Vegetation management options in almond orchards

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Summary. A well maintained orchard floor is critical for insuring year-round orchard access and a clean almond harvest operation. This study compared three methods of orchard floor vegetation management over a 4-year period. The objective of this study was to evaluate cost effective vegetation management programs for difficult to control summer annual weeds while maintaining the population of desirable winter annual species. Common purslane *(Portulaca oleracea)* can be a major summer weed problem that interferes with almond harvesting operations. A low rate residual herbicide program controlled purslane more consistently than mechanical or chemical mowing programs. Desirable winter weed cover was preserved in all three management systems. The costs for each program were similar; however, there was a reduction in the number of operations required for both chemical mowing and low rate residual programs compared to the mechanical mowing program.

Orchard floor management in California almonds [*Prunus dulcis* (syn. *Prunus amygdalus)*] ranges from managing existing resident vegetation (weeds) by mowing, to planting a cover crop between tree rows, to a complete removal of vegetation on the soil surface (Elmore, 1989). Cultivation or tillage is rarely used in California almond orchards due to increased dust, soil compaction, tree injury, and inconvenience. Currently, most almonds are farmed by mowing the middles between the tree rows using a nontilled orchard floor management system (Meith and Connell, 1984). Nontillage combined with strip weed control within the tree rows was developed in the late 1950s and was found to be cost effective and efficient (Meith and Parsons, 1965). This system reduced costs since cultural operations were only needed in one direction rather than requiring cross-tillage.

Maintaining a good stand of winter annual vegetation between tree rows improves orchard access throughout the rainy winter and spring months, for pruning and other required cultural operations (Connell et al., 1996). Important benefits of a winter annual cover that accrue during the growing season include improved water penetration due to reduced soil surface strength and increased soil permeability (Folorunso et al., 1992).

Perennial weeds are normally eliminated from almond orchards as they interfere with sprinkler irrigation and harvest operations. Summer annual weeds are controlled and eliminated prior to harvest, because a smooth, firm, weed-free surface facilitates nut drying after nuts are shaken to the orchard floor. In addition, a weed-free orchard floor makes the nut pick up operation efficient and thorough (Connell et al., 1996). In California's mediterranean climate, growers must irrigate at regular intervals during the growing season to prevent almond tree stress. Each irrigation usually initiates a new flush of summer weeds that become a problem at harvest if left uncontrolled.

Growers can achieve desired harvest conditions using various methods of managing orchard row middles, each of which can lead to a shift in orchard weed species composition (Weakley, 1987; Elmore et al., 1989). The vegetation management practiced in the commercial orchard prior to this study included mechanical and chemical mowing using low rates of glyphosate. This led to predominance in this orchard of common purslane, a less desirable summer weed. Left uncontrolled, purslane grows into large, succulent mats of vegetation that retard nut drying and reduce the efficiency of sweeping and nut pickup operations at harvest. This study compared three methods of orchard floor vegetation management over a 4-year period on cost effective management programs for purslane, a difficult-to-control summer weed species (Flint, 1985) present in this orchard. Another objective was to evaluate the effects of these selected programs on the population of desirable winter annual species.

Methods

This complex problem required a team approach between industry and the university. A management team comprised of university farm advisors, a project consultant, a pest control advisor, chemical company representatives, a university extension weed specialist, and the grower and his foreman was assembled to develop and modify the selected vegetation management programs during the four years. Three vegetation management programs were selected: 1) mechanical mowing with a supplemental preharvest glyphosate (Roundup 4S or Roundup Ultra, Monsanto Company, St. Louis) application at 1-2 qt/acre (2.4-4.7 $L \cdot ha^{-1}$) of formulation [a.i. 1-2 lb/acre (1.1-2.2 $kg \cdot ha^{-1}$)] 2) chemical mowing using glyphosate at 0.5-1 qt/acre (1.2-2.4 $L \cdot ha^{-1}$) of formulation [a.i. 0.5-1 lb/acre (0.6-1.1 $kg \cdot ha^{-1}$)] through the spring, supplemented with mechanical mowing, and 3) a low rate residual program applying oryzalin (Surflan 4AS, Dow AgroSciences LLC, Indianapolis) at 1 qt/acre of formulation (a.i. 1 lb/acre)

plus glyphosate at 1 qt/acre of formulation timed just prior to purslane emergence in the spring, and supplemented with mechanical mowing. Management programs were arranged in a randomized complete block design employing five replications of approximately 1 acre (0.41 ha) per plot.

Plant composition. Winter annual vegetation consisted primarily of annual bluegrass (*Poa annua*), shepherdspurse (*Capsella bursa-pastoris*), chickweed (*Stellaria media*), and filaree (*Erodium spp*.). Other winter annuals present in low numbers included common groundsel (*Senecio vulgaris*), sowthistle (*Sonchus oleraceus*), and prickly lettuce (*Lactuca serriola*). Summer annual vegetation consisted primarily of common purslane and spotted spurge (*Euphorbia maculata*). Perennial weeds are not allowed to establish in almond orchards since they interfere with harvest operations.

Soil characteristics. The trial was located near Dayton in California's Sacramento Valley. The soil is mapped as Farwell clay loam. This dark brown clay loam is a class II soil located on a young alluvial fan. Soil analyses performed by the Division of Agriculture and Natural Resources Analytical Laboratory at the University of California, Davis, indicated a cation exchange capacity of 35.5 meq/100 g, and mechanical analysis for soil texture indicated 34% sand, 43% silt, and 23% clay. After the vegetation management programs had been in place for four years, soil organic matter averaged 2.74%. There was no difference in organic matter between the low rate residual herbicide program and the mechanical mowing program at the conclusion of the study.

Rainfall and irrigation. Rainfall at this site (July through June) averages 26 inches (66 cm) annually and generally occurs between October and May. Actual rainfall in 1995, 1996, 1997, and 1998 was 32, 25, 21, and 44 inches (81.3, 63.5, 53.3, and 111.8 cm) respectively. In

addition, during an average year, growers typically apply 30 inches (76.2 cm) of irrigation between May and September with a dry 6-week harvest period in August and early September.

Program operations. The mechanical mowing program began in February prior to almond bloom to reduce frost hazard and remove competing groundcover bloom. An average of seven mowings were done annually to adequately maintain the orchard floor vegetation, with a final mowing just prior to a pre-harvest glyphosate treatment that averaged 1.25 sprays annually over the 4 years (in 1998, an unseasonable August rain resulted in the need for the additional treatment).

The chemical mowing program began similarly in February with mechanical mowing followed by glyphosate chemical mowing in late spring and early summer. This program averaged 4.25 mechanical mowing trips and 2.75 chemical mowings per season. Timing for each of these practices was based on weather and on the appropriate stage of weed growth in the orchard.

The low rate residual program began the same as the other programs with mechanical mowing in February. The oryzalin plus glyphosate treatment was applied in late April to early May to occur just prior to purslane germination and emergence. This program averaged 3**.**5 mowings and 2**.**25 chemical applications annually over the 4-year period. Pre-harvest glyphosate treatments were standard in all programs; however, the low rate residual program sometimes reduced this need to spot treatments only.

All herbicides were applied using the grower's boom sprayer towed by an all terrain vehicle. The sprayer was equipped with flat fan nozzles calibrated to deliver a total of 10 gal/acre (93.54 $L \cdot ha^{-1}$).

Six sub-plot weed counts were made in each replicate and reported as the average number of plants per replicate. Data are reported as plants per square meter (10.76 ft^2) for each year's determination and as an average of all 4 years. Summer purslane counts were made and the percent bareground was visually estimated before harvest. Winter vegetation counts of all species were made annually to evaluate the management program effects on the species composition of winter annual vegetation. Data were subjected to an analysis of variance and means were separated by Fisher's Protected LSD at $P \leq 0.05$. Cultural practices and costs for each program were compared. Application and mowing cost estimates are based on Buchner et al., (1995). Chemical treatment costs were based on average retail costs for materials in the area and values shown reflect actual treatment costs at application.

Results and Discussion

Summer vegetation management. Summer vegetation management was improved with both chemical programs compared to the standard mechanical mowing when the density of purslane (Table 1) was compared over the 4 years of our study (an average of 1.1 and 6.5 plants/m^2 [0.1 and 0.6 plants/ft^2] respectively for the low rate residual and the chemical mowing treatments compared to 36.3 plants/m^2 [3.4 plants/ft^2] for the mechanical mowing treatment). The low rate residual herbicide program controlled purslane better than mechanical mowing in each of the 4 years and was superior to both mechanical mowing and chemical mowing in 1995.

When pre-harvest percent bareground (Table 2) estimates were averaged over the 4-year period, the low rate residual program controlled summer weeds better than mechanical mowing. In 1998 the low rate residual treatment was superior to both chemical and mechanical mowing. In 1996 and 1997 both chemical treatments were superior to mechanical mowing. No significant differences were apparent among treatment programs in 1995. By harvest time in August (Table

3) there was no difference in percent bareground among the three orchard floor management programs. A pre-harvest glyphosate application applied where required as a clean up spray before the August rating readied all vegetation management programs for a clean harvest operation.

Winter vegetation management. Maintenance of winter annual vegetation is an important goal for all programs because a vegetation-covered surface affords needed access and soil protection in the orchard during the winter rainy period. Annual bluegrass is a major component of the winter ground cover that is desired. Over the course of this study all programs preserved the annual bluegrass population (Table 4). The low rate residual program using oryzalin (1 qt/acre of formulation) resulted in an annual bluegrass reduction in the dry 1997 spring but good recovery was seen in 1998.

Other common winter annuals potentially affected by orchard floor management programs include chickweed, shepherdspurse, and filaree. Among these, the filaree (data not shown) population was unaffected by the selected management programs. A paired t-test showed a significant decline in the chickweed population under all three vegetation management programs from the beginning of the study in 1995 to the end of the study in 1998. The shepherdspurse populations (Table 5) increased from the initial counts in 1995 for all vegetation management programs with no significant differences in density among the three treatments in 1996 and 1998. Shepherdspurse populations in 1997 were significantly lower with chemical mowing than with the other two treatments.

Program costs. Total accumulated 4-year orchard floor vegetation management costs (Table 6) were similar among the three selected management programs. Mechanical mowing was the least expensive program followed by the low rate residual program (2% higher than

mechanical mowing). The chemical mowing program was the most expensive of the three management systems (8% higher than mechanical mowing). The total number of operations required (trips through the orchard) is the major difference among the three management systems with 33, 28, and 23 trips over 4 years for the mechanical mowing, chemical mowing and low rate residual programs, respectively.

Conclusions

The low rate residual program provided the most consistent management of purslane, a summer annual weed that is difficult to control and interferes with almond harvesting operations. Oryzalin at 1 qt/acre of formulation plus glyphosate at 1 qt/acre of formulation applied prior to weed germination controlled purslane through the harvest season. Purslane germination must be anticipated so that chemical application can occur shortly before weed emergence. Application timing is therefore critical to program success. A mid to late April spray timing is optimum in California's northern Sacramento Valley. Low rate residual program benefits included reductions in the number of mowings, and, compared to chemical mowing, a reduction in the number of glyphosate applications, as only spot treatments were required for pre-harvest cleanup. Following the pre-harvest glyphosate treatment, all three management programs provided clean, firm ground for harvest. No harvest efficiency differences were noted among the treatments since complete nut pickup occurred in all plots.

All three programs preserved winter annual vegetation. Rate and timing of oryzalin application must be carefully managed to avoid shifts away from desirable annual grassy weeds. Residual herbicide activity persisting into the winter months will reduce desirable annual bluegrass populations. Adjustment of rates may be needed under some conditions in order to

preserve the winter cover. The mechanical mowing and chemical mowing programs caused less variation in the annual bluegrass population.

Ultimately, all programs resulted in comparable costs averaging about $65 to $70/acre ($161 to $173/ha) per year. The major benefit was a reduction in the total number of operations (trips through the orchard) that were required by both chemical programs as compared to the mechanical mowing. Significant time and labor savings resulted since chemical mowing saved 5 trips through the orchard over a 4 year period and the low rate residual program saved 10 trips through the orchard during the same period. After 2 years, grower cooperators adopted the low rate residual program for their almond orchard floor management due to the reduced requirement for mechanical operations.

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Table 1. Summer vegetation management was improved with both chemical programs compared to the standard mechanical mowing when the purslane population density was compared in June.[z]

	Density (plants/m^2)				
Treatment	1995	1996	1997	1998	Average
Mechanical mowing	8.6	99.6	24.0	13.0	36.3
Chemical mowing	6.7	11.4	1.4	6.6	6.5
Low rate residual herbicide	1.5	2.2	0.2	0.3	1.1
$LSD_{0.05}$	3.1	17.9	12.4	7.7	9.8

[z] 1.0 plant/m^2 = 0.09 plants/ft^2.

Table 2. A clean orchard floor is important for an efficient almond harvest. The low rate residual herbicide program controlled summer weeds better than mechanical mowing as shown by significant improvements in the percent bareground in July prior to the pre-harvest glyphosate application.

	Bareground (%)				
Treatment	1995	1996	1997	1998	Average
Mechanical mowing	58.0	83.5	58.0	72.2	67.9
Chemical mowing	72.6	97.8	86.2	79.0	83.9
Low rate residual herbicide	82.2	99.8	97.6	93.9	93.4
$LSD_{0.05}$	ns	12.1	19.4	13.4	18.0

Table 3. By harvest time in August after the pre-harvest glyphosate application there was no difference in percent bareground among the three orchard floor management programs.

	Bareground (%)				
Treatment	1995	1996	1997	1998	Average
Mechanical mowing		90.6	84.5	96.4	99.0	92.6
Chemical mowing		79.3	95.6	96.0	97.0	91.9
Low rate residual herbicide		85.8	98.8	100.0	100.0	96.2
$LSD_{0.05}$	ns	ns	ns	ns	ns	

Table 4. Annual bluegrass is a major component of the desirable winter ground cover. Except for the low rate residual herbicide program in the dry 1997 spring, all programs preserved the annual bluegrass population density.[zy]

	Density (plants/m^2)				
Treatment	1995[x]	1996	1997	1998	Average
Mechanical mowing	245.5	274.8	214.2	346.8	270.3
Chemical mowing	245.5	238.5	286.0	271.8	260.5
Low rate residual herbicide	245.5	283.7	97.2	372.6	249.8
$LSD_{0.05}$	ns	ns	86.7	ns	ns

[z] 1.0 plant/m^2 = 0.09 plants/ft^2.

[y] Counts in February 1995-97 and March 1998.

[x] Initial vegetation count, averaged across the entire trial area.

Table 5. The shepherdspurse population density increased from the initial counts in all vegetation management programs. Sheperdspurse populations in 1997 were significantly lower with chemical mowing than with the other two treatments.[zy]

	Density (plants/m^2)				
Treatment	1995[x]	1996	1997	1998	Average
Mechanical mowing	0.8	4.9	28.6	26.5	15.2
Chemical mowing	0.8	20.7	13.0	13.5	12.0
Low rate residual herbicide	0.8	24.8	31.0	13.5	17.5
$LSD_{0.05}$	ns	ns	14.2	ns	ns

[z] 1.0 plant/m^2 = 0.09 plants/ft^2.

[y] Counts in February 1995-97 and March 1998.

[x] Initial vegetation count, averaged across the entire trial area.

Table 6. Total accumulated orchard floor management costs from Jan. 1995 through Aug. 1998 were similar among the three selected management programs. The total number of operations required (trips through the orchard) is the major difference among the three management systems. Chemical mowing saved 5 trips and the low rate residual herbicide program saved 10 trips through the orchard resulting in significant time and labor savings over the 4-year period compared to mechanical mowing.

Treatment	Chemical cost ($/acre)[z]	Application cost ($/acre)	Mowing cost ($/acre)	Total cost ($/acre)
Mechanical mowing + pre-harvest glyphosate	84 (5)[y]	25 (5)	149(28)	258 (33)
Chemical mowing w/glyphosate, mechanical mowing, and pre-harvest glyphosate	136 (11)	55 (11)	91 (17)	281 (28)
Low rate residual herbicide w/oryzalin + glyphosate, mechanical mowing, and pre-harvest glyphosate spot treatment.	144 (9)	45 (9)	75 (14)	264 (23)

[z] $1/acre = $ 2.47/ha.

[y] (x), the numbers inside the parenthesis indicate the total number of times the applications or operations were conducted during the study**.**