Citrus Orchard Floor Management 2001: Comparison of a Disk, "Perfecta" Cultivator, and Weed Sensing Sprayer.[1]

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Abstract

Mechanical (disk and Perfecta cultivator) and chemical weed control strategies were compared in a Yuma, AZ lemon orchard. In addition, an optical weed sensing sprayer (WeedSeeker) was evaluated for making post-emergence Roundup Ultramax herbicide applications. The use of pre-emergence herbicides in conjunction with the WeedSeeker spray units has the potential to significantly reduce the amount of post-emergence herbicide and water needed to spray flood irrigated citrus orchards. There was a relationship between weed ground cover and the area sprayed by the WeedSeeker units that indicated the maximum herbicide saving will occur a low weed densities. The use of the Kawasaki Mule with its superior suspension system allowed for faster spraying speeds than were possible with the tractor mounted sprayer and this also reduced spray volume per plot. Weed control was similar for the conventional and the WeedSeeker sprayers. Future investigations will include efforts to improve the estimation of percent weed groundcover, the use of higher rates of pre-emergence herbicides and the development of crop budgets based on experimental operations.

Introduction

Weeds are a significant impediment to the efficient production of Arizona tree, nut and vine crops. Whether orchards are flood, furrow, micro-sprinkler, or drip irrigated, water is a limiting resource in Arizona crop production systems. Several studies in citrus have shown weeds reduce tree crop yields by using irrigation water and other resources. In an experiment in Yuma, Arizona in a 'Limoneira 8A Lisbon' lemon grove, disking provided acceptable weed control except underneath the tree canopies where bermudagrass, purple nutsedge, and other weed species survived (McCloskey *et al*., 1997). Mowing the orchard floor suppressed broadleaf weed species allowing the spread of grasses, primarily bermudagrass. A clean culture treatment that used pre-emergence (Solicam and Surflan) and post-emergence (Roundup and Poast) herbicides for weed control had a greater cumulative 3 year yield (11,537 kg/30 trees) than the disk (9,964 kg/30 trees) or mow treatments (9,600 kg/30 trees) (McCloskey *et al*.,

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1997). In addition, the clean culture treatment had a significantly greater percentage of fruit in the 115 and larger size category at the first harvest than either the disk or mow treatments thus increasing economic returns to growers. Jordan (1981) measured the effect of competition from annual weeds or bermudagrass on 'Valencia' orange tree growth and found that tree volume, trunk circumference, leaf area per tree, and length of new shoot growth were greatest in the absence of weeds. 'Valencia' orange tree yields under sprinkler irrigation were 66.9 kg/tree in the absence of weed competition but trees competing with annual weeds or bermudagrass yielded 28.7 and 15 kg/tree, respectively (Jordan, 1981). Trees competing with weeds were also more water stressed than trees not competing with weeds. Tree leaf water potentials were correlated with soil moisture content leading to the conclusion that the weeds and trees were competing for water (Jordan, 1981). Similarly, Tucker *et al*. (1997) found that mechanical mowing of weeds in citrus tree row middles resulted in greater soil moisture depletion than intensive herbicide use combined with infrequent mowing.

Both pre-emergence (McCloskey and Maurer, 1997) and post-emergence herbicides can be used to maintain a clean orchard floor. Common strategies include: the exclusive use of post-emergence herbicides, a combination of pre- and post-emergence herbicides, and a combination of pre- or post-emergence herbicides in conjunction with an occasional cultivation. Pre-emergence herbicides must be incorporated and are usually broadcast on the entire orchard floor since growers do not know where weeds will emerge. Growers with drip irrigated or micro-sprinkler irrigated orchards have a difficult time adequately incorporating pre-emergence herbicides and are often reduced to trying to predict when significant rainfall will occur. Mechanical incorporation with a disk or Perfecta field cultivator can prune feeder roots near the surface of the soil, especially in flood-irrigated orchards, while water incorporation is feasible only in flood irrigated orchards. The degree of root injury increases when mechanical weed control equipment is used to control weeds growing close to the tree. Careless operation of equipment can also result in tree damage (i.e., broken branches and injured trunks) that can provide an entry point for plant pathogens (Matheron et al., 1998). In addition to damaging roots and trees, mechanical weed control strategies such as disking and use of the Perfecta field cultivator, incorporate and bury weed seeds in the soil inducing seed dormancy and bring buried seed to the soil surface breaking their dormancy and priming them for germination (Ross and Lembi, 1999). In addition, mechanical weed control, particularly disking, buries weed biomass into the soil and creates breeding habitat for the Liohippelates eye gnat, *Liohippelates collus*, which is quite annoying to homeowners and workers in citrus orchards (Metcalf and Metcalf, 1993). As a result of these considerations, post-emergence herbicides, especially glyphosate (e.g., Roundup), have become popular tools for weed control in Arizona tree crops. Although some Roundup foliar injury can result from incidental contact with bearing citrus trees, this injury does not cause yield losses or result in permanent injury to trees (McCloskey and Wright, 1998).

The advantages associated with the use of post-emergence herbicides include not disturbing the soil profile and stimulating weed emergence, having the ability to select an herbicide based on the type of weeds in the orchard, and being able to spray herbicide only where weeds are present. Currently, tree crop growers in Arizona choose between broadcast applications of post-emergence herbicides to the entire orchard floor or spot spraying weeds. Broadcast applications waste chemical by spraying bare ground, especially when weeds are small and percent ground cover is low. Spot spraying is slow and incurs high labor costs. An ideal solution to this dilemma would be to use a sprayer that could optically distinguish between weeds and bare ground and only spray when and where weeds are present. One such sprayer, the Patchen Weed Seeker sprayer that utilizes infrared light to detect chlorophyll, was found to reduce herbicide use up to 60% at 20% weed ground cover and up to 86% at 5% weed ground cover (Prather et. al., 2002; Hanks and Beck, 1998).

While many different orchard floor management strategies are used, there is no consensus as to which regime results in the greatest yield and tree growth and the most cost effective weed control. Arizona tree crop producers need more information regarding the use of the Perfecta cultivator and currently do not use weed-sensing sprayers. Thus, the objectives of this project are; 1) to evaluate the effect of the Perfecta cultivator on tree yields and eye gnat populations, 2) to evaluate the potential for reduced herbicide use in Arizona tree crops with the Patchen Weed Seeker sprayer; 3) evaluate the utility of the Patchen sprayer used in conjunction with pre-emergence herbicides or the Perfecta, and 4) collect tree yields and field operational data in order to develop crop budgets and determine the economics of using the Perfecta cultivator and the Patchen sprayer technology.

Materials and Methods

The study was established in a flood-irrigated, lemon grove planted in spring 1998 on the Yuma Mesa (soil series: Superstition Sand) managed by Glen Curtis, Inc. Trees are 'Limoneira 8A Lisbon' on *Citrus. macrophylla* rootstock. Experimental design was randomized complete block with six blocks. A previous experiment was modified on May 6, 2001 to establish the current plots. Each plot (i.e., experimental unit) consisted of a row of 10 trees and the tree middles on either side of the tree row. Adjacent plots were separated from each other by a row of trees that provided a buffer between plots. The experimental treatments were:

1. (D) Disk only: The treated orchard floor was disked in two directions (east-west and north-south) with a standard orchard disk 6 or more times annually, depending on weed growth. Weeds at the base of the trees were spot sprayed with herbicides.

2. (P1) Perfecta field cultivator: The treated orchard floor was cultivated in two directions with a "Perfecta" cultivator 6 to 7 times or more annually, depending on weed growth. Weeds at the base of the trees were spot sprayed with herbicides.

3. (P2) Perfecta field cultivator plus broadcast herbicide (Surflan @ 3 lb a.i./acre + Solicam 2.0 lb a.i./acre applied in the fall): The treated orchard floor was cultivated in both directions with a "Perfecta" cultivator 6 to 7 times or more annually (at the same time as treatments P1 and P3), depending on weed growth. Pre- and post-emergence herbicides were used to control weeds as needed. Weeds at the base of the trees were spot sprayed with herbicides. Comparison of this treatment with treatment 2 (P1) was designed to assess the possible effects of root damage caused by the "Perfecta" cultivator.

4. (P3) Perfecta field cultivator plus herbicide strip on tree line (Surflan @ 3 lb a.i./acre + Solicam 2.0 lb a.i./acre applied in the fall): The treated orchard floor was cultivated in one direction (east-west) with a "Perfecta" cultivator leaving an uncultivated strip centered on the treatment tree line. Cultivation operations took place 6 to 7 or more times annually, depending on weed growth and were conducted at the same treatments P1 and P2 were cultivated. The non-cultivated strip was treated with pre- and post-emergence herbicides. The Patchen sprayer was used to spot spray weeds in the uncultivated strip.

5. (H1) Patchen post-emergence herbicide: The Patchen WeedSeeker sprayer was used to spray glyphosate (various formulations of Roundup) on the orchard floor 10 to 12 times per year.

6. (H2) Broadcast pre-emergence plus Patchen post-emergence herbicide: Surflan (3 lb a.i./acre) and Solicam (2.0 lb a.i./acre) were applied in the fall followed by applications of glyphosate (Roundup Ultramax) applied with the Patchen WeedSeeker sprayer on an as needed basis.

7. (H3) Broadcast Post-emergence herbicide: glyphosate (Roundup Ultramax) was sprayed on an as needed basis using a conventional orchard sprayer.

For each treatment, records of material, equipment, and labor costs were maintained for economic analysis. Interim economic analysis is not presented in this report. Emergence cages were used to monitor eye gnat emergence from the soil in treatments D, P1, P2, H1 and H2. Weeds at the base of the trees not controlled by mechanical cultivation were spot sprayed with herbicides in D, P1, and P2. Weed populations were monitored regularly. The growth of mature trees was determined by collecting fruit yield and packout data.

In April and May of 2001, a sprayer with a 16 gallon tank, diaphragm pump, and a side and rear boom was constructed and mounted on a 50 hp tractor (John Deere 2240). Patchen WeedSeeker spray units were mounted on the side and rear booms and cables were routed to a control computer mounted near the driver's seat. The side boom contained spray units mounted at angles (from the end of the boom to the tractor) of 45, 30, 15, 0 and 0 degrees from vertical. This allowed the spray swath to extend about 2 feet beyond the end of the boom. The outside three spray units were protected from tree branches by a shield. The rear boom contained eight WeedSeeker spray units so that the total spray swath was about 13 feet wide. The orchard was mowed to reduce weed height on May 1, 2001, the entire orchard was sprayed with Roundup Ultramax at 1.5 lb acid equivalent (a.e.)/acre or 52 oz of product/acre on May 24, and the disking and Perfecta cultivation were done on May 31, 2001. (Note that unless

otherwise specified, all Roundup treatments included spray grade ammonium sulfate at a rate of 8.5 lb/100 gallons of spray solution). The appropriate treatments were sprayed again with either a conventional spray boom or the Patchen spray boom on June 6 to 8, 2001 using Roundup Ultramax at 1.125 lb a.e./acre. Weed control was evaluated on July 10, 2001 and the appropriate treatments were disked and cultivated with the Perfecta on July 17 and 18, 2001.

Several problems were identified with the Patchen WeedSeeker sprayer during the June spray operations. The diaphragm pump did not produce sufficient pressure or spray volume, the small spray tank required frequent mixing and loading operations, the 0 to 10 GPM (gallons per minute) flowmeter used was not sensitive enough to measure the small flow rates that were observed, the lack of a suspension system limited tractor speed, and the tractor with the rear mounted sprayer was too long, making it difficult to maneuver in the orchard. Thus, a second spray system was constructed using a 65 gallon cone tank, an electric roller pump (10 GPM) and equipped with a 0.3 to 3 gpm flowmeter (Great Plains Industries, Wichita, KS) in August 2001. This spray system, the Patchen computer controller and the previously constructed Patchen WeedSeeker spray booms were mounted on a 4 wheel drive Kawasaki Mule equipped with a radar ground speed detector. In late July, the entire orchard was disked and, following irrigation, treatments P2, P3, H1, H2, and H3 were sprayed with Roundup Ultramax at 1.5 lb a.e./acre on August 22, 2001 using a conventional orchard sprayer. On August 27, 2001, treatments P2, P3, and H2 were sprayed with a tank mix of pre-emergence herbicides, Surflan at 2.5 lb active ingredient (a.i.)/acre and Solicam at 2 lb a.i./acre using a conventional orchard sprayer. On October 15, 2001, treatments P2, P3, and H3 were sprayed with a conventional orchard sprayer while H1 and H2 were sprayed using the Patchen spray booms. Roundup Ultramax at 0.75 lb a.e./acre was used in all sprayed treatments. The flowmeters were used to measure the spray volume used in each plot.

An Olympus Camedia C3030 digital camera mounted 2 m above the ground on a pole was used to take 4 pictures per plot in treatments sprayed with the Patchen sprayer. A software package, SigmaScan from SPSS Science Software, was used to digitally analyze the ratio of green picture pixels to non-green pixels and calculate percent ground cover. A general weed control rating was done on October 31, about two weeks after the previous Roundup applications.

The experiment was strip-harvested (all fruit removed from the trees) on November 14 and 15, 2001. Fruit yields for each plot were estimated by counting the whole and fractional standard 545 kg wooden bins containing harvested fruit. A 32 kg sample was collected from each bin to determine fruit size and exterior quality. The sample fruit were passed through a trailer-mounted, completely automated photographic fruit sorter (Autoline, Inc., Reedley, CA) on November 16, 2001. The fruits that passed through the sorter were weighed and then fruit color, exterior peel quality (% blemish), and fruit diameter data were optically determined and recorded by a computer that is an integral part of the sorter.

The disking and Perfecta cultivation operations were conducted again in the appropriate treatments on December 4 and 5, 2001, January 28, 2002, and May 23 and 24, 2002. Post-emergence Roundup Ultramax applications with the conventional sprayer (P2 and H3) or Patchen sprayer (P3, H1 and H2) were made in the appropriate treatments on December 6, 2001 (Roundup Ultramax at 52 oz/acre) and March 4, 2002 (Roundup Ultramax at 40 oz/acre). On May 23 and 24, 2002 the Perfecta cultivator and disk operations, respectively, were conducted. On June 4, all of the treatments that received post-emergence Roundup Ultramax applications (P2, P3, H1, H2, and H3) were sprayed with Roundup Ultramax at 40 oz/acre using the conventional orchard sprayer. Eye gnat emergence was monitored from June 12 to 19, 2002 using metal cages placed in the disk, Perfecta, and herbicide treatments. The field was mowed on July 12, 2002 and the mechanical cultivation operations (i.e., disk and Perfecta cultivator) were conducted again on July 17, 2002. Post-emergence Roundup Ultramax applications with the conventional sprayer (P2 and H3) or Patchen sprayer (P3, H1 and H2) were again made in the appropriate treatments on July 16, 2002 (Roundup Ultramax at 52 oz/acre). Four digital pictures were taken in each plot sprayed with the Patchen sprayer as described above to determine percent ground cover.

Results and Discussion

The orchard floor became quite weedy in the spring of 2001 for a variety of reasons including our inability to obtain sufficient quantities of Surflan. The orchard was mowed on May 1 to reduce weed height and the orchard was

irrigated. At this time, the experiment was reconfigured and converted from three to six blocks by reducing plot size, and the treatments were re-randomized. The P3 and H3 treatments were sprayed with Roundup Ultramax at 1.5 lb a.e./acre using a conventional sprayer on May 24, 2001. The disking (D) and Perfecta cultivation (P1, P2, and P3) were conducted on May 31, 2001 and treatments P2, H1, and H2 were sprayed with Roundup Ultramax at 1.12 lb a.e./acre using the WeedSeeker spray units on June 6 and 8, 2001. Several problems during spraying on June 6 and 8 precluded comparing spray volumes in treatments sprayed with the conventional sprayer versus those sprayed with the WeedSeeker spray units. However, observation of the spray patterns and the red LED lights on each WeedSeeker unit indicated that the units were spraying intermittently and applying less spray volume compared to the conventional sprayer. A weed control assessment on July 10th showed that the chemical control treatments, H1 and H2, had superior weed control compared to the mechanical weed control treatments including even P2 which was sprayed at the same time as H1 and H2 (Table 1). Weed control in H3 was not as good as in H1 and H2 probably because there was a longer time interval between herbicide application and the weed control evaluation. The appropriate plots were disked (D) and cultivated with the Perfecta (P1, P2, P3) on July 17 and 18, 2001. Several problems were noted at this time. The Perfecta treatments (P1, P2, and P3), particularly P1, still contained substantial living bermudagrass and the soil surface was very lumpy or non-uniform. In addition, in the other Perfecta and herbicide treatments there was a large amount of standing, dead weed biomass that would interfere with the application of pre-emergence herbicides onto the soil surface. Thus, all treatments were disked on July 25, 2001. This resulted in a soil surface free of weed biomass and made the treatments the same with respect to weed competition with the trees. Treatments P2, P3, H1, H2, and H3 were sprayed with Roundup Ultramax on August 22, 2001 and treatments P2, P3 and H2 were sprayed with Solicam and Surflan on August 27, 2001.

Weed growth in the orchard during September and early October prompted Roundup Ultramax applications in October 15, 2001. All post-emergence herbicide treatments were applied using two different booms mounted on the Kawasaki Mule sprayer. Treatment H3 was a conventional broadcast post-emergence Roundup application that sprayed the entire ground surface of each plot, about 0.37 acre, using 5.84 gal./plot (Table 2). Treatment H1 did not include pre-emergence herbicides and had a percent weed groundcover similar to H3. Roundup Ultramax was applied in treatment H1 using the WeedSeeker spray units which sprayed 0.206 A/plot using 4.17 gal/plot (Table 2). Treatment H2, pre-emergence herbicides followed by post-emergence Roundup Ultramax applied with the WeedSeeker units, had a much smaller percent weed groundcover than H1 and H3 and, not surprisingly, had the smallest area sprayed and spray volume, 0.095 A/plot and 1.92 gal/plot, respectively (Table 2). The Perfecta cultivator treatment P3 was similar to H2 because at the time of the October 15th herbicide applications there were no differences in field operations between these treatments since the disking on July 25, 2001. Weed control ratings on October 31, about two weeks after the post-emergence herbicide applications, showed that weed control resulting from spraying Roundup Ultramax was similar for the conventional and WeedSeeker spray booms (Table 1).

The field was strip-harvested (all fruit removed from the trees) on November 14 and 15, 2001 and fruit samples were sorted on November 16, 2001. There were no significant yield or packout differences between any of the treatments (Table 3). Yield was variable due in part to the young age of the trees and because treatments had not been imposed long enough prior to harvest for differences in tree growth to affect treatment yields.

In December, the appropriate treatments were disked or cultivated with the Perfecta cultivator on December 4 and 5, 2001 and the herbicide treatments were sprayed on December 6, 2001. Similar to the October 15th data, the area sprayed in H2 was smaller than in H1 reflecting the residual weed control provided by the pre-emergence herbicides in treatment H2 (Table 4). Interestingly, cultivating with the Perfecta just prior to spraying did not reduce the area sprayed as much as on October 15th. We speculate that perhaps this occurred because the rough soil surface texture and dying biomass still present on the soil surface triggered the Weedseeker spray units to spray. We may also need to experiment with the sensitivity setting on computer that controls the discrimination between bare ground and green plants by the WeedSeeker units. Also, on this spray date there was a poor correlation between the weed groundcover calculated from the digital pictures and weed detection and spraying by the WeedSeeker units for unknown reasons. The post-emergence herbicide treatments were again applied on March 4, 2002 following disking and Perfecta cultivating operations on January 28, 2002. On this application date, the area sprayed in treatments H1 and H2 were similar suggesting that the Surflan at 2.5 lb ai/acre plus Solicam at 2 lb ai/acre were no longer providing residual weed control 6.5 months after their application (Table 5). Better year long pre-emergence herbicide weed control could be obtained by applying higher rates or making semiannual residual herbicide applications. The Perfecta cultivation on January 28, 2002, about a month before spraying, was much more effective in reducing the sprayed area in treatment P3 compared to December 6, 2001 perhaps because irrigation had

smoothed the soil surface and uprooted weeds died before spraying. On March 4th, there was a good correlation between weed groundcover calculated from the digital photographs similar to the data collected on October 15, 2001. The weed groundcover data was highly variable on December 6th and to a lesser extend on other dates suggesting that the area of ground photographed in each plot is too small.

Following cultivation with the Perfecta, disking, and herbicide applications on May 23, May 24 and June 4, respectively, eye gnat emergence from the treatments was monitored using cages placed on the soil surface between June 12 and June 19, 2002. The total numbers of gnats emerging from the disk, Perfecta and herbicide treatments were 614, 12, and 1, respectively, suggesting that the Perfecta cultivator may not provide suitable breeding habitat for *Liohippelates collus*. After remove of the gnat emergence cages, spray operations were conducted again on July 16, 2002. The spray data again indicated that the pre-emergence herbicides were no longer providing residual weed control in agreement with the March 4, 2002 data (Table 6). There were few differences between treatments on July 16th perhaps due to the cultural and herbicide spray operations that took place between March 4th and July 16, 2002 and the lack of residual herbicide effects.

In summary, there were consistent trends in the data from four different spray application dates. The use of pre-emergence herbicides in conjunction with the WeedSeeker spray units has the potential to significantly reduce the amount of herbicide and water needed to spray flood irrigated citrus orchards. There was a relationship between weed ground cover and the area sprayed by the WeedSeeker units that indicated the maximum herbicide saving will occur a low weed densities (Figure 1). The use of the Kawasaki Mule with its superior suspension system allowed for faster spraying speeds than were possible with the tractor mounted sprayer and this also reduced spray volume (H3 versus H2 and H2). Weed control was similar for the conventional and the WeedSeeker spray booms. Future investigations will include efforts to improve the estimation of percent weed groundcover, the use of higher rates of pre-emergence herbicides and the development of crop budgets based on treatment experimental operations. The economic evaluation will allow assessment of the long-term benefits of purchasing the expensive WeedSeeker spray units.

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Table 1. Visual estimation of general weed control in mechanical and chemical control treatments in a Yuma, AZ Limoneira 8A Lisbon lemon orchard. Means followed by the same letter within a column are not significantly different at P = 0.05 according to analysis of variance and the Student-Newman-Keuls mean separation test.

Trt. Name	Mechanical Treatment	Herbicide Treatment and Sprayer Type	General Weed Control (% weed control)	
			July 10, 2001	Oct. 31, 2001
D	Disk	None	0 ± 0 d	23.3 ± 8.8 b
P1	Perfecta cultivator	None	12.5 ± 19.4 cd	33.3 ± 20.9 b
P2	Perfecta cultivator	PREE[a] Surflan - conventional PREE Solicam - conventional POST Roundup - conventional	23.0 ± 22.8 c	84.3 ± 9.5 a
P3	Perfecta cultivator in strip along tree line	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	15.8 ± 12.4 c	84.2 ± 3.8 a
H1	None	POST Roundup - WeedSeeker	71.7 ± 13.7 a	87.8 ± 3.2 a
H2	None	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	69.2 ± 69.2 a	94.2 ± 2.8 a
H3	None	POST Roundup - conventional	36.7 ± 12.9 b	88.8 ± 6.4 a

[a]PREE = pre-emergence herbicide, POST = post-emergence herbicide

Table 2. Percent groundcover, spray volume per plot, and area sprayed during herbicide applications on October 15, 2001 in a Yuma, AZ Limoneira 8A Lisbon lemon orchard. Means followed by the same letter within a column are not different at P = 0.05 according to analysis of variance and the Student-Newman-Keuls mean separation test.

Trt. Name	Mechanical Treatment	Herbicide Treatment and Sprayer Type	Weed Groundcover[a]	Spray Volume[b]	Area Sprayed
			(%)	*(gal/plot)*	*(acre)*
P3	Perfecta cultivator	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	0.59 ± 0.82 b	2.01 ± 0.84 c	0.099 ± 0.041 c
H1	None	POST Roundup - WeedSeeker	7.47 ± 2.83 a	4.17 ± 0.52 b	0.206 ± 0.026 b
H2	None	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	1.41 ± 1.33 b	1.92 ± 0.58 c	0.095 ± 0.029 c
H3	None	POST Roundup - conventional		5.84 ± 0.15 a	0.371 ± 0.009 a

[a]Digital photographs, four pictures per plot, were taken with an Olympus 3030 Camedia digital camera mounted 2 m above the soil surface with a field of view equal to 3.20 m^2 or 34.5 ft^2. Computer software, SigmaScan Pro 5.0, was used to calculate the percent green pixels in each picture which was considered equal to percent weed groundcover.
[b]The output of the sprayers if operated in a continuous spray mode was 15.57 and 20.23 GPA for the conventional and WeedSeeker spray booms, respectively. Sprayer speed was about 6 MPH. The conventional spray boom contained TeeJet DG8003VS nozzles operated at about 35 PSI. The WeedSeeker spray units were operated at a sensitivity setting of 3 and contained TeeJet brass 6503EVS nozzles also operated at approximately 35 PSI.

Table 3. Lemon yield and packout in 2001-02 yield under disking, Perfecta cultivation, and herbicide orchard floor management regimes.

Treatment	Yield (lb/tree)	Packout (%)						
		63[a]	75	95	115	140	165	200
Disk	28.1	24.01	26.77	27.17	13.00	6.01	2.09	0.64
H1	33.6	31.07	25.37	22.67	11.99	5.43	2.17	0.90
H2	32.1	29.41	26.00	24.33	11.54	5.49	2.16	0.71
H3	37.5	34.54	25.25	22.76	9.83	4.85	2.00	0.52
P1	40.1	26.70	25.41	22.69	12.36	7.62	3.41	1.26
P2	34.1	35.56	25.64	21.64	9.79	4.72	1.82	0.59
P3	34.7	38.93	25.31	20.31	8.84	4.16	1.86	0.37
Significance[b]	0.847	0.131	0.932	0.114	0.305	0.105	0.190	0.239

[a] Number of fruit per box.
[b] Significance at "=0.05.

Table 4. Percent groundcover, spray volume per plot, and area sprayed during herbicide applications on December 6, 2001 in a Yuma, AZ Limoneira 8A Lisbon lemon orchard. Means followed by the same letter within a column are not different at P = 0.05 according to analysis of variance and the Student-Newman-Keuls mean separation test.

Trt. Name	Mechanical Treatment	Herbicide Treatment and Sprayer Type	Weed Groundcover[a]	Spray Volume[b]	Area Sprayed
			(%)	*(gal/plot)*	*(acre)*
P3	Perfecta cultivator	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	11.5 ± 12.6 a	4.37 ± 0.98 c	0.260 ± 0.058 c
H1	None	POST Roundup - WeedSeeker	8.1 ± 6.9 a	5.17 ± 0.65 b	0.308 ± 0.039 b
H2	None	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	2.03 ± 1.18 a	3.31 ± 0.71 d	0.197 ± 0.043 d
H3	None	POST Roundup - conventional		11.23 ± 0.01 a	0.382 ± 0.00 a

[a]Digital photographs, four pictures per plot, were taken with an Olympus 3030 Camedia digital camera mounted 2 m above the soil surface with a field of view equal to 3.20 m^2 or 34.5 ft^2. Computer software, SigmaScan Pro 5.0, was used to calculate the percent green pixels in each picture which was considered equal to percent weed groundcover.

[b]The output of the sprayers if operated in a continuous spray mode was 29.4 and 16.8 GPA for the conventional and WeedSeeker spray booms, respectively. Conventional and WeedSeeker sprayer speeds were 2.84 and about 6 MPH, respectively. The conventional spray boom contained TeeJet DG8003VS nozzles operated at about 35 PSI. The WeedSeeker spray units were operated at a sensitivity setting of 3 and contained TeeJet brass 6503EVS nozzles also operated at approximately 35 PSI.

Table 5. Percent groundcover, spray volume per plot, and area sprayed during herbicide applications on March 4, 2002 in a Yuma, AZ Limoneira 8A Lisbon lemon orchard. Means followed by the same letter within a column are not different at P = 0.05 according to analysis of variance and the Student-Newman-Keuls mean separation test.

Trt. Name	Mechanical Treatment	Herbicide Treatment and Sprayer Type	Weed Groundcover[a]	Spray Volume[b]	Area Sprayed
			(%)	*(gal/plot)*	*(acre)*
P3	Perfecta cultivator	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	1.61 ± 1.59 a	1.61 ± 0.84 c	0.096 ± 0.050 c
H1	None	POST Roundup - WeedSeeker	3.58 ± 0.87 a	3.24 ± 0.71 b	0.193 ± 0.042 b
H2	None	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	4.72 ± 2.35 a	3.52 ± 1.17 b	0.210 ± 0.070 b
H3	None	POST Roundup - conventional		10.75 ± 0.00 a	0.382 ± 0.00 a

[a]Digital photographs, four pictures per plot, were taken with an Olympus 3030 Camedia digital camera mounted 2 m above the soil surface with a field of view equal to 3.20 m^2 or 34.5 ft^2. Computer software, SigmaScan Pro 5.0, was used to calculate the percent green pixels in each picture which was considered equal to percent weed groundcover.
[b]The output of the sprayers if operated in a continuous spray mode was 28.14 and 16.8 GPA for the conventional and WeedSeeker spray booms, respectively. Conventional and WeedSeeker sprayer speeds were about 3 and 6 MPH, respectively. The conventional spray boom contained TeeJet DG8003VS nozzles operated at about 35 PSI. The WeedSeeker spray units were operated at a sensitivity setting of 3 and contained TeeJet brass 6503EVS nozzles also operated at approximately 35 PSI.

Table 6. Percent groundcover, spray volume per plot, and area sprayed during herbicide applications on July 16, 2002 in a Yuma, AZ Limoneira 8A Lisbon lemon orchard. Means followed by the same letter within a column are not different at P = 0.05 according to analysis of variance and the Student-Newman-Keuls mean separation test.

Trt. Name	Mechanical Treatment	Herbicide Treatment and Sprayer Type	Weed Groundcover[a]	Spray Volume[b]	Area Sprayed
			(%)	*(gal/plot)*	*(acre)*
P3	Perfecta cultivator	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	30.3 ± 19.8 a	3.56 ± 1.06 b	0.212 ± 0.063 b
H1	None	POST Roundup - WeedSeeker	24.8 ± 20.8 a	4.27 ± 0.78 b	0.254 ± 0.046 b
H2	None	PREE Surflan - conventional PREE Solicam - conventional POST Roundup - WeedSeeker	24.0 ± 9.47 a	3.88 ± 0.55 b	0.231 ± 0.033 b
H3	None	POST Roundup - conventional		10.75 ± 0.00 a	0.382 ± 0.00 a

[a] & [b] Refer to Table 5 footnotes.

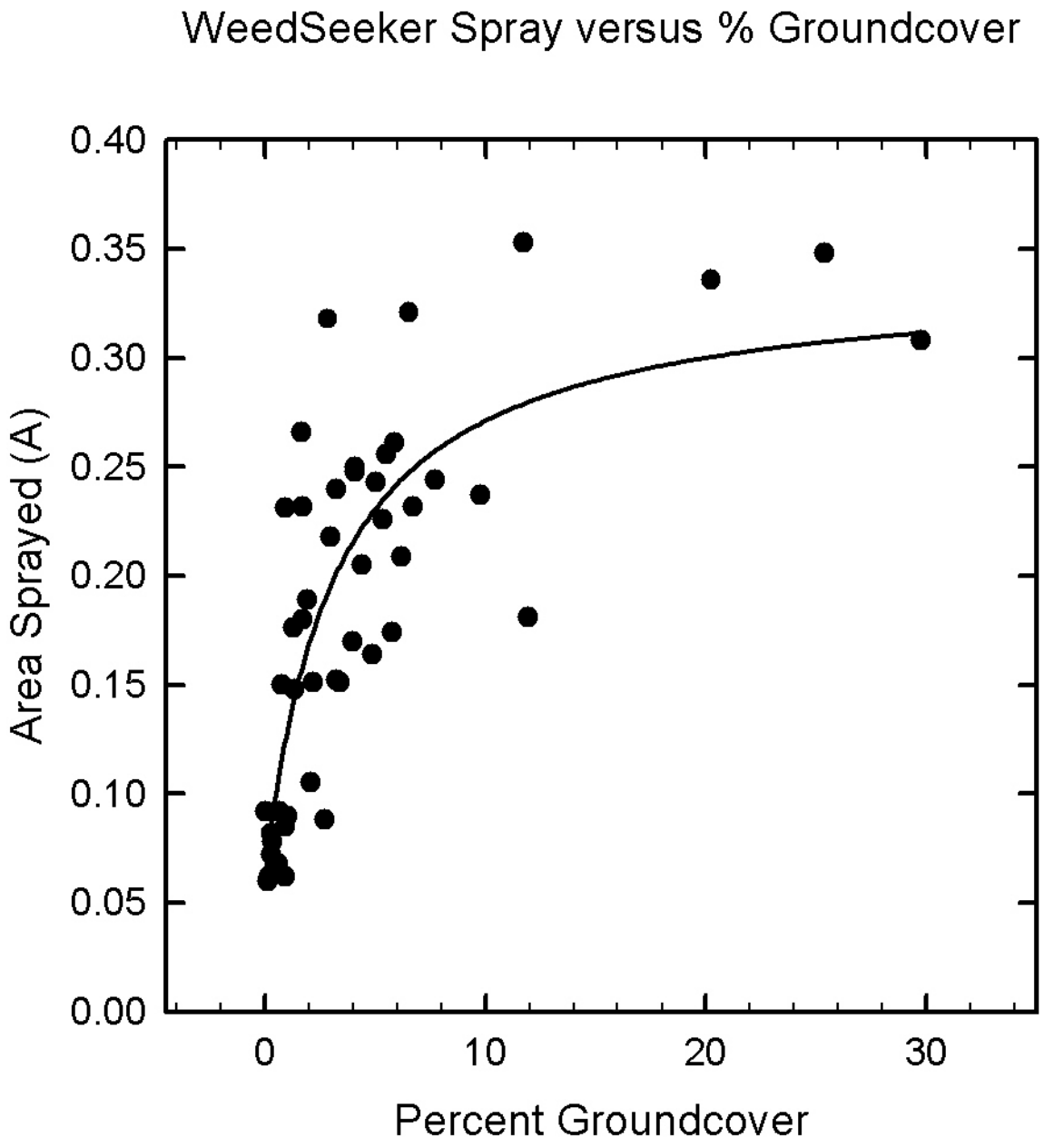

Figure 1. Area of plot sprayed as a function of percent weed groundcover calculated from digital pictures. Maximum area of plot is about 0.38 acres. Fitted curve is a rectangular hyperbola. Only, October, December and March datasets are included.