Managing Vegetation on the Orchard Floor in Flood Irrigated Arizona Citrus Groves[1]

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Abstract

Several orchard floor management strategies were evaluated beginning in the fall of 1993 in experiments on the Yuma Mesa in a 'Limoneira 8A Lisbon' lemon grove and in a 'Valencia' orange grove at the University of Arizona Citrus Agricultural Center (CAC) in Waddell, Arizona. On the Yuma Mesa, disking provided satisfactory weed control except underneath the tree canopies where bermudagrass, purple nutsedge, and other weed species survived. Mowing the orchard floor suppressed broadleaf weed species allowing the spread of grasses, primarily bermudagrass. Pre-emergence (Solicam and Surflan) and post-emergence (Roundup and Torpedo) herbicides were used to control weeds in the clean culture treatment in Yuma. After three harvest seasons (1994-95 through 1996-97), the clean culture treatment resulted in greater yield than the other treatments. At the CAC, clean culture (in this location no pre-emergence herbicides were used,) mowed resident weeds, and Salina strawberry clover orchard floor management schemes were compared. Again the clean culture treatment yielded more than the mowed resident weeds. The yield of the strawberry clover treatment was somewhat less than the clean culture yield but not significantly less. The presence of cover crops or weeds on the orchard floor were found to have beneficial effects on soil nitrogen and soil organic matter content, but no effect on citrus leaf nutrient content. The decrease in yield in the mowed resident weed treatments compared to the clean culture treatment in both locations was attributed to competition for water.

Introduction

Managing weeds on orchard floors in flood irrigated Arizona citrus groves can be accomplished by disking, mowing, applying pre-emergence and post-emergence herbicides, and by growing a cover crop. Weeds in Yuma county lemon groves have traditionally been managed by frequent disking of the orchards. Disking adequately controls weeds on the orchard floor except underneath the tree canopies where bermudagrass, purple nutsedge, and other weeds survive. Disking orchards occasionally damages tree branches, may incorporate plant debris into the

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surface soil that creates a breeding habitat for eye gnats (on the Yuma Mesa), and some growers think it may damage shallow tree roots. Mowing weeds on the orchard floor has not been widely practiced. Mowing can be expected to favor grass and nutsedge species because these plants have growing points (*i.e.*, meristems) close to the soil surface at the base of their leaves in contrast to broadleaf weeds that have meristems at shoot apices. Pre-emergence herbicides have not been widely used in Yuma County in the past because flood irrigation of sandy soils, especially on the Yuma Mesa, can leach some herbicides such as bromacil (*e.g.*, Hyvar X and Krovar I), diuron (*e.g.*, Karmex, Krovar I), and simazine (*e.g.*, Princep) into the tree root zone causing injury. Maricopa County citrus growers have long used pre-emergence herbicides but some suspect that this long-term herbicide use, especially the use of Krovar I, may be partly responsible for declines in grove yields. Post-emergence herbicides, especially glyphosate (*e.g.*, Roundup), have been widely used in Arizona citrus groves and occasionally some foliar injury symptoms from glyphosate can be found on the skirts of trees.

Recently there has been renewed interest in using cover crops in Arizona citrus groves. Cover crops may suppress weeds, increase the complement of beneficial microorganisms in the soil, decrease soil compaction, increase water infiltration, and improve root growth by increasing soil organic matter. Increasing soil organic matter content improves nutrient availability to plants by increasing both the cation exchange capacity and buffering capacity of the soil. Irrigated cover crops are known to decrease soil and canopy temperatures and have the potential to harbor beneficial predatory insects. Reduced canopy and root zone temperatures may increase the amount of carbohydrates available for fruit production by increasing the amount of photosynthetically fixed carbon and by decreasing the amount of carbon respired at night. Also, increased humidity due to evapotranspiration by the cover crop may improve 'Navel' orange pollination. Legume species that can be adapted to citrus production practices appear to have greater potential benefits than covers of non-legume broadleaf and grass species or resident weed species because legumes add nitrogen to the soil. This legume-derived nitrogen may increase the nitrogen available for fruit production and decrease the requirement for nitrogen fertilizer inputs. Non-legume species and resident weeds will consume nitrogen and other nutrients as well as water. Potential disadvantages of using cover crops in citrus orchards include unfavorable shifts in insect (*e.g.*, thrips, whiteflies, and aphids) and nematode populations, difficulty in irrigating the citrus and cover crops in flood irrigated systems, and orchard cooling in the winter which increases the risk of freeze damage.

Financial incentives to reduce disking in Yuma County, the availability of alternative herbicides for weed control, and an increased awareness of the possibility that present herbicide use and disking may injure trees, has prompted citrus growers to investigate alternative methods of orchard floor management. This project includes two studies. On the Yuma Mesa we compared the traditional practice of disking with three alternatives, mechanical mowing, clean culture using pre-emergence and post-emergence herbicides, and a treatment combining disking and the use of herbicides. The pre-emergence herbicides, oryzalin (trade name: Surflan) and norflurazon (trade name: Solicam), were used in this study because citrus injury caused by these herbicides is exceedingly rare. Spot treatments of glyphosate (trade name: Roundup Ultra) and sethoxydim (trade names: Poast and Torpedo) were used in the clean culture and the disk plus clean culture treatments to control weeds in the middles and bermudagrass under the tree canopies, respectively. Data collected included tree yields, fruit packout, weed population levels, and leaf nutrient content. A second study at the University of Arizona Citrus Agricultural Center (CAC) in Waddell, Arizona compared clean culture (*i.e.*, no weeds) to a resident weed cover, and a Salina strawberry clover cover with respect to temperature modification in the orchard, leaf nutrient levels, soil characteristics, and yield. The objective of this project is to provide growers with information needed to choose between orchard floor management systems and to learn how to grow and use cover crops in Arizona citrus groves.

Materials and Methods

Yuma Mesa Experiment. This experiment was initiated in the fall of 1993 in a four year old, flood irrigated 'Limoneira 8A Lisbon' lemon orchard on the Yuma Mesa (soil series: Superstition Sand) managed by Glen Curtis, Inc. Weed control in the orchard prior to the beginning of the experiment was accomplished by frequent disking. The original four methods of weed control evaluated in the experiment were mowing, chemical mowing, clean culture using herbicides, and disking (the grower standard against which the other treatments were compared). The four treatments were arranged in the orchard using a randomized complete block experimental design with four blocks. Each plot consisted of a row of 30 trees separated from adjacent plots by a row of trees that provided a buffer between plots. The experiment began after the orchard was disked in late October 1993. The chemical mow treatment was terminated in the summer of 1994. After two attempts to establish a cover crop in this treatment failed, a combination treatment of disking and clean culture with herbicides (disk & clean) was initiated in the fall of 1995. Cultural operations in each treatment are listed below.

Mow:
mowed 3/16/94, 5/9/94, 7/26/94, 12/15/94, 3/30/95, 6/28/95, 9/13/95, 5/7/96, 8/24/96

Disk:
disked 3/16/94, 6/10/94, 10/19/94, 3/30/95, 6/28/95, 9/13/95, 10/27/95, 5/7/96, 8/24/96

Chemical Mow:
3/11/94 applied 1 pt/A Roundup plus 0.5% (v/v) non-ionic surfactant (NIS)
5/12/94 applied 1 pt/A Roundup plus 0.5% (v/v) NIS
7/26/94 mechanically mowed and on 8/4/94 applied 3 qt/A Roundup plus 0.5% (v/v) NIS to terminate treatment

Clean & Disk:
disked 9/13/95, 10/27/95, 5/7/96, 8/24/96
10/31/95 applied a tank-mix of 2.5 lb./A Solicam, 2 qt./A Surflan and 1 qt/A Roundup plus 0.5% (v/v) NIS to tree middles and inter-tree spaces

Clean Culture:
11/3/93 applied a tank-mix of 2.5 lb./A Solicam and 3 qt/A Surflan
5/12/94 spot sprayed bermudagrass with 1.5% (v/v) Poast plus 1% (v/v) crop oil concentrate (COC)
5/18/94 spot sprayed row middles with 2% (v/v) Roundup plus 0.5% (v/v) NIS
8/4/94 applied 3 qt/A Roundup plus 0.5% (v/v) NIS to orchard middles on both sides of treatment tree row
8/4/94 spot sprayed bermudagrass with 1.5% (v/v) Poast plus 1% (v/v) COC
11/7/94 applied a tank-mix of 2.5 lb./A Solicam, 2 qt/A Surflan and 1 qt/A Roundup plus 0.5% (v/v) NIS in tree middles
12/15/94 applied a tank-mix of 2.5 lb./A Solicam, 2 qt/A Surflan and 1 qt/A Roundup plus 0.5% (v/v) NIS to inter-tree spaces
6/25/95 spot sprayed bermudagrass in tree canopies with 2.25% Torpedo plus 1% COC
6/25/95 spot sprayed row middles with 2% (v/v) Roundup plus 0.5% (v/v) NIS
10/31/95 applied a tank-mix of 2.5 lb./A Solicam, 2 qt./A Surflan and 1 qt/A Roundup plus 0.5% (v/v) NIS to tree middles and inter-tree spaces

On 12/7/94, the entire experimental area was mowed to shred prunings that hindered the application of herbicides to the ground between trees within a tree row. Weed species composition and population numbers were estimated on 12/15/93, 1/24/94, 3/28/94, 6/7/94, 7/22/94, 10/21/94, 2/22/95, 5/9/95, 9/1/95, 1/8/96, 4/24/96, 7/31/96 and 10/29/96. Early weed counts were made in four locations along a tree row by counting the number of species in 0.25 m^2 (12/15/93) or 0.5 m^2 (1/24/94). Subsequently, weed populations were assessed by visually estimating the percent ground cover of each species in 37.2 m^2 (400 ft^2). Percent ground cover could potentially exceed 100 percent because plants of different species covered the same surface area. Lemons were harvested with a #7 ring on 9/29/94 and strip picked on 12/2/94. Yield data from the two harvests of 30 trees per plot were combined to give total yields per plot. Mean treatment yields were calculated from the four replicate plots per treatment. Lemons were harvested in a similar fashion in 1995-96 and 1996-97 starting with an early fall ring pick and one or two additional harvests. The final harvest of the season was a strip pick. Leaves were collected in August of 1994, 1995 and 1996 from three trees in each treatment in each block and pooled by treatment and block. For analysis of nitrogen, phosphorus, potassium, and sulfur, the samples were dried in a forced air oven at 60 C and ground through a 40-mesh screen prior to wet digestion. The digestion for nitrogen analysis was as described by Mitchell (1972). A nitric acid digestion method was used to prepare the leaf samples for potassium, phosphorus, and sulfur analysis (Perkin-Elmer Agriculture Applications, 1982). Nitrogen, phosphorus, and sulfur were analyzed colorimetrically (Mitchell, 1972; Jackson, 1958); and potassium was determined using atomic absorption spectrometry at 766.5 nm.

Citrus Agricultural Center Experiment. This experiment compared clean culture (i.e., no weeds) with two alternatives, a Salina strawberry clover cover crop and a resident weed cover crop. This experiment was established in the fall of 1993 in a 'Valencia' Orange grove that was planted using a row and tree spacing of 22' x 22' on 5/5/90 at the U of A Citrus Agricultural Center. The experimental design was a randomized complete block with three treatments and four blocks. Guard row trees (*i.e.*, trees not included in any treatment) surround the experiment and separated each block from other blocks. Each plot consisted of 9 trees arranged in a 3 tree by 3 tree square. The treatments were: (1) 'Salina' strawberry clover on the orchard floor middles, (2) mechanically mowed resident weed populations on the orchard floor middles, and (3) clean culture with no vegetation on the orchard floor (bare ground). The strawberry clover and resident weeds occupied about 15 feet in the middles leaving a strip of bare ground about 7 feet wide centered on the tree rows. The clean culture treatment and vegetation free strips in each tree row were maintained using a hoe or spot treatments with glyphosate herbicide. Water was applied to the orchard using flood irrigation. A temperature probe (Campbell Scientific, Inc. model 107 thermistor) was placed in the canopy on the east side of each tree in the center row of three trees in each plot. Thus, a total of nine canopy temperature measurements were made for each treatment. The temperature probes were connected to a data logger (Campbell Scientific Inc., model 21X Micrologger). The temperature monitoring equipment was installed on 4/29/94. A solar panel and car battery system were installed to power the system on 9/26/94 rather than continue to use the internal batteries of the 21X Micrologger. Several probes that were damaged by coyotes were repaired 10/28/94 and metal screens were installed to protect exposed thermistor wires. An anemometer (R.M. Young model 03101-5 wind sentry anemometer) and an air temperature probe (Campbell Scientific, Inc. model ASPTC aspirated shield with fine wire thermocouple) were installed on 2/10/95. Weather data was collected continuously by reading the sensors every 3 min and averaging the data from each sensor every 15 min. The 1994-95 harvest was conducted in stages as follows: block 1 on 2/24/95, block 2 on 3/2/95, block 3 on 3/10/95 and block 4 on 3/7/95. The 1995-96 and 1996-97 harvests were conducted in a similar fashion.

Leaf samples were collected in August 1994, 1995 and 1996 from three trees in each treatment in each block and pooled by treatment and block. The analysis of nitrogen, phosphorus, potassium, and sulfur was conducted as described above for the Yuma Mesa Experiment. Soil samples were collected on 12/5/96 from the top foot of the soil profile to measure total nitrogen, total organic carbon, and total organic matter in the soil in the different orchard floor treatments. Ten gram soil samples were air dried prior to grinding with a chain grinder through a 2 mm sieve. These samples were milled in a Spex ball mill. A 4 g subsample was treated with 10% phosphoric acid and oven dried at 80°C for 48 hrs to remove inorganic carbon for the determination of organic carbon and organic matter (Artiola, 1990). The remaining sample was analyzed for total nitrogen content. Samples were analyzed for total organic carbon and nitrogen by high temperature combustion using a Carlo Erba 1500 Nitrogen, Carbon, Sulfur Analyzer (Artiola, 1990). Organic matter content for these samples was calculated by multiplying the total organic carbon content by a factor of 2 (Page *et al.*, 1982).

Results and Discussion

Yuma Mesa Experiment. Changes in weed populations as a result of the different orchard floor management schemes were evident for warm season weeds by July 1994 (Table 1) and for winter and spring weeds by February 1995 (Table 2) as illustrated by the percent cover data for some of the more common weeds. In general, the population levels of all weed species were very low in the clean culture treatment indicating the efficacy of the herbicide treatments. The percent ground cover of bermudagrass remained very low in the clean culture plots because the Surflan killed bermudagrass seedlings emerging from seed and the post-emergence applications of Poast Plus or Torpedo provided good control of established plants (Table 1). Purple nutsedge control in the clean culture treatment was due primarily to the use of Solicam and the spot treatments of Roundup (Table 1). Disking provided reasonable control of bermudagrass in the orchard middles although ground cover increased in the intervals between disking operations as can been seen from the data collected in September 1995 (Table 1). The bermudagrass plants present in the disk treatment under the canopy of the trees were not contacted by the disk and provided a source for re-infestation of the middles. Similarly, purple nutsedge percent ground cover increased during the summer months between disking operations as shown by the data collected in July 1994, May 1995, and September 1995 (Table 1). Percent bermudagrass cover rapidly increased in the mow treatment over the course of this experiment (Table 1). Bermudagrass became the dominant weed in the mow treatment and it appears that this very competitive weed will eventually completely cover the ground in this treatment. Other warm season species that increased in the mow treatment were field sandburr (*Cenchrus pauciflorus*) and purple nutsedge (*Cyperus rotundus*) although their population numbers are still low (Table 1).

Comparison of the disk and mow treatments indicates that mowing favored grasses and purple nutsedge over broadleaf weeds. For example, common purslane covered 33.8% of the ground in the disk treatment but only 7% in the mow treatment in July 1994, and covered 10.9% of the ground in the disk treatment versus 0.8% in the mow treatment in July 1996 (Table 1). Similarly, the percent ground cover of two winter weed species, London rocket in February 1995, and annual sowthistle in February 1995 and April 1996, were greater in the disk treatment than in the mow treatment (Table 2). Grass and nutsedge species are more tolerant of mowing because their meristems or growing points are near the ground at the base of the shoots whereas the meristems of broadleaf weeds are at the top or apex of the shoots. In addition, as the amount of space occupied by bermudagrass and nutsedge plants increased, the opportunity for broadleaf weeds to become established in the mow treatment decreased. This trend was most evident in the data for the percent ground cover of common purslane in the summer (Table 1), and London rocket and annual sowthistle in the winter (Table 2). During the summer bermudagrass is actively growing and displaces summer annual weeds. Even in the winter when bermudagrass is either dormant or slowly growing on the Yuma Mesa, the above ground living and dormant grass biomass physically occupies space that prevents other species from becoming established. The seed of many small seeded winter annuals such as annual sowthistle do not easily make contact with the soil.

The population levels of broadleaf weeds such as common purslane in the summer, and London rocket and annual sowthistle in the winter (Table 2), rapidly increased in the disk treatment between disking operations. These and other broadleaf weeds were favored over grass type weeds in the disk treatment because of their taller stature compared to grasses and fast growth rates that allowed them to shade plants growing closer to the soil surface. It should be noted that the traditional practice of disking the orchard floor for weed control resulted in the buildup of a large soil seed bank for many weed species prior to the start of the experiment. The high numbers of seed in the soil resulted in a large number of emerged weeds following irrigations. In addition, bermudagrass was well established under the canopy of the trees at the start of the experiment. Thus, numerous herbicide applications were required to maintain the clean culture treatment.

Low rate applications of Roundup in the chemical mow treatment were not effective in controlling many weed species and the populations of several undesirable weed species such as bermudagrass and purple nutsedge began to increase. In addition, rank growth of weeds began to restrict access to the plots and hinder additional chemical mow treatments. On 7/26/94 this treatment was mowed and on 8/4/94 Roundup was applied at 3 qt/A to terminate the treatment. Thus, yield data from this treatment is not truly reflective of a chemical mow weed management scheme. Plots assigned to the chemical mow treatment were disked to prepare a seedbed, planted with strawberry clover on 10/28/94, and irrigated in an attempt to establish a cover crop. Emergence and establishment of strawberry clover was very poor so a second attempt at planting was made in spring 1995 also without success. The difficulty in establishing the strawberry clover was probably due to the rapid drying of the sandy soil surface after irrigation. Seed quality may also have been a factor. In October 1996, the plots formerly assigned to the chemical mow treatments were treated with pre-emergence herbicides at the same time as the clean culture treatment and converted to a treatment that is a combination of the disk and clean culture treatments (referred to as clean & disk). Thus, the disk and clean treatment was disked on the same schedule as the disk treatment and treated with herbicides at the same time as the clean culture treatment. The disk and clean culture treatment allowed for the assessment of the impact of disking on yield without the confounding influence of weed competition.

The lemon harvest data for the 1994-95 season suggested that the different orchard floor management schemes might result in yield differences between treatments although the differences were not statistically significant at this harvest (Table 3). The 1995-96 and 1996-97 treatment yields confirmed that the yield of the clean culture treatment was significantly greater than either the mow or the disk treatments (Table 3). The mow and disk treatments were not significantly different from one another and the relative yields of the two treatments were different in the 1994-95 through 1996-97 harvests. The percent ground cover of bermudagrass in the mow treatment was greater during the 1995-96 harvest and 1996/97 harvest than the 1994-95 harvest, suggesting that the disk treatment may surpass the yield of the mow treatment over the long-term as the effect of the bermudagrass infestation becomes more severe.

In addition to greater total yield, the clean culture treatment resulted in greater yield at the first (10/4/95) and second (12/12/95) harvests of the 1995-96 season (Table 4), and the second harvest (12/6/96) of the 1996-97 season (Table 5). Furthermore, at the first harvest, the clean culture treatment had a significantly greater percentage of fruit in the 115 and larger size category than the disk or mow treatments (Table 7). Similar results occurred during the 1996-97 season (data not shown). These yield benefits of the clean culture treatment have the potential to enhance economic returns to growers relative to the disk or mow orchard floor management schemes.

The clean & disk treatments led to intermediate total yields during the 1996-97 harvest season (Table 3), and significantly reduced yields for the second harvest (12/6/96), compared to the clean culture, suggesting that there may be some reduction in yield due to damaged shallow tree roots.

Weeds compete with crops for light, nutrients, and water in agricultural production systems. Given the stature of the lemon trees relative to the weeds, the lemon trees are the dominant competitor for light in this experiment. Thus, the lower yields of the disk and the mow orchard floor management treatments may be due to either competition for water, or competition for nutrients, or both. There were no significant differences between treatments in the level of nitrogen, potassium, phosphorous, and sulfur in leaves collected in August 1994 and 1995 (Table 8), and none of the nutrients were limiting for tree growth or fruit production. This suggests that competition for water in the mow and the disk treatments and possibly damage to shallow roots in the disk treatments resulted in lower yields than in the clean culture treatment

Citrus Agricultural Center Experiment. The Valencia orange harvest for the 1994-95 and 1996-97 season was inconclusive as there were no significant differences between the three orchard floor management treatments (Table 9). There was large variation in the 1994-95 yields because there were large differences in yields of trees in the same treatment. This variation was probably due the young age of the trees and varying degrees of frost injury sustained by the trees in 1992. The 1994-95 harvest data should also be viewed with caution because the strawberry clover cover crop was not well established until early 1995. The 1995-96 harvest data indicate that the clean culture treatment yielded significantly more than the mowed resident weed treatment (Table 9). This result is consistent with the yield differences measured between the clean culture and mow treatments in the Yuma Mesa experiment discussed above. The major weeds in the mowed resident weed plots were barnyard grass (*Echinochloa crusalli*), Mexican sprangletop (*Leptochloa uninerva*), horseweed (*Conyza canadensis*), prostrate pigweed (*Amaranthus graecizans*), and sowthistle (*Sonchus oleraceus*) in the winter; bermudagrass was not present at this study site. The Salina strawberry clover cover crop treatment had a mean yield that was intermediate between and not significantly different from the clean culture or mowed resident weed treatment yields (Table 9).

Soil samples collected in December 1995 showed that the resident weed and strawberry clover treatments had a beneficial impact on soil characteristics. The strawberry clover treatment had significantly more total soil nitrogen, total organic carbon, and total organic matter than either the resident weed or the clean culture treatments (Table 10). The resident weed treatment had intermediate amounts of organic carbon and organic matter but did not have significantly more soil nitrogen than the clean culture treatment (Table 10). Although there were differences between treatments in total soil nitrogen levels, there were no significant differences between treatments in the level of nitrogen in the leaf samples collected in August of 1994 and 1995 (Table 11). There were also no differences in potassium, phosphorus, and sulfur content of the leaf samples and none of the four nutrients were limiting for tree growth or fruit production (Table 9). These results were similar to those discussed in the Yuma Mesa experiment and suggest that water may be the limiting factor that reduces yield. However, the improvement of soil characteristics and the intermediate yield of the strawberry clover treatment (that was not significantly different from the clean culture yield) offer encouragement that better irrigation management may avoid tree water stress and result in higher yields. Another benefit of the strawberry clover treatment observed in this experiment was effective suppression of weeds.

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Table 1. Effect of mowing, disking, and herbicide applications on the percent ground cover for some common summer weeds on the Yuma Mesa.

Species	Date	Percent ground cover			
		Mow	Disk	Clean Culture	Clean & Disk
		%	%	%	%
bermudagrass	3/94	0.6 ± 1.0[a]	1.3 ± 2.2	0.2 ± 0.8	--
(*Cynodon dactylon*)	7/94	31 ± 29	6.2 ± 1.7	0.7 ± 0.5	--
	10/94	48 ± 35	0.0 ± 0.0	3.3 ± 5.1	--
	2/95	39 ± 29	2.4 ± 1.0	1.5 ± 1.2	--
	5/95	58 ± 32	2.8 ± 2.5	1.1 ± 1.0	--
	9/95	76 ± 35	19.6 ± 27	2.4 ± 3.7	--
	1/96	69 ± 38	1.6 ± 1.3	0.1 ± 0.2	0.4 ± 0.5
	4/96	75 ± 28	6.2 ± 7.2	0.6 ± 0.8	1.9 ± 1.3
	7/96	77 ± 33	22.4 ± 19	3.0 ± 2.6	1.4 ± 2.2
	10/96	70 ± 35	12.6 ± 11.8	3.3 ± 4.9	2.1 ± 2.6
purple nutsedge	3/94	0.8 ± 0.3	0.1 ± 0.3	0.9 ± 2.2	--
(*Cyperus rotundus*)	7/94	4.2 ± 4.5	8.4 ± 11.7	2.6 ± 4.7	--
	10/94	8.9 ± 12.2	0.0 ± 0.0	1.0 ± 1.2	--
	2/95	0.8 ± 1.1	0.2 ± 0.5	0.0 ± 0.0	--
	5/95	8.4 ± 12.1	12.2 ± 19.2	0.2 ± 0.5	--
	9/95	9.8 ± 19.4	10.8 ± 15.9	0.1 ± 0.2	--
	1/96	4.5 ± 12.4	0.1 ± 0.2	0.0 ± 0.0	0.0 ± 0.0
	4/96	5.6 ± 11.0	2.8 ± 5.1	0.0 ± 0.0	0.3 ± 0.5
	7/96	7.2 ± 5.3	7.4 ± 5.4	0.8 ± 1.3	1.5 ± 2.0
	10/96	18.5 ± 12.6	7.6 ± 15.0	0.7 ± 0.9	1.8 ± 1.8
common purslane	3/94	8.8 ± 12.4	18.0 ±15.2	3.1 ± 7.2	--
(*Portulaca oleracea*)	7/94	7.0 ± 1.8	33.8 ± 3.2	1.9 ± 1.1	--
	10/94	0.1 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	--
	2/95	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	--
	5/95	0.2 ± 0.7	14.3 ± 14.5	0.0 ± 0.0	--
	9/95	0.1 ± 0.2	2.2 ± 1.4	0.8 ± 1.1	--
	1/96	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	4/96	0.0± 0.0	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
	7/96	0.8 ± 2.2	10.9 ± 8.9	10.8 ± 11.5	0.2 ± 0.5
	10/96	0.1 ± 0.2	0.1 ± 0.2	0.2 ± 0.4	0.0 ±0.0
field sandburr	7/94	10.6 ± 12.2	0.3 ± 0.6	0.0 ± 0.0	--
(*Cenchrus pauciflorus*)	9/95	1.3 ± 1.7	0.2 ± 0.5	0.0 ± 0.0	--
	1/96	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	4/96	0.1 ± 0.2	0.4 ± 0.9	0.0 ± 0.0	0.0 ± 0.0
	7/96	0.6 ± 0.9	1.6 ± 3.7	0.4 ± 0.6	0.0 ± 0.0
	10/96	0.3 ± 0.8	0.3 ±1.2	0.0 ±0.0	0.0 ± 0.0

[a] Values are means ± standard deviations.

Table 2. Effect of mowing, disking, and herbicide applications on the percent ground cover for some common winter and spring weeds on the Yuma Mesa.

Species	Date	Percent ground cover			
		Mow	Disk	Clean Culture	Clean & Disk
		%	%	%	%
horseweed	3/94	48 ±109[a]	0.0 ± 0.0	0.0 ± 0.0	--
(*Conyza canadensis*)	7/94	10.5 ± 18.2	0.1 ± 0.3	0.0 ± 0.0	--
	10/94	0.1 ± 0.3	0.0 ± 0.0	0.1 ± 0.2	--
	2/95	6.8 ± 2.6	5.0 ± 1.9	0.1 ± 0.4	--
	5/95	12.8 ± 21.2	0.3 ± 0.8	0.0 ± 0.0	--
	9/95	0.8 ± 1.4	0.6 ± 0.9	0.0 ± 0.0	--
	1/96	0.0 ± 0.0	1.4 ± 3.7	0.0 ± 0.0	0.0 ± 0.0
	4/96	0.1± 0.3	11.5 ± 21.8	0.1 ± 0.5	0.1 ± 0.2
	7/96	1.5 ± 0.4	0.5 ± 0.2	0.1 ± 0.3	0.4 ± 1.2
	10/96	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
London rocket	10/94	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	--
(*Sisymbrium irio*)	2/95	11.2 ± 2.3	26.9 ± 3.5	0.0 ± 0.0	--
	5/95	0.1 ± 0.2	0.1 ± 0.3	0.0 ± 0.0	--
	9/95	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	--
	1/96	0.1 ± 0.2	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
	4/96	0.7 ± 1.1	1.0 ± 1.6	0.0 ± 0.0	0.0 ± 0.0
	7/96	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	10/96	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
annual sowthistle	3/94	30.5 ± 18.3	0.6 ± 1.1	0.1 ± 0.5	--
(*Sonchus oleraceus*)	7/94	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.3	--
	10/94	0.4 ± 0.5	0.0 ± 0.0	1.1 ± 0.9	--
	2/95	13.4 ± 2.7	31.9 ± 3.5	0.0 ± 0.0	--
	5/95	0.9 ± 1.6	0.2 ± 0.4	0.0 ± 0.0	--
	9/95	0.2 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	--
	1/96	0.1 ± 0.3	0.6 ± 1.3	0.0 ± 0.0	0.0 ± 0.0
	4/96	1.6 ± 1.8	11.5 ± 18.9	0.0 ± 0.0	0.0 ± 0.0
	7/96	0.4 ± 0.7	0.1 ± 0.2	0.1 ± 0.3	0.0 ± 0.0
	10/96	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

[a] Values are means ± standard deviations.

Table 3. Total yield of lemon trees on the Yuma Mesa in response to the use of mowing, disking, and clean culture with herbicides to manage orchard floor vegetation.

Treatment	1994-95 total	1995-96 total	1996-97 total	Cumulative total 1994-1997
	lbs/30 trees	lbs/30 trees	lbs/30 trees	lbs/30 trees
Mowing	7,020 ± 1150[a] a	10,730 ± 1102 b	3415 ± 733 b	21,165 ± 2130 b
Disking	6,638 ± 483 a	11,500 ± 915 b	3830 ± 1090 b	21,967 ± 1115 b
Clean & Disk	---	---	3950 ± 947 ab	---
Clean Culture	7,655 ± 788 a	13,320 ± 848 a	4460 ± 706 a	25,435 ± 1037 a

[a] Values are means ± standard deviations. Values within a column followed by the same letter are not significantly different according to Duncan's multiply range test at P=0.05.

Table 4. Yield by picking date for the 1995-96 harvest of lemon trees on the Yuma Mesa in the mowing, disking, and clean culture with herbicides orchard floor management treatments.

Treatment	October 4,1995	December 12, 1995	February 28, 1996
	lbs/30 trees	lbs/30 trees	lbs/30 trees
Mowing	1,000 ± 383[a] b	3,690 ± 781 b	6,040 ± 822 a
Disking	1,480 ± 445 b	4,425 ± 223 ab	5,595 ± 1044 a
Clean culture	2,370 ± 329 a	4,950 ± 1059 a	6,000 ± 118 a

[a] Values are means ± standard deviations. Values within a column followed by the same letter are not significantly different according to Duncan's multiply range test at P=0.05.

Table 5. Yield by picking date for the 1996-97 harvest of lemon trees on the Yuma Mesa in the mowing, disking, and clean culture with herbicides orchard floor management treatments.

Treatment	October 3, 1996	December 6, 1996
	lbs/30 trees	lbs/30 trees
Mowing	555 ± 145 a	2860 ± 747 c
Disking	505 ± 171 a	3325 ± 953 b
Clean & Disk	335 ± 62 a	3615 ± 887 a
Clean Culture	325 ± 145 a	4135 ± 849 b

[a] Values are means ± standard deviations. Values within a column followed by the same letter are not significantly different according to Duncan's multiply range test at P=0.05.

Table 6. Lemon fruit size under mowing, disking, and clean culture orchard floor management treatments in the first (10/5/95) and second (12/12/95) picks of the 1995-96 harvest on the Yuma Mesa.

		Fruit size (fruit/box) as a percentage of all fruit harvested					
Date	Treatment	200	165	140	115	95 and larger	115 and larger
		%	%	%	%	%	%
10/5/95	Mowing	1.75 a	39.75 a	46.72 a	9.80 b	1.93 b	11.73 b
	Disking	1.90 a	37.85 ab	46.67 a	11.05 b	2.50 b	13.55 b
	Clean Culture	1.55 a	30.75 b	47.85 a	15.22 a	4.66 a	19.88 a
12/12/95	Mowing	3.42 a	35.51 a	28.53 a	8.39 c	1.69 a	10.08 b
	Disking	2.22 a	23.47 a	28.07 a	26.45 a	3.81 a	30.27 ab
	Clean Culture	5.27 a	22.61 a	28.18 a	14.35 bc	8.41 a	22.77 ab

[a] Values are means; values within a column followed by the same letter are not significantly different according to Duncan's multiply range test at P=0.05.

Table 7. Lemon fruit size under mowing, disking, and clean culture orchard floor management treatments in the first (10/3/96) and second (12/6/96) picks of the 1996-97 harvest on the Yuma Mesa.

		Fruit size (fruit per box) as a percentage of all fruit harvested				
Date	Treatment	200	140	115	95	140 and larger
		%	%	%	%	%
10/3/96	Mow	25.12 b	18.17 a	3.05 a	0.35 a	21.60 a
	Disk	32.62 a	14.62 a	2.17 ab	0.20 a	17.05 ab
	Clean & disk	31.97 a	14.77 a	2.30 ab	0.30 a	17.43 ab
	Clean culture	33.37 a	13.42 a	1.70 b	0.18 a	15.32 b
12/6/96	Mowing	21.97 a	21.22 b	2.90 b	0.17 a	24.30 b
	Disking	20.17 ab	25.15 b	3.80 b	0.25 a	29.22 b
	Clean & disk	19.62 b	25.00 b	3.70 b	0.23 a	28.92 b
	Clean culture	16.92 c	30.35 a	5.17 a	0.30 a	35.85 a

[a] Values are means; values within a column followed by the same letter are not significantly different according to Duncan's multiple range test at P=0.05.

Table 8. Effect of mechanical mowing, disking, and clean culture orchard floor management treatments on the levels of nitrogen, potassium, phosphorous and sulfur levels in Lisbon 8A lemon leaves on the Yuma Mesa. For each nutrient within each year, none of the treatment means were significantly different from other treatments.

Year	Treatment	Nitrogen	Potassium	Phosphorus	Sulfur
		% dry wt.	% dry wt.	% dry wt.	% dry wt.
1994	Mowing	2.90	1.69	0.22	0.24
	Disking	2.88	1.70	0.23	0.33
	Clean Culture	2.90	1.74	0.21	0.32
	Chemical mow	2.83	1.64	0.21	0.25
1995	Mowing	2.69	2.86	0.22	1.09
	Disking	2.73	2.94	0.22	1.20
	Clean Culture	2.59	2.87	0.21	0.99
	Clean and disk	--	--	--	--

Table 9. Yield of Valencia oranges in the clean culture, mowed resident weeds, and Salina strawberry clover orchard floor vegetation management treatments at the Citrus Agricultural Center in Waddell.

Treatment	1994-95	1995-96	1996-97
	(lbs/ tree)	(lbs/ tree)	(lbs/ tree)
Clean Culture	61 ± 24 a	114 ± 38 a	111 ± 37 a
Resident weeds	55 ± 27 a	88 ± 24 b	93 ± 49 a
Strawberry clover	48 ± 29 a	97 ± 41 ab	97 ± 33 a

[a] Values are means ± standard deviation. Values within a column followed by the same letter are not significantly different according to Duncan's multiply range test at P=0.05.

Table 10. Effect of the clean culture, mowed resident weeds, and Salina strawberry clover orchard floor vegetation management treatments on total soil nitrogen, total soil organic carbon, and total soil organic matter in Valencia oranges at the Citrus Agricultural Center in Waddell.

Treatment	Total soil nitrogen	Total organic carbon	total organic matter
	ppm	% w/w	% w/w
Clean Culture	367 ± 65 b	0.247 ± 0.035 c	0.493 ± 0.069 c
Resident weeds	433 ± 65 b	0.345 ± 0.042 b	0.690 ± 0.084 b
Strawberry clover	567 ± 98 a	0.452 ± 0.089 a	0.903 ± 0.174 a

[a] Values are means ± standard deviation. Values within a column followed by the same letter are not significantly different according to Tukey-Kramer Honestly Significant Difference test at P=0.05.

Table 11. Effect of the clean culture, mowed resident weeds, and Salina strawberry clover orchard floor vegetation management treatments on the levels of nitrogen, potassium, phosphorous and sulfur levels in Valencia orange leaves at the Citrus Agricultural Center in Waddell. For each nutrient within each year, none of the treatment means were significantly different from the other treatments.

Year	Treatment	Nitrogen	Potassium	Phosphorus	Sulfur
		% dry wt.	% dry wt.	% dry wt.	% dry wt.
1994	Clean Culture	2.81	1.70	0.20	1.08
	Resident weeds	2.60	1.63	0.19	0.99
	Strawberry clover	2.50	1.64	0.21	1.14
1995	Clean Culture	3.46	2.64	0.31	0.40
	Resident weeds	3.64	2.80	0.31	0.42
	Strawberry clover	3.37	2.84	0.31	0.41