Effect of Timing of Topping to Reduce Tree Height on Subsequent Year Vigor of Early-Season 'Arctic Star' Nectarine

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Abstract

Production costs could be substantially reduced if the height of fruit trees could be lowered enough to eliminate the need for, or reliance upon, ladders in the orchard. Recent research demonstrates that high yields can be obtained on shorter trees with appropriate management techniques, but vigor control can be a problem. In 2004, selected rows of 'Arctic Star' nectarine trees growing in the Dinuba, CA area were topped in July, September and November. In July and September the plots chosen for topping were divided into two sub-treatments. One sub-treatment was topped to 3 m (down from approximately 5.5 m) and the other was topped at 3.7 m. In November, each of the 3.7 m July and September sub-treatments were re-topped to 3 m along with a block that was previously not topped. One treatment was also left untopped, and received normal dormant pruning during which height was reduced to ~4 m. All trees were hand pruned during dormancy to select fruiting wood, and pruning weights were recorded. Trunk and rootstock samples of wood tissue were taken from four trees of each treatment by using a 12 mm hole saw to extract a plug of wood from about 20 cm above the graft union and 10 cm below the graft union on December 1, 2004. Topping increased light penetration, and the July severe topping treatment stimulated regrowth that resulted in delayed bloom and fruit maturity in the following year. Contrary to our hypothesis, stored carbohydrates in the roots were greatest in the early topping treatments and lowest in the late topping events. Topping in September resulted in the lowest amount of summer pruning necessary in the subsequent year.

INTRODUCTION

Over half of the annual production costs for peaches, nectarines and plums in California involve hand labor for pruning, thinning and harvest which is done from ladders because of tall trees (Day et al., 2004; DeJong et al., 1999). It is widely recognized (Day et al., 2005) that production costs could be substantially lowered if the height of trees could be contained to reduce the need for ladders in the orchard. Our recent research demonstrates that high yields can be obtained on shorter trees with appropriate management techniques (Day and Johnson, 2003). One technique that growers use extensively to uniformly reduce tree height is topping. Mechanical tree topping has been practiced for more than 40 years and there are many theories about optimal timing of topping operations. Physiological reasoning predicts that the earlier one tops after the primary period of shoot growth (approximately June 30th), the greater the loss in carbohydrate storage for the subsequent year and this should result in less vigorous re-growth in the subsequent year. However, there have been no systematic studies to test this theory.

MATERIALS AND METHODS

In June 2004 a fairly uniform, excessively vigorous 7-year-old block of early maturing, 'Arctic Star' nectarine trees growing in northern Tulare County (California) was selected for the study. The orchard was managed for optimum growth by the growers and received normal amounts of irrigation and fertilizer throughout the experiment. Beginning in July, selected rows of trees were topped in July, September and November. In July and September the plots chosen for topping were divided into two sub-treatments. One sub-treatment was topped to ~3 m (down from approximately 5.5 m) and the other was topped at ~3.7 m. In November, each of the 3.7 m July and September sub-treatments were re-topped to 3 m feet along with a treatment block that was previously not topped. One treatment was also left untopped and received normal dormant pruning and was reduced to a height of ~4 m in the winter. Data were collected from four 4-tree experimental units within each treatment.

The weight of biomass removed by the topping treatments was assessed by weighing the pruned material after topping. All trees were hand pruned to select fruiting wood during the winter and pruning weights were recorded. Shortly after fruit harvest in June, 2005, all treatments were summer pruned (most of the major water sprout growth was removed) and pruning weights were recorded.

Trunk and rootstock samples of wood tissue were taken from four trees of each treatment by using a 12 mm hole saw to extract a plug of wood from about 20 cm above the graft union and 10 cm below the graft union on December 1, 2004. The xylem tissue that was extracted was dried, ground and sent to the UC DANR tissue analysis laboratory for total glucose (digested starch and soluble glucose) analysis to determine if there were any topping treatment effects on carbohydrate storage in the tree major storage organs.

To assess the effects of the topping treatments on orchard light interception, measurements of percent ambient sunlight penetrating the orchard canopy and reaching the orchard floor were taken with a light ceptometer on June 29, 2004 during mid-day, shortly after the first topping treatments. Since the September topping treatments were just a repeat of treatment done in July these were not repeated subsequent to those treatments. Readings were taken on four sets of four trees within each treatment. Average photosynthetically active radiation (PAR) was computed, and also expressed as percentage readings taken in full sun.

Since the goal of this research was to assess the effects of different topping treatments on tree regrowth the subsequent year and not on crop yield effects detailed yield data by treatment were not collected. However the grower kept rough track of the amount of fruit that were harvested in each treatment by counting the number of 425 kg bins produced by each treatment in 2005.

RESULTS AND DISCUSSION

Both topping heights improved light penetration into and through the tree when measured in late June (Table 1). Topping at ~3 m removed an average of more than 40 kg of wood biomass per tree in both July and November (Table 2) and probably also in September; however the brush weight data were not available after the topping in September because the prunings were shredded before the data could be collected. When the trees were topped to ~3 m in one operation, a little more than half of the prunings were in the form of brush and the remainder was in the form of major scaffold pieces. Topping the trees at 3.7 m in one operation and following that with a second operation to cut the trees down to ~3 m resulted in removing about the same total amount of total biomass in two operations, but in the first topping the majority of the prunings were comprised of brush (water sprouts) while scaffold wood was primarily removed in the second topping operation.

As expected, the topping treatments dramatically reduced the amount of prunings that were removed in the dormant season compared to the non-topped treatment (Table 2). However, the total prunings (combined topping and dormant) from the topping treatments was significantly more than the non-topped treatment regardless of when the topping was done. This was partly due to greater height of the dormant pruned trees (4 m) vs the topped trees (3 m). There was a tendency for the trees in the July topping treatments to have more dormant pruning weight than the other topping treatments and, although these differences were not statistical, they may reflect the fact that there was a visually substantial stimulation of shoot growth that occurred subsequent to the July topping treatments. In August, after the first topping treatments were applied, lateral vegetative buds on many normal, fruiting shoots on trees in both topping treatments sprouted secondary lateral shoots. This type of shoot growth was not observed in any other parts of the orchard and was clearly the result of the early topping. Although we were concerned about the effects that this type of vegetative bud break could have on subsequent year bloom and cropping, the only noticeable effect on bloom was a delay of full-bloom by about 3-5 days. Nevertheless, the stimulating effects of severe early topping on promoting lateral bud breaks on the shoots that would be expected to bear the next year's crop would likely be of concern to a grower who applied such treatments.

Probably the most surprising aspect of the results of this project was the lack of clear differences in stored carbohydrate reserves in the trunk and the root of the trees in the various treatments (Table 3). It is generally understood that the woody parts of the trunk and roots of deciduous fruit trees are major carbohydrate storage organs that supply much of the carbohydrates required for the rapid flush of growth as the tree comes out of dormancy. The 'Arctic Star' nectarine cultivar used in this project is harvested in late May and early June, shortly after the spring flush of vegetative growth, and fruit are generally thought to be a priority sink for assimilates. Thus it was expected that stored carbohydrates would be low by the end of June and that the July topping treatments would maintain lower concentrations of carbohydrates in the major carbohydrate storage organs compared to other treatments (especially the non-topped control) because both whole canopy light interception (and thus tree photosynthesis) was substantially reduced (Table 1) and because active use of new assimilates was stimulated by new shoot growth. However, the differences in root and trunk stored carbohydrates among treatments were relatively minor and did not support the original hypothesis (Table 3).

Corresponding to the carbohydrate results, there were also no major differences in shoot regrowth (as determined by summer pruning weights) in the summer (June 8, 2005) after the various topping treatments the previous year (Table 4). There was a trend toward lower mean summer pruning weights in the September topping treatments as well as the two-stage, July and November treatment, while the July topping to 3 m was the same as the non-topped control. Perhaps the most interesting aspect of these data is the fact that the topping treatments did not stimulate more growth than the non-topped, dormant pruned only, treatment. Thus these data do show that severe, early fall topping could be done in September without stimulating more vegetative growth the following year compared to trees that are conventionally pruned.

Although crop yield was not a central focus of this experiment the bin-count yield data do indicate interesting trends in cropping (Table 5). As expected, using topping to lower tree height by 0.6-1.2 m did have a tendency to reduce yield but the reductions were not as great as expected. Additionally there were essentially no yield differences among the two-stage July/Nov treatment, the two-stage Sept/Nov treatment and the Sept treatment. The severe early (July) and late (Nov) one-stage topping treatments both appear to have had substantially lower yields than the other treatments. This was somewhat expected since we did see the problem with early regrowth of shoots after topping in the severe topping treatment. And from previous research we know that not summer pruning or topping vigorous orchards can lead to the shading out of lower fruit wood. The late topping treatment was probably the worst treatment because the lower fruit wood was weak from excessive shading and the upper fruit wood could not be selected to compensate for the loss of lower fruit wood during dormant pruning because it was removed during the late topping operation. It is also interesting to note that the early severe topping delayed harvest relative to the other treatments. This was consistent with the delayed bloom observed in this treatment.

CONCLUSIONS

The primary conclusion from this experiment and previous studies is that when severe topping is done to reduce tree height it should be done by or during September. If it is done prior to September, it is probably a good practice to do it as a two-stage process, removing the vigorous water sprout growth in the first pass and then reducing scaffold length a couple of months later. This practice can reduce the tendency for stimulating bud break on next year's fruiting wood in the current year and may also reduce the tendency for regrowth slightly in the next year. When done at these times topping can be done without major effects on tree yield. Furthermore, topping treatments conducted in an irrigation experiment concurrent to this trial (Johnson et al., 2006) indicate that summer topping followed by moderate water stress can substantially reduce vegetative regrowth in the same season as the topping is done and thus growers should carefully consider their post-topping irrigation regime if they have the goal of using in-season topping to reduce tree height.

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Tables

Table 1. Mean photosynthetically active radiation (PAR) and percentage relative to full sun reaching the ground within each of three treatments.

Treatment	Mean PAR ($mmol\ m^{-2}\ s^{-1}$ ± se)	% of full sun ± se
Full Sun	1565	
Topped at ~3 m	678 ± 60.8	43.3 ± 3.9
Topped at ~3.7 m	483 ± 26.2	30.9 ± 1.7
Not topped	200 ± 44.5	12.8 ± 2.8

Table 2. Mean weight (kg ± se) of branches and scaffold wood removed from the top of the test trees in six pruning treatments in 2004.

Topping treatment	Shoot	Scaffold	Topping total	Dormant pruning	Topping plus dormant pruning
A) 3 m July 15	23.2±2.4	20.8±4.2	44.1±6.6	3.1±0.3	47.2
B) 3.7 m July 15	12.4±1.5	2.09 ±0.7	14.5±2.1	2.1±0.3	40.7
then 3m Nov 15	6.2±0.4	17.9±3.5	24.1±3.6		
C) 3 m Sept. 15	na	na	na	1.4±0.2	na
D) 3.7 m Sept. 15	na	na	na	1.6±0.1	na
then 3 m Nov. 1	3.72±0.2	17.44±4.1	21.2±4.3		
E) 3 m Nov. 1	25.4±1.8	18.6±1.5	44.0±2.9	2.0±0.4	46.0
No topping, hand pruned to ~4 m in Dec.	-	-	-	24.9±2.3	

Table 3. Mean (± se) total glucose (hydrolyzed starch and glucose) of scion trunk and rootstock core samples taken in December 2004 from the test trees in six pruning treatments.

Treatment	Rootstock	Scion trunk
A) 3 m July 15	11.85 ± 0.75	8.83 ± 0.26
B) 3.7 m July 15 then 3 m Nov 15	10.5 ± 0.50	8.43 ± 0.23
C) 3 m Sept. 15	10.28 ± 0.59	8.23 ± 0.15
D) 3.7 m Sept. 15 then 3 m Nov. 1	9.45 ± 0.93	8.03 ± 0.23
E) 3 m Nov. 1	8.88 ± 0.42	7.73 ± 0.39
No topping, conventionally pruned to ~4 m in Dec.	9.78 ± 0.31	7.73 ± 0.30

Table 4. Mean weight (kg ± se) of branches removed during summer pruning (June 8, 2005) from the test trees in the six previous-year pruning treatments.

Treatment	Summer prunings removed
A) 3 m July 15	18.3 ± 1.6
B) 3.7 m July 15 then 3m Nov. 15	16.2 ± 1.1
C) 3 m Sept. 15	14.7 ± 1.0
D) 3.7 m Sept 15 then 3 m Nov. 1	15.1 ± 0.7
E) 3 m Nov. 1	17.5 ± 0.9
No topping, conventionally pruned to ~4 m in Dec.	18.6 ± 1.1

Table 5. Mean 2005 harvest totals (bins/row) and percentage of harvest for each picking date for the trees in the six treatments.

Treatment	Bins/row (~425 kg/bin)	% May 28	% May 31	% June 3	% June 6
A) 3 m July 15	4.3	18	20	41	22
B) 3.7 m July 15 then 3 m Nov 15	5.1	39	17	29	15
C) 3 m Sept. 15	5.0	33	17	32	18
D) 3.7 m Sept. 15 then 3 m Nov. 1	5.3	38	19	29	14
E) 3 m Nov. 1	3.9	32	19	32	16
No topping, conventionally pruned to ~4 m in Dec.	5.8	34	20	34	11