String Blossom Thinner Designed for Variable Tree Forms Increases Crop Load Management Efficiency in Trials in Four United States Peach-growing Regions

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SUMMARY. Hand thinning is a necessary and costly management practice in peach (*Prunus persica*) production. Stone fruit producers are finding it increasingly difficult to find a workforce to manually thin fruit crops, and the cost of farm labor is increasing. A new "hybrid" string thinner prototype designed to adjust crop load in vase or angled tree canopies was evaluated in processing and fresh fruit plantings in varying production systems in four U.S. growing regions in 2009. Data were uniformly collected across regions to determine blossom removal rate, fruit set, labor required for follow-up green fruit hand thinning, fruit size distribution at harvest, yield, and economic impact. String thinner trials with the variable tree forms demonstrated reduced labor costs compared with hand-thinned controls and increased crop value due to a larger distribution of fruit in marketable and higher market value sizes. Blossom removal ranged from 17% to 56%, hand thinning requirement was reduced by 19% to 100%, and fruit yield and size distribution improved in at least one string-thinning treatment per experiment. Net economic impact at optimum tractor and spindle speeds was $462 to $1490 and $264 to $934 per acre for processing and fresh market peaches, respectively. Case study interviews of growers who thinned a total of 154 acres indicated that commercial adoption of string-thinning technology would likely have positive impacts on the work place environment.

Labor utilization and availability are of great concern to specialty crop growers. Many of the current labor-intensive activities required in the production of specialty crops will need to be replaced by more mechanized and automated techniques. Glozer and Hasey (2006) estimated that hand-thinning labor represents 31% of all cultural costs associated with cling peach production, with labor requirements ranging from 25 to over 100 h/acre. Estimates for other fresh fruit peach cultivars are similar (Krawczyk, 2010). The availability and efficacy of chemical-thinning programs varies by crop, orchard, and season, thus follow-up hand thinning is often required to adjust crop load for optimal fruit size, quality, and to promote return bloom. This is particularly true for stone fruit, where chemical-thinning options are limited and unpredictable.

Mechanical-thinning devices that were tested on peach trees in the past included trunk shakers (Berlage and Langmo, 1982), low-frequency electrodynamic limb shakers (Diezma and Rosa, 2005; Glozer and Hasey, 2006), high-pressure water streams (Byers, 1990), rotating rope curtains (Baugher et al., 1991), and spiked drum shaker fruit removal systems (Glenn et al., 1994). None of the thinning mechanisms were widely adopted by the stone fruit industry due to lack of uniform thinning, insufficient economic incentive, or adverse effects on fruit size.

A mechanical string thinner designed to thin apple (*Malus*×*domestica*) blossoms in organic orchards was tested on peach trees for the first time in 2007 (Schupp et al., 2008). The string thinner evaluated in 2007 was designed to thin narrow vertical canopies; therefore, it was evaluated on peach trees trained to perpendicular V or quadrilateral V systems. As many peach orchards are trained to open-center or vase systems, an over-tree, horizontal string thinner prototype was evaluated in 2008 (Baugher et al., 2009). Peach blossom removal in upper canopy regions ranged from 23% to 69%, with the new string thinner oriented in a horizontal or inclined position to thin the tops of vase-shaped trees. Optimal thinning with the horizontal string thinner was with a 1.0 mph tractor speed, reducing peach crop load by an average of 47%, reducing follow-up hand thinning time 32%, and increasing fruit in higher market size categories 22% to 31%. Net economic impact (realized economic savings) of mechanical thinning versus

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
6.4516	inch^2	cm^2	0.1550
0.4536	lb	kg	2.2046
1.6093	mph	km·h^{-1}	0.6214
2.2417	ton/acre	Mg·ha^{-1}	0.4461

hand thinning alone ranged from $323 to $368 per acre. Total yield was sometimes reduced by string thinner treatments; however, high market value yields were comparable across treatments.

The goal of peach blossom thinning research conducted in 2009 was to determine if a new string thinner prototype designed to thin vase or angled tree canopies could be adapted for varying orchard systems in four peach growing regions of the U.S. Trials with the "hybrid" mechanical blossom string thinner were performed in California, South Carolina, Washington, and Pennsylvania commercial orchards. Data were uniformly collected across regions to determine blossom removal rate, fruit set, labor required for follow-up hand thinning, fruit size distribution at harvest, yield, and economic impact. Case study interviews were conducted to assess sociological implications relative to grower adoption.

A B

Fig. 1. Hybrid string blossom thinner prototype evaluated in 2009 in four peach production regions. The height and angle of the spindle are adjustable to conform to the height (A) and form (B) of the tree canopy, and the intensity of thinning is adjustable by changing the rotation speed, the tractor speed, and the string arrangement (photograph by M. Wherley).

A B

Fig. 2. Molded hollow cords (A) tested in 2009 permitted greater extension into the peach tree canopy than the coiled plastic cords (B) used with earlier thinner prototypes (photograph by M. Wherley and S. Hollabaugh).

Materials and methods

MECHANICAL STRING THINNER DESCRIPTION. The 2009 string thinner prototype is a hybrid of a vertical rotating string thinner (Darwin 300; Fruit-Tec, Deggenhausertal, Germany) designed by H. Gessler to remove apple blossoms in organic orchards (Bertschinger et al., 1998) and a horizontal prototype evaluated in 2008 peach thinning trials (Baugher et al., 2009). The hybrid string thinner has a 2.5-m-long spindle that can be oriented in a vertical or a horizontal position and tilts 30° in either direction from center (Fig. 1). To permit greater extension into the tree canopy, the strings attached to the spindle are rows of molded hollow cords (Fig. 2) (rather than the coiled plastic cords used with earlier versions of the thinner). String length is 20 inches. The spindle is turned by a hydraulic motor, and speed is adjusted by a proportional flow control valve. The height and angle of the frame supporting the spindle are adjustable to conform to the height and inclination of the tree canopy, and the intensity of thinning is adjustable by changing the spindle rotation speed, the tractor speed, and the string arrangement. Two rows of molded cords were used in each trial, and they were arranged with alternating gaps (Fig. 2A). Depending on production system and bloom density, rotation speed ranged between 150 and 250 rpm, and tractor speed ranged from 1.5 to 3.0 mph.

COMMERCIAL ORCHARD TRIALS CONDUCTED IN FOUR PEACH PRODUCTION REGIONS. Trials with the 2009 hybrid string blossom thinner prototype were conducted in California, South Carolina, Washington, and Pennsylvania in three canning peach orchards and three fresh fruit peach plantings. Canopies were angled at 60° to 70° with two (perpendicular V) or four (quad V) main scaffolds. Tree architecture varied by region and market destination. In four plantings, the string thinner spindle was oriented to thin the sides of the trees, and in two perpendicular V canning peach blocks, the spindle thinned the sides followed by the tops of the trees. Where both the sides and tops of the trees were thinned, alternating strings were shortened by one-third. The cultivars were Tuolumne, Loadel, and Late Ross canning peach (California); Saturn peento (donut-shaped) peach (Pennsylvania); Grand Bright nectarine [*Prunus persica* (Washington)]; and Nesstar fresh peach (South Carolina). The experimental design in each trial was randomized complete block, with six blocks and multiple-tree plots (two blocks in 'Nesstar' due to delayed shipping of the thinner). Data were collected from two to eight center trees in each plot. The mechanical treatments in all trials were compared with hand thinning at 35 to 40 d after full bloom (DAFB) and/or hand blossom thinning. String thinning was performed at bloom stages ranging from pink bud to fruit set.

The stage of flower/fruit development was recorded.

Flower density and crop load were determined on three pre-tagged hangers (processing peaches) or one pre-tagged scaffold (fresh market peaches) on each of the test trees. Initial blossom density ranged from 8.7 flowers/cm² limb cross-sectional area in 'Grand Bright' to 66 flowers/cm² limb cross-sectional area in 'Tuolumne'. Blossom removal with mechanical thinners was evaluated by counting all or a section of blossoms in the upper and lower canopy regions of the tagged hangers and scaffolds immediately before and after thinning. Reduction in fruit set was evaluated the day of thinning and again following physiological drop (35–40 DAFB) by calculating the number of blossoms or fruit per limb cross-sectional area in the upper canopy and the lower canopy. All trees were uniformly hand thinned by growers to commercial levels, during which follow-up hand thinning time was recorded. At harvest, a sample of 40 to 50 firm-ripe fruit collected from the center trees in each plot ('Tuolumne', 'Loadel', 'Saturn', and 'Grand Bright') was evaluated for mean fruit diameter and fruit size distribution. In the processing cultivars and 'Nesstar', fruit from each plot were weighed and graded at the processing or packing facility, respectively. In 'Grand Bright' and 'Saturn', yields were calculated from fruit per scaffold counts and percentage size distribution. All data were subjected to an analysis of variance and treatments were separated using Fisher's protected least significant difference test.

Economic and technology adoption implications. Economic partial budget analyses were performed to evaluate the potential impact of each thinning treatment on fruit returns. Mechanical-thinning costs, based on a 15-year useful life of equipment and an 8% interest rate averaged $15/acre for the string thinner, including tractor cost ($12.00/h) and labor ($12.00/h). Realized economic savings were calculated from follow-up hand-thinning time, fruit size distributions, and average yields. Follow-up hand-thinning costs were based on a labor rate of $11.20/h in California, $10.00/h in Washington, $8.50/h in Pennsylvania, and $7.25/h in South Carolina. Current commercial prices for the various size categories for each cultivar were obtained from the California Canning Peach Association (processed fruit) or the *USDA Agricultural Marketing Service Report* (USDA, 2009). All the Pennsylvania growers who tested the mechanical thinner in 2009 agreed to participate in case study interviews to report observations relative to stakeholder adoption. These growers had cooperated in demonstrations on a total of 154 acres.

Table 1. Peach and nectarine blossom thinning and fruit set response to string thinner compared with hand-thinned control treatments in uniformly designed trials in California (CA), Pennsylvania (PA), Washington (WA), and South Carolina (SC) in 2009.

Thinning treatment[z]	Blossoms removed (%)	Flower density after thinning (flowers/cm² limb cross-sectional area)[y]	Crop load (density) at 35 DAFB (fruit/cm² limb cross-sectional area)
'Tuolumne' canning peach Perpendicular V training, CA			
String thinner, petal fall 250 rpm, 1.5 mph	46	40.3 b[x]	17.5 b
Hand-thinned control, 35 DAFB	0	66.0 a	34.0 a
'Loadel' canning peach Perpendicular V training, CA			
String thinner, 60% FB 200 rpm, 1.5 mph	50	43.0	28.6 b
Hand-thinned control, 35 DAFB	0	—[w]	40.8 a
'Late Ross' canning peach Quad V training, CA			
String thinner, 80% FB 185 rpm, 1.5 mph	20	—	21.9 a
String thinner, 80% FB 200 rpm, 2.0 mph	18	—	26.0 a
String thinner, 80% FB 200 rpm, 2.5 mph	17	—	26.1 a
Hand-thinned control, 35 DAFB	0	—	32.3 a
'Saturn' peento peach Perpendicular V training, PA			
String thinner, pink 150 rpm, 1.8 mph	25	14.1 b	6.4 b
Hand-thinned control, 35 DAFB	0	29.2 a	14.4 a
'Grand Bright' nectarine Perpendicular V training, WA			
String thinner, pink 225 rpm, 3.0 mph	53 a	5.6 bc	2.4 c
String thinner, 60% FB 225 rpm, 3.0 mph	22 b	6.8 b	2.2 c
String thinner, fruit set 225 rpm, 3.0 mph	29 b	6.6 b	3.5 b
Hand-thinned control, FB	50 a	4.2 c	—
Hand-thinned control, 35 DAFB	0	8.7 a	6.1 a
'Nesstar' fresh peach Quad V training, SC			
String thinner, petal fall 200 rpm, 1.8 mph	36 b	24.6 a	—
String thinner, petal fall 220 rpm, 1.8 mph	56 a	14.9 b	—
Hand-thinned control, 35 DAFB	0	31.0 a	—

[z]String thinner was fitted with two rows of molded cords with alternating gaps; DAFB = days after full bloom before follow-up hand thinning, FB = full bloom, 1 mph = 1.6093 km·h^{-1}.
[y]1 flower or fruit/cm² = 6.4516 flowers or fruit/inch².
[x]Mean separation within columns and cultivars by Fisher's protected least significant difference at $P \leq 0.05$.
[w]No data available.

Results and discussion

BLOSSOM REMOVAL, FLOWER DENSITY, AND FRUIT SET RESPONSES. Blossom removal in plots thinned by the hybrid string thinner ranged from 18% to 56%, with an average of 36% across experiments (Table 1). The experiments with the highest levels of blossom removal were the 'Tuolumne' and 'Loadel' in which the mechanical thinner was used to thin the sides and the tops of the trees. The string thinner reduced flower density (flowers/cm^2 limb cross-sectional area) compared with the nonthinned control in the canopies of all cultivars, except Nesstar, thinned at 220 versus 200 rpm (Table 1). In the 'Grand Bright' nectarine experiment, flower density in the plots thinned at the pink stage of bloom was equal to that in the hand blossom-thinned control plots, and later string thinning at 60% full bloom (FB) or fruit set also reduced flower density compared with the control. Crop load (fruit/cm^2 limb cross-sectional area), measured at 35 to 40 DAFB and before follow-up hand thinning, was reduced by mechanical thinning in 'Tuolumne', 'Loadel', 'Saturn', and 'Grand Bright', but not in 'Late Ross'. The grower cooperators made the decisions on how many blossoms to remove in each experiment, weighing anticipated impacts on yield and fruit size.

FOLLOW-UP HAND THINNING COMPARISONS. The hybrid string thinner reduced follow-up hand thinning time in all experiments compared with green fruit thinning alone (hand-thinned control, 35–40 DAFB) (Table 2). The percentage of reduction in hand-thinning time ranged from 19% to 40% in the processing peach trials and 38% to 100% in the fresh peach trials, with the exception of the 'Grand Bright' treatment plots where thinning was conducted at fruit set. The reduction in hand-thinning time at this post-bloom stage of 'Grand Bright' was only 17%. The poorest follow-up hand-thinning response in processing trials was when the tractor speed was increased to 2.5 mph versus 1.5 or 2.0 mph. The associated reductions in hand-thinning costs were \$297/acre for 'Tuolumne', \$386/acre for 'Loadel', \$128/acre for the 2.0 mph treatment in 'Late Ross', \$55/acre for the 2.5 mph treatment in 'Late Ross', \$308/acre for 'Saturn', \$198/acre for the pink treatment in 'Grand Bright', \$84/acre for the fruit set treatment in 'Grand Bright', and \$83 to \$100 per acre in 'Nesstar' (Table 3). The labor cost for hand blossom thinning followed by green fruit thinning was \$206/acre higher than the green fruit-thinned control.

FRUIT SIZE AND YIELD COMPARISONS. Peach and nectarine fruit size, size distribution, and market value were increased by the string thinner treatments. Mean fruit diameter increased in string-thinned plots compared with hand-thinned plots in the 'Tuolumne' and 'Saturn' experiments, but not in the 'Grand Bright' experiments. The percentage of fruit in number 1 grade increased in the processing plantings, the percentage greater than 2 ¾ inches in diameter increased in the peento peach planting, and the percentage greater than 3 inches in diameter increased in the 'Grand Bright' plots thinned at pink and the 'Nesstar' thinned at petal fall (Table 4). Marketable size of processing grade number 1 was a fruit diameter greater than or equal to 2 ⅜ inches in diameter plus up to 10% of fruit 2 ¼ inches (number 2 grade), depending on cultivar. High market value fresh fruit were all fruit greater than or equal to 3 inches in diameter, with the exception of peento peaches, which were all fruit greater than or equal to 2 ¾ inches in diameter. Yield of marketable and high market value-fruit increased compared with hand-thinned control treatments with at least one string thinner treatment in five of the six experiments. Total yield was increased by string thinner treatments in the 'Tuolumne', 'Saturn', and 'Grand Bright' experiments, and in no string thinner treatments was yield reduced. In our 2008 mechanical-thinning research (Baugher et al., 2009), yield was reduced by some treatments; therefore, 2009 cooperating growers monitored blossom density to avoid similar reductions. Yields in the South Carolina trial were reduced due to hail damage.

Table 2. Follow-up hand thinning time required in string thinner compared with hand-thinned control treatments in uniformly designed peach and nectarine trials in California (CA), Pennsylvania (PA), Washington (WA), and South Carolina (SC) in 2009.

Thinning treatment[z]	Hand thinning at 35–40 DAFB (h/acre)[y]
'Tuolumne' canning peach Perpendicular V training, CA	
String thinner, petal fall 250 rpm, 1.5 mph	92.1 b[x]
Hand-thinned control, 35 DAFB	118.5 a
'Loadel' canning peach Perpendicular V training, CA	
String thinner, 60% FB 200 rpm, 1.5 mph	91.7 b
Hand-thinned control, 35 DAFB	126.2 a
'Late Ross' canning peach Quad V training, CA	
String thinner, 80% FB 185 rpm, 1.5 mph	22.0 c
String thinner, 80% FB 200 rpm, 2.0 mph	19.2 c
String thinner, 80% FB 200 rpm, 2.5 mph	25.8 b
Hand-thinned control, 35 DAFB	30.7 a
'Saturn' peento peach Perpendicular V training, PA	
String thinner, pink 150 rpm, 1.8 mph	18.5 b
Hand-thinned control, 35 DAFB	37.5 a
'Grand Bright' nectarine Perpendicular V training, WA	
String thinner, pink 225 rpm, 3.0 mph	41.8 c
String thinner, 60% FB 225 rpm, 3.0 mph	46.6 c
String thinner, fruit set 225 rpm, 3.0 mph	53.2 b
Hand-thinned control, FB	22.1 d
Hand-thinned control, 35 DAFB	62.4 a
'Nesstar' fresh peach Quad V training, SC	
String thinner, petal fall 200 rpm, 1.8 mph	36.8 b
String thinner, petal fall 220 rpm, 1.8 mph	34.5 b
Hand-thinned control, 35 DAFB	48.3 a

[z]String thinner was fitted with two rows of molded cords with alternating gaps; DAFB = days after full bloom, FB = full bloom, 1 mph = 1.6093 $km \cdot h^{-1}$.
[y]1 h/acre = 2.4711 $h \cdot ha^{-1}$.
[x]Mean separation within cultivars by Fisher's protected least significant difference at $P \leq 0.05$.

Table 3. Follow-up hand thinning cost, thinning savings, and net economic impact as affected by string thinner treatments in uniformly designed peach and nectarine orchard trials in California (CA), Pennsylvania (PA), Washington (WA), and South Carolina (SC) in 2009.

Thinning treatment[z]	Follow-up hand thinning cost ($/acre)[y]	Gross income ($/acre)[x]	Net economic impact ($/acre)[w]
'Tuolumne' canning peach Perpendicular V training, CA			
String thinner, petal fall 250 rpm, 1.5 mph	1031	9127	1250
Hand-thinned control	1328	8173	—
'Loadel' canning peach Perpendicular V training, CA			
String thinner, 60% FB200 rpm, 1.5 mph	1027	5838	1490
Hand-thinned control, 35 DAFB	1413	4735	—
'Late Ross' canning peach Quad V training, CA			
String thinner, 80% FB 185 rpm, 1.5 mph	247	5120	236
String thinner, 80% FB 200 rpm, 2.0 mph	216	4267	(648)
String thinner, 80% FB 200 rpm, 2.5 mph	289	5459	462
Hand-thinned control, 35 DAFB	344	4997	—
'Saturn' peento peach Perpendicular V training, PA			
String thinner, pink 150 rpm, 1.8 mph	330	6757	934
Hand-thinned control, 35 DAFB	638	5831	—
'Grand Bright' nectarine Perpendicular V training, WA			
String thinner, pink 225 rpm, 3.0 mph	426	12,288	847
String thinner, 60% FB 225 rpm, 3.0 mph	475	11,962	472
String thinner, fruit set 225 rpm, 3.0 mph	540	11,846	291
Hand-thinned control, FB	830	12,058	(206)
Hand thinned control, 35 DAFB	624	11,630	—
'Nesstar' fresh peach Quad V training, SC			
String thinner, petal fall 200 rpm, 1.8 mph	280	7319	264
String thinner, petal fall 220 rpm, 1.8 mph	263	5097	(241)
Hand-thinned control, 35 DAFB	363	7153	—

[z]String thinner was fitted with two rows of molded cords with alternating gaps; DAFB = days after full bloom before follow-up hand thinning, FB = full bloom, 1 mph = 1.6093 $km \cdot h^{-1}$.
[y]Follow-up hand thinning cost is based on a labor rate of $11.20/h in California, $10.00/h in Washington, $8.50/h in Pennsylvania, and $7.25/h in South Carolina; $1/acre = $2.4711/ha.
[x]Thinning savings includes reduced follow-up hand thinning inputs and added mechanical thinner, tractor, and tractor operator inputs (also additional hand thinning cost for hand blossom-thinned control). Mechanical thinner cost is based on a 15-year useful life of equipment and 8% interest rate. Tractor cost is $12.00/h; equipment operator cost is $12.00/h. Market prices for each region obtained from the California Canning Peach Association (processed fruit) or the *USDA Agricultural Marketing Service Report* [fresh fruit (USDA, 2009)].
[w]Net economic impact (realized economic savings) is defined as cost/benefit beyond hand thinning alone and takes into account reduced hand thinning inputs and increased value of fruit in higher size categories. Values in parentheses are negative.

Economic and technology adoption implications. The savings in hand-thinning requirement and increases in fruit size distribution realized in all trials increased the economic value of the peach crops beyond that of hand thinning alone (Table 3). Gross income ranged from $4,267 to $9,127 per acre in processing plantings and $5,097 to $12,288 per acre in fresh fruit plantings. Net positive economic impact from mechanical thinning (realized economic savings beyond hand thinning alone) ranged from $236 to $1490 per acre and $264 to $934 per acre, respectively, with the exception of one treatment in 'Late Ross' and 'Nesstar' in which the economic impact was negative. Economic impact also was negative in the hand blossom-thinned control treatment. The cost-benefit results are consistent with those reported in research on previous string thinner prototypes (Baugher et al., 2009; Schupp et al., 2008). Increased fruit size had a greater positive impact for fresh market producers, while labor savings and yield increases (due to larger fruit size) were of greater importance for canning peach growers.

Case study interviews of 11 Pennsylvania growers and orchard managers who had thinned a total of 154 acres suggested that commercial adoption of mechanical string-thinning technology would have positive impacts on the work place. All case study cooperators reported that blossom string thinning impacted orchard management by making crop load management more efficient and by reducing follow-up hand-thinning time. Eighty percent of the growers noted that fruit from thinned trees were larger. Additional observations included the following: 1) hand thinning of peaches was completed earlier, allowing more timely work in other crops; 2) employees were satisfied with mechanical thinning, as it saved them time and minimized ladder use; and 3) the seasonal distribution of labor-intensive work was improved.

The research results across four peach-growing regions suggest that future trials with the string blossom thinner should focus on increasing access to the peach tree canopy. Sensors and controls that would allow automatic positioning of the spindle could potentially increase the accuracy of thinning. Modifications to tree canopy architecture also should be investigated. The string thinner hybrid

Table 4. Peach and nectarine fruit size, size distribution, and high market value yield as affected by string thinner treatments in uniformly designed trials in California (CA), Pennsylvania (PA), Washington (WA), and South Carolina (SC) in 2009.

	Fruit in high market value size categories[x]				
Thinning treatment[z]	Fruit diam (cm)[y]	Fruit ≥ 2 ⅜ inches (canning) (%)	Fruit ≥ 3 inches (fresh) (%)	Total yield (tons/acre)[w]	Yield of high market value size fruit (tons/acre)[v]
'Tuolumne' canning peach Perpendicular V training, CA					
String thinner, petal fall 250 rpm, 1.5 mph	6.6 a[u]	97.2 a		28.7 a	27.8 a
Hand-thinned control, 35 DAFB	6.3 b	94.0 b		25.7 b	24.2 b
'Loadel' canning peach Perpendicular V training, CA					
String thinner, 60% FB 200 rpm, 1.5 mph	—[t]	70.1 a		20.6 a	16.4 a
Hand-thinned control, 35 DAFB	—	63.1 b		19.8 a	13.4 b
'Late Ross' canning peach Quad V training, CA					
String thinner, 80% FB 185 rpm, 1.5 mph	—	73.0[s]		13.4	9.9
String thinner, 80% FB 200 rpm, 2.0 mph	—	33.0		16.1	5.5
String thinner, 80% FB 200 rpm, 2.5 mph	—	50.0		17.2	8.6
Hand-thinned control, 35 DAFB	—	33.0		15.7	5.3
'Saturn' peento peach Perpendicular V training, PA					
String thinner, pink 150 rpm, 1.8 mph	6.9 a		21.2 a	9.2 a	2.0 a
Hand-thinned control, 35 DAFB	6.5 b		5.0 b	5.6 b	0.3 b
'Grand Bright' nectarine Perpendicular V training, WA					
String thinner, pink 225 rpm, 3.0 mph	7.2 a		51.7 a	15.6 b	8.1 a
String thinner, 60% FB 225 rpm, 3.0 mph	7.2 a		21.7 b	19.8 a	4.3 b
String thinner, fruit set 225 rpm, 3.0 mph	7.2 a		21.7 b	14.5 b	3.1 b
Hand-thinned control, FB	7.1 a		10.0 b	16.8 b	1.7 b
Hand-thinned control, 35 DAFB	7.3 a		13.8 b	15.5 b	2.2 b
'Nesstar' fresh peach Quad V training, SC					
String thinner, petal fall 200 rpm, 1.8 mph	—		57.0 a	7.8 a[q]	4.3 a
String thinner, petal fall 220 rpm, 1.8 mph	—		64.4 a	6.0 b	2.9 b
Hand-thinned control, 35 DAFB	—		42.3 b	8.3 ab	5.0 ab

[z]String thinner was fitted with two rows of molded cords with alternating gaps; DAFB = days after full bloom before follow-up hand thinning, FB = full bloom, 1 mph = 1.6093 $km \cdot h^{-1}$.
[y]1 inch = 2.54 cm.
[x]Fruit diameter and packout distribution determined on 40 to 50 fruit harvested per treatment from each of six replicates ('Tuolumne', 'Loadel', 'Saturn', and 'Grand Bright'). For 'Late Ross' and 'Nesstar', fruit were graded at the processing and packing facility, respectively.
[w]Fruit from 'Tuolumne', 'Loadel', 'Late Ross', and 'Nesstar' plots weighed; other yields calculated from fruit counts and size distributions; 1 ton/acre = 2.4711 $kg \cdot ha^{-1}$.
[v]Marketable processing fruit are all fruit ≥2 ⅜ inches (number 1 grade) plus up to 5% of fruit 2 ¼ to 2 ⅜ inches (number 2 grade) with the exception of 'Loadel', which are allowed up to 10% number 2 fruit. High market value fresh fruit are all fruit ≥3 inches diameter, with the exception of peento peaches that are all fruit ≥ 2 ¾ inches.
[u]Mean separation within columns and cultivars by Fisher's protected least significant difference at $P \leq 0.05$.
[t]No data available.
[s]Not replicated.

developed specifically for this research has been commercialized and will now be manufactured in North America, in addition to Germany.

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