Effect of Tree Architecture on the Control of Alternaria Leaf Spot in Almonds

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Background

Alternaria Leaf Spot in Kern County appeared in 1980, and stayed dormant until 1993, when it appeared in large almond orchards caused premature defoliation and poor nut removal at harvest. In 1999, this disease was not as bad as in previous years. However, we still found severely infected orchards. We have found Alternaria infected orchards in Delano, McFarland, Wasco, Shafter and Rosedale. This disease has caused premature defoliation and yield reduction, which can vary from 22% to 36%

Orchard surveys have revealed that Alternaria infected orchards have two factors in common. First, the disease first appears on the outside and at mild-section of the canopy. This is the area that opens to the sky and subject to dew formation. Second, the worst Alternaria infested trees are those with an opened canopy center which gives the tree an umbrella shape.

Objectives

1. Determine the degree of disease development and control of Alternaria due to tree architecture.

2. Evaluate Abound® fungicide sprays on control of Alternaria on tree architecture.

Objective 1:

To determine the degree of disease development and control by tree architecture, the experiment was established in a three-year old orchard that was infected with Alternaria. The orchard is planted to Sonora-Nonpareil-Butte in a 1:1:1 planting arrangement, row orientation is from east to west and is planted on the rectangle pattern at a distance of 20 x 18 ft. All three varieties are susceptible to Alternaria, but the most are Sonora and Butte. Each plot has a row of Sonora, Nonpareil and Butte. The guard row between each plot is a Nonpareil. The tree architecture was established by using a mechanical pruning machine which topped, topped-hedged and hedged according to randomization of treatments.

The treatments were the following: 1) Control, 2) hedged, 3) topped, and 4) topped and hedged. The control treatment will be pruned by hand, but hedging and topping will be done mechanically. The description of each treatment is the following:

Control: This treatment is the standard pruning system for most Kern County orchards. It consists of an open tree center and no crossing over limbs, as well as no water shoots growing through the canopy of the tree. The scaffolds are tied with a rope at the mid-section of the canopy. The rope is placed on the outside of the scaffold and goes around the canopy, making a complete loop.

Hedged: In this treatment, the trees were hedged down the tree row with a mechanical pruner leaving a 6 ft. wide avenue between rows.

Topped: In this treatment, the trees were topped to an average of 27 to 36 inches below the tree top by a mechanical pruner. This has been done each of the last three years.

Topped and Hedged: In this treatment, the trees were topped and hedged down the tree row with a mechanical pruner. The topping was done by taking 27 to 36 inches from the tree's top, every year for the last three years. The hedging was done by hedging down the tree row, leaving a 6 ft. avenue between rows. There were five replications of each treatment randomized in a complete block design.

In January, 2000, five trees were randomly selected from each variety on each plot. At a height of six inches above the ground, trunk circumference was taken. This height was marked with a nail for future tree circumference measurements. Two scaffolds from each tree were selected, one on the north and one on the south. They were selected to determine the degree of canopy openness from winter to summer. Each branch was marked at an approximate height of 10 ft. The mark was done with a paint for initial and subsequent measurements. Holding a telescoping measuring pole, perpendicular to the ground, a measurement was taken from the ground to the painted mark and from the pole to the trunk. These measurements are referred as height and distance in our data. The initial height and distance measurements were made in the dormant season. A follow-up (second measurement) of height and distance was done at the onset of hull split. Trunk circumferences measurements are done every year during the dormant season.

A. 2000 Results

The results for the year 2000 are summarized in the following paragraphs:

The tree architecture due to different pruning methods didn't improve the control of Alternaria this year. However, this is not unexpected since it takes more than one year to position scaffolds and limbs in an upright position.

The yields of the Nonpareil were affected by the pruning methods. The hedged-topped method significantly reduced yields. This is expected since the more you prune, the more you reduce the bearing canopy.

There were no significant differences among pruning methods in total pest damage. However, the topped pruning treatment had significant pinhole damage in Nonpareil and significant ant damage in Sonora.

There was no significant influence of tree architecture on tree openness on any of the varieties except Sonora. In this variety, the scaffolds move downward but not away from the trunk. This means that the tree opening occurred in the upper part of the tree. The opening of this variety is due to its growth habit and not to crop load, since there were no significant differences in crop load.

B. 2001 Results

Objective 1:

The results for Objective 1 are found on Table 1. A negative number (Height) represents a drop from the first measurement to the second measurement. A positive number (distance) represents the amount of inches the scaffold moved away from the trunk. This is to say that the higher the negative number (height) and the higher the positive number (distance), the greater the openness of the tree.

Table 1. Change in branch height (in) from winter to summer and change of branch distance (in) from the trunk from winter to summer in Nonpareil, Sonora and Butte.

Treatment	Nonpareil		Sonora		Butte	
	Height	Distance	Height	Distance	Height	Distance
Hedged	-15.5 a*	3.2	-5.3 a	7.7 a	-11.7a	5.3 a
Topped	-20.8 a	10.6 a	-10.6 a	2.7 a	-12.7 a	3.4 a
Topped-hedged	-5.0 a	-0.2 a	-11.5 a	5.5 a	-12.9 a	4.4 a
Control	.23.0 a	10.6 a	-12.5 a	4.3 a	-9.67 a	5.3 a

*Values followed by the same letters are not statistically different as measured by the least significant difference test of P < L 0.05.

The negative height numbers and the positive distance numbers indicate that there was a downward and outward movement of the canopy. The movement, however, was not significantly different in any of the other pruning systems or varieties.

Yields are very important in almond production. The impact of the architecture (pruning systems) on yields is being considered in this experiment. The yield data for 2001 is found in Table 2. The yields were not affected in Nonpareil and Butte due to the

different pruning systems. However, the topped treatment significantly reduced the Sonora yields.

Table 2. Yields (meat pound per acre, and kernel weight (gm) of Nonpareil, Sonora, and Butte due to different pruning systems.

Treatment	Nonpareil		Sonora		Butte	
	Yield	Kernel	Yield	Kernel	Yield	Kernel
Hedged	3310 a*	1.1 a	2215 b	1.4 a	2118 a	0.8 a
Topped	2957 a	1.1 a	2042 a	1.4 a	1879 a	0.8 a
Topped-hedged	2991 a	1.1 a	2222 b	1.4 a	1967 a	0.8 a
Control	3237 a	1.0 a	2255 b	1.4 a	1932 a	0.8 a

*Values followed by the same letters are not statistically different as measured by the least significant difference test of $P > 0.05$.

Insect pest damage, or reject levels due to navel orangeworm (NOW). Peach twig borer (PTB), ants and other insects are very important to almond growers. Table 3 shows the percent of insect damage from each pruning treatment. There were no significant differences in insect damage due to pruning systems in Sonora and Butte. The Nonpareil, however, showed significant NOW differences due to different pruning systems. The hedged and control treatment showed significant more NOW damage than the topped and topped-hedged treatments.

Table 3. Percent of damage due to PTB, NOW, ants, pinhole, and dry fruit beetle in four different pruning systems.

Nonpareil

Treatment	PTB	NOW	Ants	Pinhole	Dry Fruit Beetle
Topped	.45 a	1.70 a	2.55 a	.90 a	1.40 a
Hedged	.45 a	3.90 c	3.35 a	.75 a	1.75 a
Topped-Hedged	.40 a	1.85 ab	3.00 a	.50 a	1.90 a
Control	.35 a	3.70 bc	2.95 a	.60 a	1.05 a

Butte

Treatment	PTB	NOW	Ants	Pinhole	Dry Fruit Beetle
Topped	0.00	.35 a	.00 a	.00 a	.05 a
Hedged	0.00	.15 a	.10 a	.05 a	.05 a
Topped-Hedged	0.00	.20 a	.10 a	.05 a	.15 a
Control	0.00	.40 a	.10 a	.15 a	.25 a

Sonora

Treatment	PTB	NOW	Ants	Pinhole	Dry Fruit Beetle
Topped	1.00 a	7.05 a	2.45 a	2.20 a	3.00 a
Hedged	0.35 a	5.45 a	2.45 a	1.10 a	3.25 a
Topped-Hedged	0.40 a	6.65a	2.95 a	2.10 a	3.15 a
Control	0.80 a	7.80 a	1.90 a	1.00 a	3.15 a

*Values followed by the same letters are not statistically different as measured by the least significant difference test of $P > 0.05$.

The Alternaria control due to different pruning systems was determined by the number of infected leaves from 100 leaf samples that were taken randomly around the canopy of the tree. It was also determined by the percent of tree defoliation, which was taken after the harvest.

Table 4 shows a significant difference of Alternaria leaf infection on the hedged treatment. This treatment had significant more lesions in all three varieties. Table 5 however, shows no significant differences on any variety due to any of the pruning systems.

Table 4. Alternaria leaf infection (percent) due to different pruning systems on Nonpareil, Sonora, and Butte varieties.

Pruning System	Varieties		
	Nonpareil	Sonora	Butte
Hedged	14.5 b*	34.8 b	24.9 b
Topped	4.31 a	17.7 a	16.3 a
Topped-Hedge	6.3 a	10.9 a	12.2 a
Control	5.7 a	19.2 a	13.7 a

*Values followed by the same letters are not statistically different as measured by the least significant test of $P > 0.05$

Table 5. Amount of the tree defoliation (percent) in the Nonpareil, Sonora, and Butte varieties due to different pruning systems.

Pruning System	Varieties		
	Nonpareil	Sonora	Butte
Hedged	53.4 a*	48.0 a	57.6 a
Topped	26.4 a	39.8 a	27.6 a
Topped-Hedge	27.4 a	39.2 a	39.2 a
Control	25.0 a	27.2 a	32.4 a

*Values followed by the same letters are not statistically different as measured by the least significant test of $P > 0.05$.

Objective 2:

To determine the degree of disease control with Abound®, sprays on tree architecture due to pruning methods; the orchard was divided in halves. One half received Abound ® spray and the other half was left untreated. These treatments were randomized for each plot. There were three Abound ® sprays (Apr. 16, Apr. 30, and May 14) applied at 12 oz. Per acre in 100 gallons of water. The degree of Alternaria control was based on tree defoliation in October, because defoliation is the end result of Alternaria infection.

Table 6 shows that the fungicide Abound ® controls Alternaria in Nonpareil, Sonora and Butte. In each of these varieties the number of infested leaves were significantly reduced due to a fungicide spray. However, fungicide sprays didn't make a difference in Alternaria control in any of the other pruning system and variety (Table 7).

Table 6. Control of Alternaria (percent of infested leaves) due to fungicide sprays on Nonpareil, Sonora, and Butte.

Treatment	Varieties		
	Nonpareil	Sonora	Butte
Fungicide (Abound ®)	1.6 a*	5.0 a	3.9 a
Untreated Control	7.7 b	19.4 b	16.8 b

*Values followed by the same letters are not statistically different as measured by the least significant difference test of $P > 0.05$.

Table 7. The effect of fungicide sprays (Abound ®) on the percent of leaf in infestation on Nonpareil, Sonora and Butte in four different pruning systems.

Pruning Systems	Varieties		
	Nonpareil	Sonora	Butte
Hedged	7.9 a*	5.4 a	4.0 a
Topped	2.8 a	4.5 a	3.3 a
Topped-Hedge	3.9 a	5.0 a	3.9 a
Control	3.9 a	5.2 a	4.4 a

*Values followed by the same letters are not statistically different as measured by the least significant difference test $P > 0.05$.

C. Conclusions for 2001:

1. The yields were not affected by any of the pruning treatments on both Nonpareil and Butte. However, the topped treatment significantly reduced yields in Sonora.

2. The pruning systems had no effect on percent of insect damage on Sonora and Butte. However, NOW was higher in Nonpareil in both hedge and control treatments.

3. Alternaria leaf infections in Nonpareil, Sonora and Butte were significantly higher in the hedged pruned trees than on any other pruning systems.

4. Abound ® sprays effectively control Alternaria.

2002 Experiment

Objectives:

We continue with the original objectives (1 and 2).

The pruning treatments were the same as in previous years. The control treatment was done by field workers. They opened the tree center and eliminated crossing over limbs. They also cut off death lower limbs. The amount of brush from this treatment was much more than the brush removed from the mechanical pruned treatments. The mechanical pruning treatments stayed the same. However, an average of 38 inches was removed from the tree tops. This made the trees 14.2 ft. high.

The Abound ® treatments were applied in April and May at 12 oz. per acre in 100 gallons of water. Alternaria lesions were taken in June-July. Yields were taken in August to determine the effect of pruning on yields.

2002 Results

Objective 1: To determine the degree of disease development and control of Alternaria due to tree architecture.

The tree architecture due to four different pruning treatments (hedged, topped, topped-hedged and standard pruning) had no significant effect in lesion control of Alternaria. Table 8 shows the results of the four pruning systems on the percent of Alternaria infected leaves in Nonpareil, Sonora and Butte.

Table 8. Alternaria leaf infection (percent) due to different pruning systems on Nonpareil, Sonora, and Butte varieties.

Pruning System	Varieties		
	Nonpareil	Sonora	Butte
Hedged	8.8 a*	45.5 a	8.7 a
Topped	1.4 a	23.9 a	3.6 a
Topped-Hedge	0.9 a	16.6 a	1.3 a
Control-Standard	4.4 a	25.3 a	6.5 a

*Values followed by the same letters are not statistically different as measured by the least significant test of $P > 0.05$

Tree architecture due to pruning didn't affect yields of Sonora and Butte. However, there was an effect on Nonpareil. In this variety, yield from topped-hedged was significantly less than the yield from hedged treatment. However, this yield was not significantly reduced from the control-standard pruning treatment. Table 9 shows the yields of Nonpareil, Sonora and Butte due to the four pruning systems.

Table 9. Yields (meat pound per acre) of Nonpareil, Sonora, and Butte due to four pruning systems.

Treatment	Varieties		
	Nonpareil	Sonora	Butte
Hedged	3519 b	3828 a	3653 a*
Topped	3363 ab	3906 a	3734 a
Topped-Hedge	3094 a	3478 a	3423 a
Control-Standard	3231 ab	4080 a	3622 a

*Values followed by the same letters are not statistically different as measured by the least significant difference test of $P > 0.05$

Objective 2: To evaluate Abound® fungicide sprays on control of Alternaria on tree architecture.

The fungicide Abound® continues to be an effective material against Alternaria. After four years of use, this fungicide has shown efficacy against the disease. Table 10 shows this year's data.

Table 10. Control of Alternaria (percent of infected leaves) due to Abound® sprays on Nonpareil, Sonora, and Butte.

Treatment	Varieties		
	Nonpareil	Sonora	Butte
Abound®	0.5 a*	17.9 a	1.6 a*
Untreated Control	7.3 b	38.4 b	8.5 b

*Values followed by the same letters are not statistically different as measured by the least significant difference test of $P > 0.05$

Conclusions 2002

1. The yields of Sonora and Butte were not significantly affected by any of the pruning systems. However, the Nonpareil's yields from the Topped-hedged was significantly less than the Hedge treatment.

2. Alternaria leaf infections were not significantly different in any of the pruning systems. The hedged treatment showed a higher percent of infection but it was not statistically different from other treatments.

3. Abound® sprays effectively control Alternaria.

Experiment 2003

Objectives 1 and 2: They continue unchanged.

The tree architecture from the four pruning treatments continue unchanged in 2003. There was however one small change on both the Topped and Topped-hedged treatment. The height was increased to 18 feet.

The Abound® treatments were applied in April 25, May 9, and May 23 at 12.8 per acre in 100 gallons of water. Alternaria lesions were taken in June-July. Yields were taken in August and September.

D. 2003 Results

Objective 1: To determine the degree of disease development and control of *Alternaria* in trees with four different forms of architecture.

After four years, tree architectures had an effect on *Alternaria* control. The hedged-topped treatment reduced the *Alternaria* infected leaves in the Butte variety by August 7 (Table 11). At the same time, this treatment reduced the amount of *Alternaria* infected leaves in the Nonpareil and Sonora varieties. The reduction however was numerical and not significant based on the analysis of variance.

Table 11. Percent of *Alternaria* infected leaves in Nonpareil, Sonora and Buttes due to different pruning systems.

Pruning System	Nonpareil		
	06/19/03	07/10/03	08/07/03
Hedged-topped	0.00 a	2.30 a	2.90 a
Topped	0.00 a	4.10 a	4.50 a
Hedged	0.10 a	9.22 a	13.90 a
Control	0.20 a	3.50 a	23.90 a

Pruning System	Sonora		
	06/19/03	07/10/03	08/07/03
Hedged-topped	1.20 a	4.90 a	25.50 a
Topped	0.70 a	2.70 a	34.60 a
Hedged	0.90 a	5.30 a	53.60 a
Control	0.00 a	3.22 a	47.56 a

Pruning System	Butte		
	06/19/03	07/10/03	08/07/03
Hedged-topped	0.20 a	0.10 a	9.40 a
Topped	0.10 a	3.00 a b	15.20 a b
Hedged	0.20 a	5.90 b	27.60 b
Control	1.60 a	1.00 a	21.60 b

* Values followed by the same letter are not statistically different as measured by the least significant difference test of P>0.05.

The opening of the canopy was determined by how much main scaffolds moved due to crop load. Measurements were taken before and after the crop was set. The up and down of the scaffold was determined by measuring the distance from the orchard floor to a marked point on a scaffold. In Table 12 this corresponds to the height column. The movement to the outside was determined by measuring the perpendicular distance between the trunk and a marked point on the scaffold. This corresponds to the distance column (Table 12). Large negative numbers in the height column and large numbers in the distance column mean that scaffolds moved considerably with the weight of the crop.

Table 12 shows that there were no significant differences in canopy movement in Nonpareil due to any pruning systems. The Sonora showed a significant movement in distance in the Control treatment. The Butte variety showed the most canopy movement. There was a significant change in both height and distance in the Topped treatment. This means that the tree canopy opened the most in the treatment.

Table 12. Canopy movement based on height and distance changes due to crop weight.

Pruning System	Nonpareil	
	Height Change	Distance Change
	(inches)	(inches)
Hedged and Topped	- 0.34 a	9.21 a
Topped	- 0.30 a	9.40 a
Hedged	- 0.20 a	12.67 a
Control	- 0.31 a	9.31 a

Pruning System	Sonora	
	Height Change	Distance Change
	(inches)	(inches)
Hedged and Topped	- 0.14 a	6.88 a
Topped	- 0.23 a	4.73 a
Hedged	- 0.25 a	3.85 a
Control	- 0.22 a	13.10 b

Pruning System	Butte	
	Height Change	Distance Change
	(inches)	(inches)
Hedged and Topped	- 0.18 b	9.48 a b
Topped	- 0.33 a	16.17 b
Hedged	- 0.24 a b	6.60 a
Control	- 0.18 b	5.83 a

* Values followed by the same letter are not statistically different as measured by the least significant difference test of P>0.05.

The effect of different pruning systems on yields can be found in Table 13. The Nonpareil yields are not included in this table due to malfunctioning of weighing scales. In the Sonora, the highest yields were in the hedged-topped and topped. There were no differences in yields between hedged and control. The Butte variety produced higher yields in the hedged and control treatments. Kernel weights in the Butte variety were not affected by pruning treatments. However, Sonora showed an increase in kernel weight in both hedged and control. These two treatments also had the lowest yields.

Table 13. Yields (meat pounds per acre) and kernel weight (g) of Sonora and Butte due to four pruning systems.

Pruning System	Varieties			
	Sonora		Butte	
	Kernel Wt.	Pounds/Ac	Kernel Wt.	Pounds/Ac
Hedged and Topped	1.41 a	1847 b	0.78 a	2931 a
Topped	1.43 a	1886 b	0.77 a	2978 a
Hedged	1.51 b	1267 a	0.79 a	3208 b
Control	1.52 b	1430 a	0.78 a	3043 a b

* Values followed by the same letter are not statistically different as measured by the least significant difference test of P>0.05.

Objective 2. To evaluate Abound® fungicide sprays for the control of *Alternaria* in tree architecture.

The Abound® sprays continue to be effective against *Alternaria.* This is contrary to the known resistance in some Kern County orchards. Nevertheless, the data in Table 14 shows the efficacy of Abound® on *Alternaria* control.

Table 14. Control of *Alternaria* (percent of infected leaves) due to Abound® sprays on Nonpareil, Sonora and Butte at three different dates.

Treatment	Dates	Varieties		
		Nonpareil	Sonora	Butte
Abound®	06/19/03	0.00 a	0.00 a	0.15 a
Untreated Control	06/19/03	0.15 a	1.47 a	1.65 a
Abound®	07/10/03	0.70 a	0.80 a	0.15 a
Untreated Control	07/10/03	8.84 b	7.47 b	4.85 b
Abound®	08/07/03	5.60 a	30.30 a	12.30 a
Untreated Control	08/07/03	17.00 b	50.97 b	24.60 b

* Values followed by the same letter are not statistically different as measured by the least significant difference test of P>0.05.

Conclusions 2003

1. The tree architecture due to hedged-topped, topped, hedge and control had an effect on the amount of *Alternaria* leaf infections. In the Butte variety, the number of *Alternaria* lesions were significantly less in the hedged-topped and topped treatments. The number of leaf lesions in the Nonpareil and Sonora were also less in the hedged-topped and topped treatments.

2. Yield was not adversely affected by the pruning system. In Sonora (Table 13) the yields were significantly higher in hedged-topped and topped than in the control. In addition, the Butte's yields in hedged-topped, topped and hedged were not significantly different from the control.

3. *Alternaria* Leaf Spot continues to be controlled by Abound® sprays.