five weed species emerged and include common groundsel (*Senecio vulgaris*), horseweed (*Conyza canadensis*), prickly lettuce (*Lactuca serriola*), annual sowthistle (*Sonchus oleraceus*), and panicle willowweed (*Epilobium paniculata*) (Table 3 &4). Statistical analysis showed no significant difference ($P > 0.01$) in weed density between year 2000 and year 2001. Weed species were only found along the tree row in the newly planted trees in the Class I citrus orchard and were present in the middles between tree rows for other citrus classes. Along the tree row, canopy size affects light reaching the soil surface. Reduced light at the soil surface reduces germination and growth of weeds. As expected, the tree size increases as the citrus ages. The relation between tree diameter and tree classes is presented in Figure 4. Among the five species, common groundsel is the most common. The density was as high as 40 per 120 ft^2 area even in the oldest citrus orchards. Common groundsel was reported to have plant populations resistant to simazine in California. Horseweed and prickly lettuce were two species found in younger citrus without preemergence herbicide application. These data could help consultants and farmers modify weed management to reduce cost of weed control by changing application rates, skipping applications, or relying on postemergent strategies for a larger part of the season. Field evaluation of bioeconomic models has already shown their potential to reduce herbicide use while maintaining weed control and increasing economic return. Model recommendations reduced weed control costs and resulted in an average annual herbicide application of 1.1 kg ai ha^{-1} compared to 3.5 kg ha^{-1} with a standard treatment (Forcella et al., 1996). Field emergence patterns of weeds could be used for timing of postemergent application of herbicides (Ogg and Dawson, 1984). Another field evaluation conducted by Buhler et al. (1996) showed that herbicide use decreased 27% using seedbank data and 68% using seedling data compared to a standard herbicide treatment.

Discussion

The newly planted citrus in Class I showed that only few seeds were found. This field was replanted from a previous citrus orchard. Crop rotation history as well as herbicide application history are important factors in decision-making for reduced cost and reduced environmental risk weed management.

The relationship of seedbank to emergence is an active field of research but one that we are not able to go into in any depth other than what we have proposed, which is to leave 5 locations at each orchard unsprayed and to count emerged plants. We can compare these emergence counts to the seed bank data we have taken. Our sites have been without herbicide application for approximately one year prior to counts being made of emergence from the 5 locations in each orchard. Hopefully most herbicide effects have dissipated, unless bromacil was used. Our herbicide dissipation work with simazine suggests that we should have little residual effects. Most herbicide labels for diuron also show many susceptible rotational crops can be planted after one year. We evaluated weed species and density in the field in April 2000 and April 2001.

Summary and Conclusions

Total weed seeds in the soil of citrus orchards decreased with increasing duration of herbicide application. Greater seed densities were counted in the tree row than were counted in the tree middle for younger citrus orchards. Younger citrus orchard variability in total seedbank density was larger. Field evaluation of weed emergence showed weed species was only found on the tree row in newly planted citrus in Class I. Five weed species emerged and included common groundsel, horseweed, prickly lettuce, annual sowthistle, and panicle willowweed. A combination of continuous use of herbicides and shading may contribute overall to lower seed banks and weed populations as orchards age. Results from this study will help consultants and growers modify weed management to reduce cost of weed control by changing application rates, skipping applications, or relying on postemergent strategies for part of the season.

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Meetings and Publications

Appendices

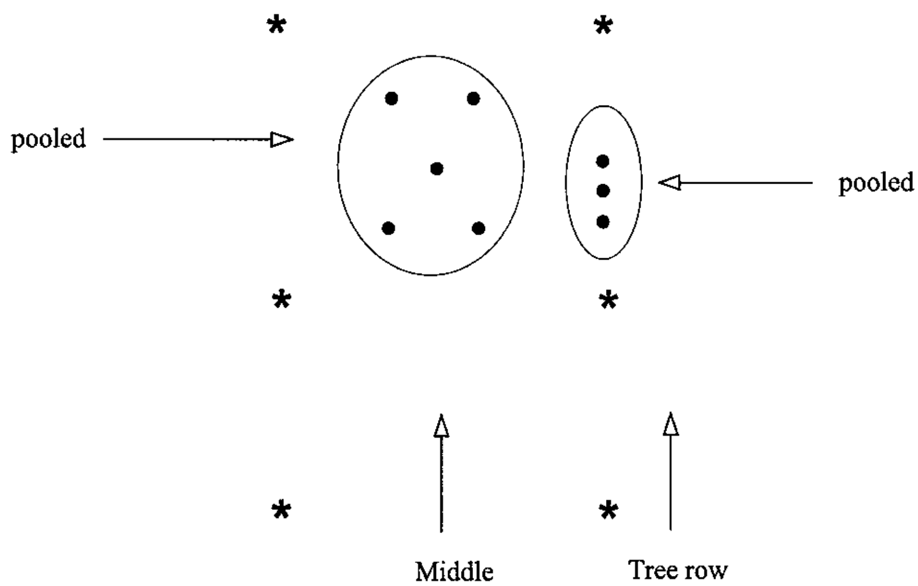

Figure 1. A diagram of soil sampling for seedbank determination.

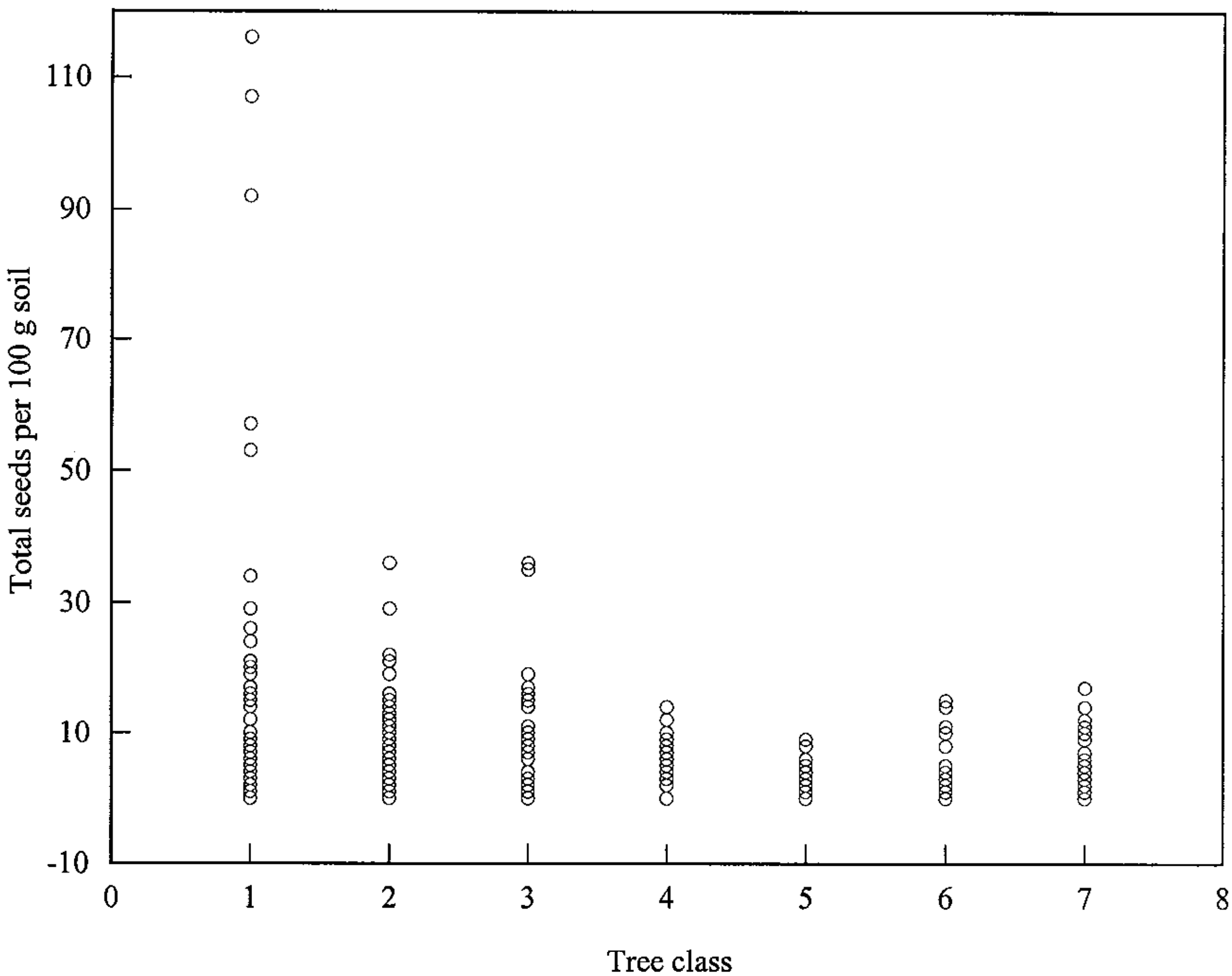

Figure 2. The number of seeds along the tree row with tree classes. (In X axis title: 1 = Class I, 2 = Class II … 7 = Class VII)

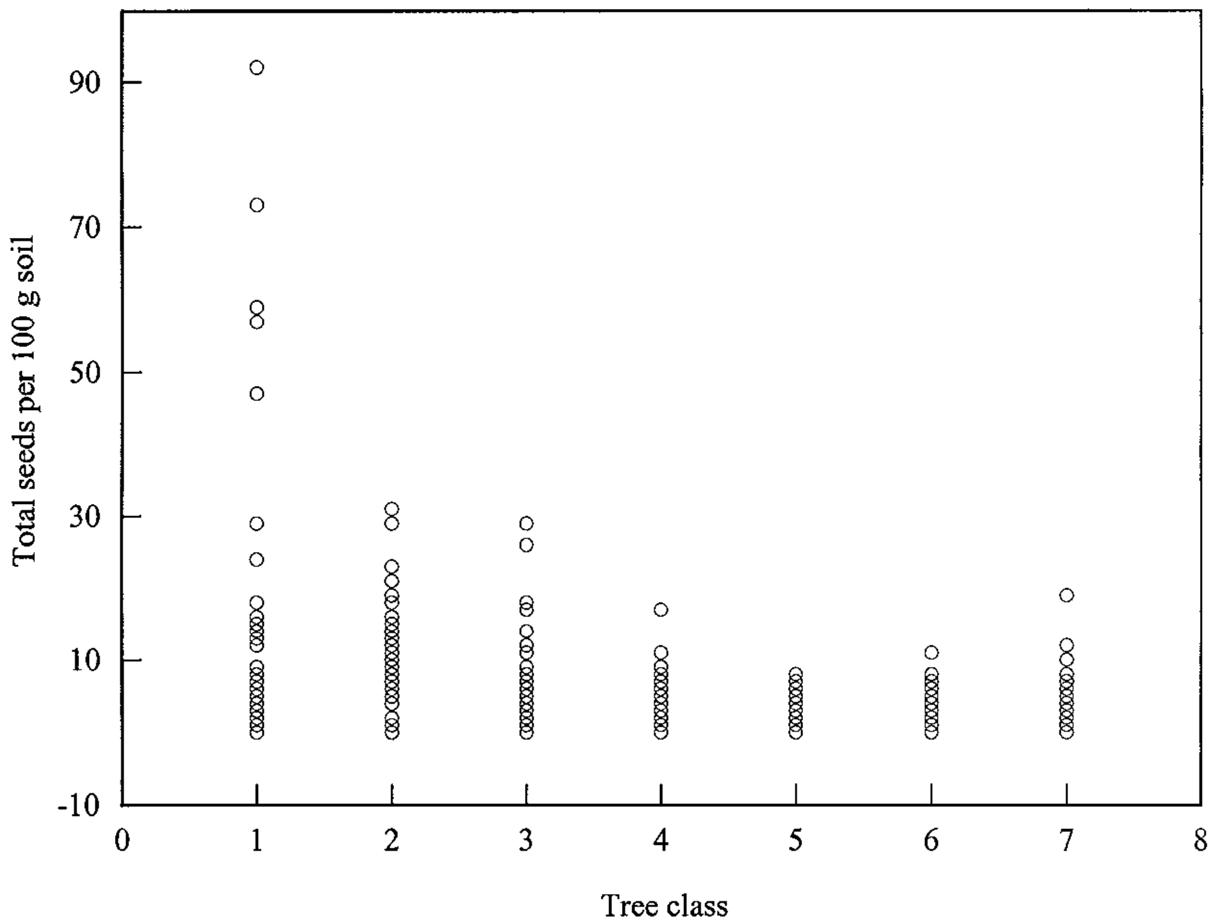

Figure 3. The number of seeds in the middle of tree rows with tree classes. (In X axis title: 1 = Class I, 2 = Class II … 7 = Class VII)

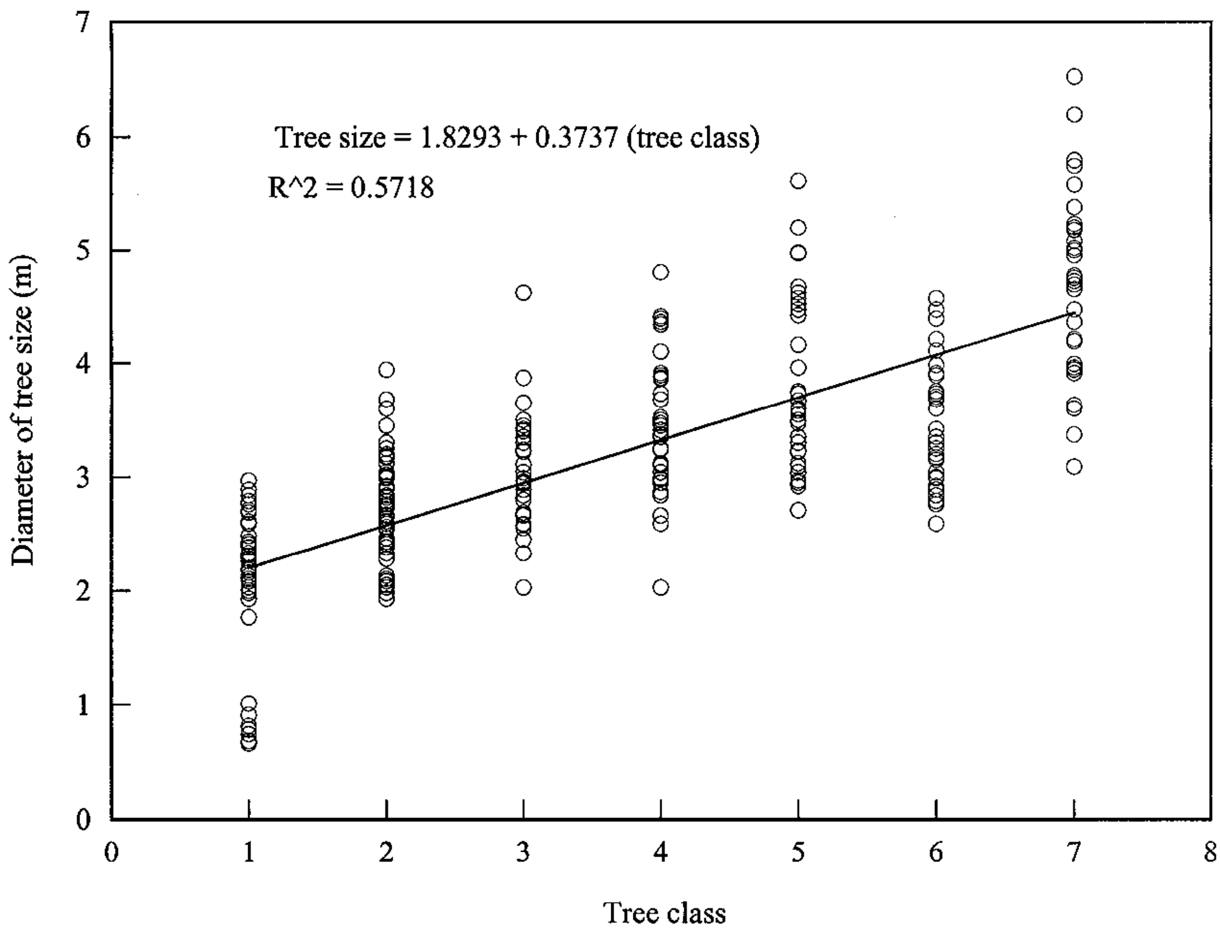

Figure 4 The relation between tree size and tree classes. (In X axis title: 1 = Class I, 2 = Class II…7 = Class VII)

Table 1. Citrus sites sampled for seed bank determination for each tree class.

Tree class	Age (year)	Number of Sites
Class I	< 4	6
Class II	4 – 8	9
Class III	9 – 13	5
Class IV	14 – 18	5
Class V	19 – 23	5
Class VI	23 – 27	5
Class VII	> 27	7

Table 2. The relation between total seeds and tree class

Tree class	Age (year)	Tree diameter (m)	Citrus sites processed	Tree row (# / 100 g soil)	Middle of tree row (# / 100 g soil)
Class I	< 4	< 1.0	2	3.0	3.1
		< 2.7	4	26.5	25.7
Class II	4 – 8	2.3 – 2.7	9	9.4	8.2
Class III	9 – 13	2.8 – 3.5	5	8.9	6.7
Class IV	14 – 18	4.0 – 4.2	5	5.9	4.5
Class V	19 - 22	3.6 – 3.7	5	3.1	2.9
Class VI	23 – 27	3.3– 3.5	5	3.0	2.8
Class VII	> 27	4.0 – 5.2	7	2.8	2.6

Table 3. Weed species and densities as determined in citrus fields from different tree class in April 2000 (# / 10 x 12 ft).

Tree class	Treatment	Common groundsel	Horse-weed	Prickly lettuce	Willow-weed	Annual sowthistle
I	Control	5.0	10.2	1.4	1.0	0.1
	Applied	3.0	2.0	0.7	0.2	0.0
II	Control	2.0	5.8	5.2	1.6	1.0
	Applied	1.7	0.5	0.0	0.0	0.0
III	Control	39.8	0.0	0.0	0.0	0.0
	Applied	29.2	0.0	0.0	0.0	0.0
IV	Control	0.7	1.0	0.0	0.1	0.0
	Applied	0.1	0.0	0.0	0.0	0.0
V	Control	1.3	1.5	1.9	0.1	0.4
	Applied	1.1	0.2	0.1	0.0	0.0
VI	Control	0.5	0.8	1.9	0.0	0.4
	Applied	0.3	0.1	0.1	0.0	0.3
VII	Control	39.0	0.8	0.6	0.2	0.0
	Applied	22.0	0.2	0.1	0.0	0.0

Table 4. Weed species and densities as determined in citrus field from different tree class in April 2001 (# / 10 x 12 ft).

Citrus class	Treatment	Common groundsel	Horse-weed	Prickly lettuce	Willow-weed	Annual sowthistle
I	Control	4.8	9.8	1.8	1.4	0.3
	Applied	3.1	1.9	0.8	0.3	0.0
II	Control	2.2	5.5	5.0	1.8	1.1
	Applied	1.4	0.6	0.0	0.0	0.0
III	Control	27.6	1.5	0.0	0.0	0.0
	Applied	16.9	0.2	0.0	0.0	0.0
IV	Control	0.8	1.0	0.4	0.2	0.0
	Applied	0.2	0.0	0.0	0.0	0.0
V	Control	1.3	0.9	1.2	0.1	0.3
	Applied	0.8	0.3	0.0	0.0	0.0
VI	Control	0.6	0.9	1.7	0.1	0.3
	Applied	0.3	0.3	0.2	0.0	0.2
VII	Control	32.6	0.7	0.4	0.1	0.0
	Applied	23.3	0.2	0.2	0.1	0.0

Table 5. Potential weed management for several age classes of citrus orchards.

Citrus Age	Potential Weed Risk	Management Options for Weed Control	Environment and Human Health Risk
1-4 years	High ↑	1) Preemergent herbicides applied to middles and tree rows in fall/spring, postemergence herbicides applied as needed. 2) Preemergence herbicidesapplied broadcast in fall and injected through emitters in spring where registered, postemergence herbicides applied as needed. 3) Preemergence herbicides applied in tree row, cover crop grown in middles.	High ↑
5-12 years		1) Preemergence herbicides applied to tree row in fall/spring, postemergence herbicidesapplied to middles in fall/spring. 2) Preemergence herbicides injected through emitters in spring where registered, postemergence herbicides applied to tree rows and middles in fall. 3) Preemergence herbicides injected through emitters where registered, postemergence herbicides applied as needed, grow cover crop in middles.	
13-20 years		1) Preemergent herbicides injected through emitters in spring where registered, postemergence herbicides applied to tree row and middles in fall. 2) Move emitters under tree canopy, postemergence herbicides applied as needed in fall/spring, preemergence herbicides injected through emitters in spring where registered. 3) Move emitters under tree canopy, postemergence herbicides applied as spot treatment, cover crop grown in middles.	
>20 years	↓ Low	1) Preemergent herbicides applied around perimeter of orchard in fall, postemergence herbicides applied as spot treatment as needed. 2) Move emitters under tree canopy, postemergence herbicides applied as spot treatment as needed. 3) Move emitters under tree canopy, postemergence herbicides applied as spot treatment, cover crop grown in middles.	↓ Low