Mechanical Blossom Thinning to Reduce Labour

Final Report to
Vineland Research and Innovation Centre
December 2009

Ken Slingerland
Tender Fruit & Grape Specialist, OMAFRA

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Chris Andrews, Beamsville
Kevin Buis, Peter Buis, Niagara-on-the-Lake
George Lepp, Niagara-on-the-Lake
John Thwaites, Niagara-on-the-Lake
Phil Tregunno, Niagara-on-the-Lake
Ron and Len Troup, Jordan

Participating Apple Fruit Growers
Peter Bosman, Smithville
Marius Botden, Thornbury
Pat Johnston, Thornbury
Torrie Warner, Beamsville

The growers provided labour wherever possible for the hand thinning and the harvest of the crop as well as donating their time and their orchards for the study.

EXECUTIVE SUMMARY

Reducing labour and related costs in the orchards is one of the highest priorities for commercial growers. The mechanical blossom thinning trials conducted in 2009 showed similar results to the research being conducted in Pennsylvania and other locations. String rotation speed had a greater effect than the string configuration on the amount of blossom thinning at the two sites that had the replicated treatments.

Approximately 40 to 70% of the peach tree blossoms were removed by the Darwin string thinners on marked limbs which resulted in a significant reduction of labour and associated costs for hand thinning. The reduction of thinning time ranged from 12 to 51% depending upon site, rotation speed of the strings and the number of strings used. This translated into a reduction of thinning costs of $119 par acre to $200 per acre.

Fruit size increased from 5 to 18%, depending upon the variables. The crop of the Darwin thinned trees was 9% bigger when compared to the hand thinned control trees of the demonstration sites. But at the replicated trials, the Darwin thinner had a larger range from 46% less yield than the control hand thinned trees to 17% more yield compared to the hand thinned trees depending upon the treatment.

There were no significant differences in split pits between the treatments at the replicated sites.

Other benefits included earlier ripening of the crop at several sites due to the larger fruit size. Stronger shoot growth was also observed on the Darwin thinned trees early in the season compared to the hand thinned trees.

Demonstrations of mechanical blossom thinning were held across the province during the month of May in Niagara-on-the-Lake, Jordan and Thornbury. Approximately 100 peach and apple growers attended the 5 events.

Growers should investigate new technology to reduce labour costs. Tree structure and design will need to change to adapt to more automation and labour efficiencies. The economic viability in the future will depend upon the ability to adapt to new labour savings technology.

BACKGROUND

The tender fruit and apple growers need to reduce labour costs in order to remain efficient. According to the OMAFRA publication "Establishment and Production Costs for Tender Fruit in Ontario 2006 Economic Report", the cost for thinning fresh market peaches contributed $500 per acre to the overall variable costs. With increases in the minimum wage in the previous 3 years, this cost has climbed significantly. Currently, all tender fruit must be hand thinned since there are no chemical thinners available.

PENN STATE COOPERATIVE EXTENSION RESEARCH

Penn State Cooperative Extension has completed two years of research using the mechanical Darwin string thinning machine. The following is a summary from an abstract from Penn State Cooperative Extension.

T. Auxt Baugher[1], J. Schupp[2], S. Miller[3], K. Lesser[1], K. Reichard[2], M. Harsh[1], C. Musselman[1], A. Leslie[1], M. Reid[1], Scott Wolford[3], M. Schupp[2], E. Moore[2], C. Witt[2], C. Sollenberger[1], Mark Price[1],

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Hand thinning of fruit is among the most labor-intensive orchard practices, and consequently contributes significantly to fruit production costs. Preliminary research in Pennsylvania commercial orchards on mechanical string or drum shaker thinners demonstrated that these methods have potential for reducing the hand thinning requirement in crop load management programs. These technologies also lessen the competition from a portion of the excess crop early and rapidly—thereby improving fruit size, quality, and return bloom. Being non-chemical, the obstacle of registration for a new compound is avoided. New mechanical thinning strategies coupled with narrow tree architectures have potential to favorably impact grower profitability both by reducing labor requirement and by improving fruit size and quality.

In the 2008, the second year of research with mechanical string and drum shaker thinners at bloom and the green fruit stage respectively, the preliminary results from 12 trials in peach orchards and studies in Gala apple and Hosui pear blocks are encouraging:

- Peach blossom removal ranged from 30 to 50% with a vertical string thinner and 25 to 70% with a horizontal string thinner prototype
- The vertical string thinner performed best at 2 mph, while optimal thinning with the horizontal string thinner was at 1 mph, the peach crop load was reduced by approx. 50%
- Vertical string thinner trials on pome fruit indicated mechanical thinning may be more effective in removing lateral blossoms (that produce smaller fruit) than chemical thinners.
- Follow-up hand thinning time was reduced by 29 to 60% by the string thinners
- Fruit in higher market value size categories increased by an average of 35%
- Net economic impact of mechanical thinning versus hand thinning alone ranged from $237 to $1164 per acre
- Net economic impacts in string thinner timing trials were greater than $237 per acre for all bloom stages (pink through petal fall), suggesting a wide window for acceptable thinning

INVESTIGATING THE DARWIN – Ken Slingerland

During April 19 to 23, 2009, I visited Penn State Cooperative Extension of Adams County, Pennsylvania to observe and co-operate with the peach blossom thinning demonstrations using the Darwin mechanical aid. Dr. Tara Baugher and Dr. Jim Schupp of Penn State University and Katie Ellis, Agricultural Innovations Coordinator were my hosts during the research and demonstration trials

The information gained was a high priority with the Ontario Tender Fruit Producers' Marketing Board and supports Vineland Research Innovation Centre's Action Plan Project Proposal 2.6A for "Strategic Evaluation of Opportunities and Methods for Increasing Productivity in Orchard and Vineyard Operations. Objective (b) examines developments in automation and mechanization related to pruning, thinning, tying vines, harvesting and packing fruit with a view to assessing technologies that could be adapted to Ontario conditions.

The economic benefit to the industry is $237 per acre based on Penn State results. The total savings to the Ontario industry could potentially be over $1 million dollars ($237 x 5,000 acres of peaches).

Several farms were visited during the 4 day stay including; Chris Bauhger – Adams County Nursery, Orchard Lane Road, Corey McClef - Biglerville Road, Route 34, Bear Mountain Orchards – Potato Road near Benderville, Douglas Lott, Mark Rice, Pleasant Dale Road and a Grower Demonstration at the Penn State Fruit Lab in Biglerville. The main orchard design tested was the "V" system of growing peahc trees usually spaced at 6 x 18 feet. One standard trained orchard was used spaced at 14 x 22 feet. Several cultivars were tested as well as tractor speed, string rotation, orientation of strings and the number of strings (Figures 1,2,3).

OBJECTIVES

The purpose of the project was to test the "Darwin" mechanical string thinner in commercial orchards in Ontario. The goals were to investigate:

1. The effectiveness of the Darwin to reduce the number of blossoms per tree based on:
    - The different variables that affect how the Darwin performs such as tractor speed, speed rotation of the strings, the number of strings and string orientation
    - The different orchard designs and training systems
    - The application time from pre-pruning the orchard at first pink to a pruned orchard at petal fall
2. The labour costs for hand thinning between the blossom thinned orchards and the normal hand thinning
3. The impact of early blossom thinning on the fruit size and yield
4. Demonstrate the new technology to growers in the tender fruit and apple growing areas

ACTION PLAN

Niagara-on-the-Lake, Vineland and Thornbury were the 3 locations used in the province

Data collected at different sites included;

- Blossom count pre-thin using Darwin and Control (hand thinning)
- Blossom count post thin – Darwin
- Fruit set, pre-thin counts for Darwin and Control
- Post hand thinning counts for Darwin and Control – thinning time data collected
- Harvest and grading – fruit counts and size grading

N.M. Bartlett Inc. purchased the mechanical thinning machine Darwin model 250 and the PT model for the thinning investigation and demonstration. Matt Peters from N.M. Bartlett Inc. coordinated the hauling of the mechanical blossom thinners from farm to farm, contacted many of the growers for the trials and coordinated all of the apple visits and demonstrations in the Thornbury area.

The field data was collected by Ken Slingerland and student help throughout the season. The data for the replicated trials was analyzed by Dr. John Cline, University of Guelph.

SUMMARY

The four treatments in the replicated trials at Buis and Lepp were designed to find out if the Darwin would under-thin and over-thin the trees. The harshest treatment (240 rpm and all 18 strings in most cases resulted in over-thinning based on the harvest yield in lbs. per tree (Figure 12, 13). The over-thinning usually resulted in a lower than desired yield but always produced the largest fruit.

Tree Structure:

Peaches - The optimal tree structure is likely the spindle shaped tree (Figure 5), but V shaped trees (Figures 1,2,3) worked equally well in Adams County, Pennsylvania. Central Leader trees (Figure 6) would also work but would need to be shaped properly to allow uniform thinning on an angle between 60-75°. Open Centre shaped trees (Figure 4) can be thinned form the sides and top between the ages of 4 and 9 years old but once the lower fruiting limbs have been "shaded out", the only effective mechanical thinning would be over the top of the tree.
Apples – High Density spindle systems worked the best for apples while the open centre systems were too wide to be effective (Figure 7,8).
Plums – The "standard" pruning system for plums did not lend itself to mechanical blossom thinning since the canopy was so dense and too wide for the Darwin to penetrate deeper into the tree. Most of the outer limbs were thinned but the inner structure of the tree was untouched. The results were too variable, over-thinning some branches and under-thinning others. However, several buds and clusters were removed and overall the early blossom thinning might contribute to healthier buds and a better return bloom in 2010 (Figure 9).

Pruning:

Mechanical thinning of blossoms prior to pruning is not beneficial. Most of limbs thinned are likely to be removed from pruning. Since the recommended practice for peach growers is to delay pruning as long as possible until warmer dryer weather in late April and early May arrives, the strategy for pruning might be to start pruning the main blocks in the prime production ages of 5 years to 10 years old first, so the trees can be mechanically thinned. The non-bearing or younger trees can be pruned next. The oldest trees can be pruned either at the very early start of the season in mid April or at the end of the pruning season in late May.

When to Mechanical Blossom Thin:

Peaches - Mechanical blossom thinning can start as early as first pink and go until near the end of petal fall. The best effect of mechanical blossom thinning is likely at full bloom but adjustments in the tractor speed, rotation speed, number of strings can also affect the removal of blossoms.
Apples – The preferred time is around 70% of the King Bloom are open to petal fall.
Plum – Need to wait until around 50% full bloom to around petal fall

Tree Damage:

Damage to trees is usually minimal. Branches form open centre systems are most often damaged by "rubbing" from the steel frame (Figure 13, 14).

How Affective is the Darwin:

Blossom Thinning – Peaches - The amount that the Darwin removes is dependent upon several factors such as; tree structure, tractor speed, rotation speed, string orientation and number of strings. The goal is to remove around 50% of the bloom. The average number of blossoms removed at the 6 demonstration sites averaged 47% (37.0 to 67.9%) using different cultivars, tree ages, pruning systems tractor speeds and string orientations (Table 1) (Figures 15, 16, 17).
The number of blossoms removed at the Lepp site ranged from 39 to 59% depending upon treatment (Table 2). The number of blossoms removed at the Buis site ranged from 60 to 85% (Table 3).
Apples – The goal for thinning apple blossoms is about 30 to 35% since many blossoms are not removed outright at the time of thinning, several more blossoms are damaged and do not likely set fruit later in the spring.

Fruit Thinning - Peaches- Follow up hand thinning is necessary but the time is reduced. At the Andrewes site, 37% less fruit need to be removed at thinning time on the Darwin thinned trees compared to the Control hand thinned trees resulting in a 21% reduced cost per acre (Table 6).
At the Lepp site, the average amount of time to thin an acre was 21 to 51% less for the Darwin thinned trees compared to the Control hand thinned trees (Table 9). At the Buis site, the average amount of time to thin an acre was 12 to 50% less for the Darwin thinned trees compared to the Control hand thinned trees (Table 10).
Apples – At one demonstration site in Thornbury using fully mature large Empire trees, the grower reported 25.83 hours to thin 1 row of mechanically thinned trees compared to almost double the time of 51 hours to thin 1 row of the hand thinned control trees. The Gala trees took 2.75 hours to thin the Darwin thinned trees while the hand thinned trees took 4.17 hours to hand thin.

Thinning Costs:

Based on the 2006 Cost of Production with additional labour costs, the estimated cost to thin 1 acre of peaches is $600 (50 hours x $12 per hour). At the Andrewes site, the Darwin thinned trees had a 21% savings in hand thinning resulting in a savings of $119 per acre ($477 versus $566). The average number of fruits removed for the control hand thinning was 58% higher than the Darwin mechanically blossom thinned trees.

At the Lepp site, the average time for the four treatments of mechanical blossom thinning reduced the time by 33% or a savings of $200 per acre ($600 x 33%). At the Buis site, the average time for the four treatments of mechanical blossom thinning reduced the time by 32% or a savings of $192 per acre ($600 x 32%).

Over-Thinning:

You can over-thin by traveling too slow, using too many strings or by having a very high rotation speeds usually over 240 rpm. But, under-thinning occurs under the opposite conditions.

What are the ideal thinning options for the Darwin:

Peaches – In the current study, tractor speeds between 2 to 3 mph, rotation between 180 and 220 rpm and using either all strings or 2 on and 2 off combination worked best under the Ontario conditions (Figure 23, 27). Usually the pruning styles of the standard pruned trees prevented the tractor operator from traveling any faster than 2 to 3 mph.

Apples – Tractor speed, especially on well trained spindle trees can be increased to 4 to 6 mph, rotation between 220 and 240 rpm and using all columns and all 18 stings per column. Tractor speeds in excess of 6 mph have been used in Germany for well trained high density spindle trees. Growers will still need to "fine tune" these variables to customize to their own operations.

Tree Growth:

Observations made in the first year of the trials indicated that there was stronger shoot growth on the Darwin blossom thinned tree versus the control hand thinned trees Figures 17, 18).

Yield:

Peach - The yield was not affected at two of the sites observed. At the Troup site using the cultivar Harrow Diamond, the control hand thinning removed 84% of the blossoms while the Darwin + follow-up hand thinning removed 85% of the blossoms. At the Thwaites site using the cultivar Garnet Beauty, the number of fruit harvested for the control hand thinning was 300 fruit per tree while the Darwin + follow-up hand thinning trees averaged 294 fruit per tree harvested, however, the yield for the Darwin thinned trees was 9% larger.

At the Lepp site, the yield for the Darwin thinned trees was varied from 1 to 18% lower compared to the hand thinned trees depending upon treatment (Table 12). At the Buis site the yield was 46% lower to 17% larger depending upon treatment (Table 13).

Apple – At the demonstration site in Thornbury, the mature Empire apple row mechanical thinned by the Darwin yielded 35.75 bins with 59% graded for fresh while the hand thinned control row yielded 31.25 bins and had 9% less fresh apples at 17 bins.

Fruit Size:

At the Andrewes site, the fruit thinned on June 22 was 8% larger for the Darwin blossom thinned trees compared to the control hand thinning trees (Figure 20). Thwaites site using the cultivar Garnet Beauty, the fruit size average for the control hand thinning was 126 grams per fruit (300 fruit per tree) while the Darwin + follow-up hand thinning trees averaged 11% larger at 140 grams per fruit (294 fruit per tree harvested) (Figure 21).

At the Lepp site, the fruit size for the Darwin thinned trees was varied from 5 to 18% larger compared to the hand thinned trees depending upon treatment (Table 12). At the Buis site the fruit size was 7% to 17% larger depending upon treatment (Table 13). This effect is associated with the reduction in crop load combined with the earlier thinning.

Split Pits:

At the Thwaites site using the cultivar Garnet Beauty, the % split pits for the control hand thinning was 2.3% while the Darwin + follow-up hand thinning trees averaged double at 4.7% split pits. However there was 28% more rainfall (450.8 mm) in 2009 April 1 to August 31 compared to the 85 year average (351.9 mm) which may have contributed to the higher rate of split-pit fruit. There was no significant difference in the amount of split pits at the Lepp and Buis site between treatments.

Harvest Dates:

The fruit was observed to be riper by colour and measured larger in size by 11%. 10.3% more peaches were harvest on the first pick on the Darwin thinned trees (51% versus 40.3%). The second pick had virtually the same fruit harvest while the last pick had 10.1% more harvest from the control hand thinned trees (23.3% versus 13.2%).

Payback for the machine:

Based on the results from the 2009 research trials at 3 grower sites there was average savings of $200 per acre. The capital cost of the Darwin model 250 at approximately $10,000 so a grower would need to mechanically thin 50 acres to break even. The capital cost of the PT 250 was approximately $15,000 so a grower would need to thin 75 acres to break even.

Other Issues

Apples - Other reported issues from Pennsylvania indicate that the disease "Fire Blight" might be spread under the ideal conditions for the disease during mechanical blossom thinning. The machine can cause minor injuries and spread existing inoculums during the spinning of the strings. Therefore it is recommended to thin apples and pears only on days without rain in the forecast.

TABLES

A. Blossom Thinning

Table 1: Peaches – Grower Demonstration Trials

Ave. % of blossoms thinned on all farms is 46.6% removed

Grower	Cultivar	Age	Pr	System	Stage	Rpm	Speed mph	Strings	Location	Means % thin
Andrewes	H. Diamond	6	Y	Open	75% PF	220	2.1	2 on 2 off	Sides	56.8
									Top	67.9
									Ave.	62.4
Buis	Vulcan	5	Y	CL	60% FB	220	3.0	2 on 2 off	Sides	49.1
									Top	44.1
									Ave.	46.6
Buis	Catherina	5	N	CL	80% FB	180	3.0	2 on 2 off	Sides	38.7
						220			Sides	48.4
Thwaites	Garnet Bty	11	Y	Open	75% FB	180	2.5	2 on 2 off	Sides	44.0
									Top	56.0
	Vivid	6	Y	Open	75% FB	210	3.0	2 on 2 off	Sides	40.4
Tregunno	H. Diamond	9	N	Open	10-20% FB		3.0	All	Sides	43.6
									Top	51.0
									Ave.	46.1
	H. Diamond	9	Y	Open	10-20% FB		3.0	All	Sides	46.3
Troup	H. Diamond	5	Y	CL	90% FB	210	3.0	2 on 2 off	Sides	37.0

- Strings - 2 on 2 off = 3 columns x 46 strings = 138 in total
- All strings are 3 columns @92 strings per = 276 strings in total
- Tregunno – approximately 50% of branches removed during pruning after mechanical blossom thinned

Table 2: Lepp – Allstar Peaches – Replicated Trials

Treatment	% of Flowers Removed	% Fruit Set Means
Control – Hand Thinned	0	51.2 a
180 RPM, 18 strings	42.2 b	35.9 b
180 RPM, 9 strings	37.5 b	38.5 b
240 RPM, 18 strings	58.5 a	24.1 c
240 RPM, 9 strings	53.3 a	25.2 c

- Values with different letters within a given column are significantly different at P=0.05

Table 3: Buis – Catherina Peaches – Replicated Trials

Treatment	% of Flowers Removed	% Fruit Set Means
Control – Hand Thinned	0	46.1 a
180 RPM, 18 strings	75.9 ab	13.5 c
180 RPM, 9 strings	60.4 c	21.4 b
240 RPM, 18 strings	85.4 a	7.0 c
240 RPM, 9 strings	70.8 bc	12.1 c

- Values with different letters within a given column are significantly different at P=0.05

Table 4: Plums – Tregunno - Grower Demonstration Trials

Cultivar	Age	Pr	System	Stage	Rpm	Speed mph	Strings	Location	% Thin
E. Golden	12	Y	Open	FB – PF	200	2.5	All	S + T	24.1
Shiro	12	Y	Open	FB	200	2.5	All	S + T	26.0

Table 5: Apples – Grower Demonstration Trials

Grower	Cultivar	Age	Pr	System	Stage	Rpm	Speed mph	Strings	Clusters % Thin	Fl % Thin
Bosman	Courtland	4	Y	Spindle	50% KB +	270	3.0	2 on 2 off	32.8	47.4
	MacIntosh	5	Y	Spindle	50% KB +	270	3.0	2 on 2 off	32.6	45.3
	Red Chief D	5	Y	Spindle	50% KB +	270	3.0	2 on 2 off	28.6	55.1
	Red Chief D	5	Y	Spindle	50% KB +	250	4.4	2 on 2 off	32.7	50.1
Botden	Red Prince	2	Y	HD Sp	80% KB +	210	3.6	All		21.0
	Red Prince	3	Y	HD Sp	80% KB +	210	3.6	All		23.9
Johnson	Empire	20	Y	CL	70% FB	220	3.8	All		47.3
	Paula Red	20	Y	CL	90% FB	220	3.8	All		43.0
Warner	Gala	9	Y	Spindle	80% FB	210	3.0	2 on 2 off	34.0	48.4
	Mutsu	19	Y	Open	70% FB	210	3.0	2 on 2 off	24.2	29.4
	Golden Del	19	Y	Open	70% FB	210	3.0	2 on 2 off	44.9	53.9

- Strings Combo – All + 2 on 2 off = 243 strings total

B. Hand Thinning

Table 6: Peaches % Removed – Andrewes - Grower Demonstration Trials

Cultivar	Thinning Method	Blossom Thin %	Pre-Hand Thin %	Post Hand Thin %	Ave. # of Fruits/Tree Thinned	Ave. Wt. of Fruit Thinned	Cost of Thinning per Acre
H. Diamond	Control	0	44	92	743*	9.3 g	$566
	Darwin	60	76	92	469	8.7 g	$447

- 58% more fruit to thin on the Control trees
- 24% ($119) extra to thin Control trees per acre
- 8% larger fruit for the Darwin

Table 7: Peaches % Removed – Thwaites - Grower Demonstration Trials

Cultivar	Thinning Method	Blossom Thin %	Pre-Hand Thin %	Post Hand Thin %
G. Beauty	Darwin	44	62	85
Vivid	Darwin	40	57	80

Table 8: Peaches % Removed – Troup - Grower Demonstration Trials

Cultivar	Thinning Method	Blossom Thin %	Pre-Hand Thin %	Post Hand Thin %
H. Diamond	Control	0	49	84
H. Diamond	Darwin	37	65	85

Table 9: Lepp – Allstar Peaches – Replicated Trials

Treatment	# of Fruit Thinned per Branch	Final Crop Load at Harvest – Fruit/Trunk Cross-Sectional Area	Time Required to Thin in hr/acre	Reduction in Thinning Time by %
Control – Hand Thinned	29.1 a	2.3 a	76.8 a	-
180 RPM, 18 strings	18.7 b	1.9 abc	61.0 ab	21
180 RPM, 9 strings	21.2 b	2.2 ab	60.0 ab	22
240 RPM, 18 strings	10.9 c	1.6 c	39.3 c	51
240 RPM, 9 strings	11.1 c	1.8 bc	47.9 bc	38

- Values with different letters within a given column are significantly different at P=0.05

Table 10: Buis – Catherina Peaches – Replicated Trials

Treatment	# of Fruit Thinned per Branch	Final Crop Load at Harvest – Fruit/Trunk Cross-Sectional Area	Time Required to Thin in hr/acre	Reduction in Thinning Time by %
Control – Hand Thinned	42.8 a	2.6 ab	20.3 a	-
180 RPM, 18 strings	6.6 c	2.1 bc	13.0 b	36
180 RPM, 9 strings	13.3 b	2.7 a	18.2 a	12
240 RPM, 18 strings	4.8 c	1.0 c	10.2 b	50
240 RPM, 9 strings	7.0 bc	1.8 d	11.9 b	31

- Values with different letters within a given column are significantly different at P=0.05

C. Tree Growth

Tree growth was observed and noted. Six year old Venture trees were mechanically blossom thinned and compared with Venture trees that were not mechanically blossom thinned. The picture in Figure 18 would indicate a stronger growth response to the trees that were mechanically blossom thinned. The picture in Figure 19 would indicate normal growth at thinning time.

D. Fruit Yield and Fruit Size

Table 11: Peaches – Thwaites - Grower Demonstration Trials

Cultivar	Thinning Method	Weight per tree in lbs.	Tons per Acre	# of Fruit per tree	Ave. Weight per Fruit in lbs.	Ave. Weight per Fruit in g	% Split Pits
G. Beauty	Control	83.3	10.1	300	.278	126	2.3
	Darwin	90.6	11.0	294	.308	140	4.7

Table 12: Lepp – Allstar Peaches – Replicated Trials

Treatment	# of Split Pits per tree	Ave. number of fruit per tree	Total Fruit Weight lbs/tree	Tons per Acre	Fruit Weight in g
Control – Hand Thinned	2.4	168 a	53.9 a	12.2	147 c
180 RPM, 18 strings	2.5	152 ab	53.3 ab	12.1	158 b
180 RPM, 9 strings	2.5	142 bc	48.3 ab	11.0	155 b
240 RPM, 18 strings	4.5	115 d	44.3 c	10.1	173 a
240 RPM, 9 strings	3.3	125 cd	46.2 bc	10.5	167 a

- Values with different letters within a given column are significantly different at P=0.05

Table 13: Buis – Catherina Peaches – Replicated Trials

Treatment	# of Split Pits per tree	Ave. number of fruit per tree	Total Fruit Weight lbs/tree	Tons per Acre	Fruit Weight in g
Control – Hand Thinned	0.6	155 a	65.6 ab	11.2	198 c
180 RPM, 18 strings	0.3	125 ab	60.0 ab	10.2	218 ab
180 RPM, 9 strings	0.5	164 a	76.5 a	13.0	219 bc
240 RPM, 18 strings	0.3	68 c	35.5 c	6.0	231 a
240 RPM, 9 strings	0.3	110 b	51.1 bc	8.7	212 bc

- Values with different letters within a given column are significantly different at P=0.05

Figure 1. Blossom thinning “V” system trees in Pennsylvania

Figure 2. “V” system peach trees in Pennsylvania

Figure 3. Blossom Thinning “V” system peach trees

Figure 4. “Standard” system Harrow Diamond peach trees

Figure 5. “Spindle” system Allstar peach trees

Figure 6. “Central Leader” system Catherina peach trees

Figure 7. Dwarf “Central Leader” apple trees

Figure 8. Dwarf High Density “Spindle” apple trees

Figure 9. “Standard” system Shiro plum tree

Figure 10. “Un-pruned” Harrow Diamond peach trees

Figure 11. Pink Stage for early blossom thinning

Figure 12. King Bloom Stage for thinning apples

Figure 13. Damage to apple leaves and clusters

Figure 14 Damage to peach branch

Figure 15. Blossom Thinned Catherina peach trees on the left row but not the right row

Figure 16. Shiro blossoms on the ground just after mechanical blossom thinning

Figure 17. Adolf Betz operating the Darwin thinning Harrow Diamond peach trees

Figure 18. Venture peach tree mechanically blossom thinned with good growth

Figure 19. Venture peach tree hand thinned with moderate growth

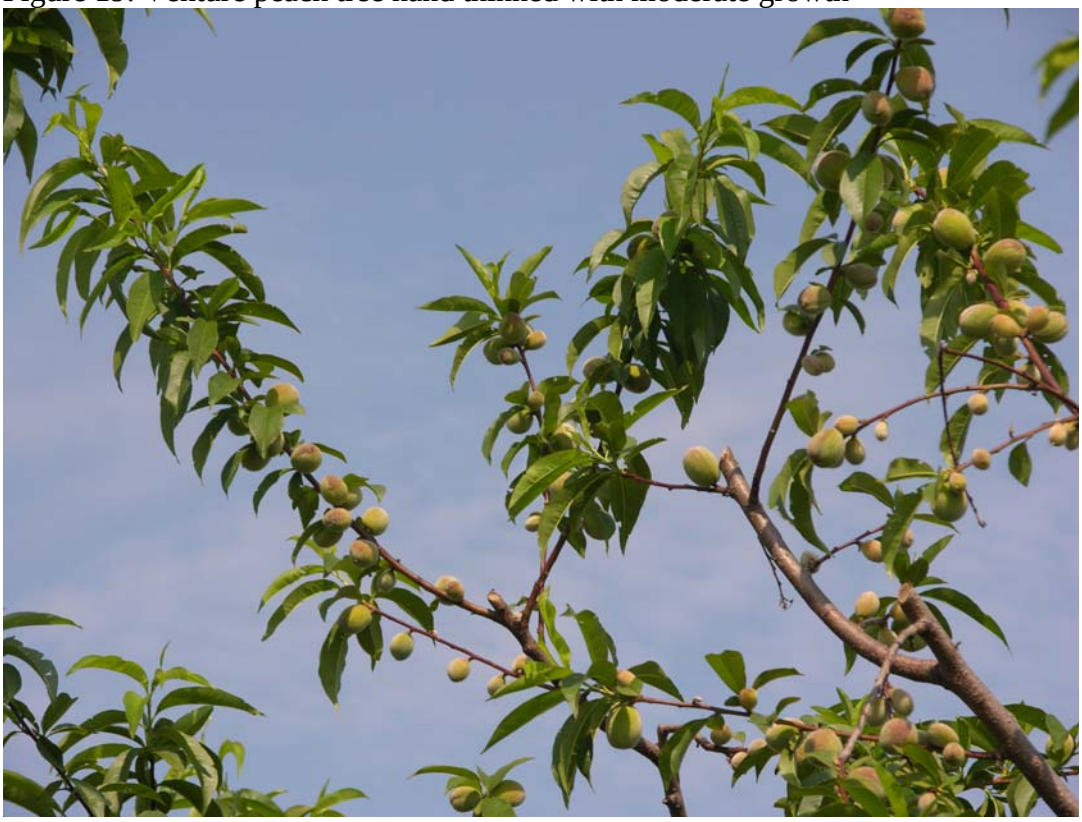

Figure 20. Fruit Size at thinning time

Figure 21. Harvest of Garnet Beauty fruit mechanically thinned

Figure 22. Summer Students assisting with the project

Figure 23. Art Moyer assisting with string adjustment

Figure 24. Ken Slingerland observing apple blossoms

Figure 25. Driver using the Darwin

Figure 26. Dr. John Cline recording data in the field

Figure 27. Matt Peters adjusting the strings on the Darwin

Figure 28. Adolf Betz driving the tractor, Torrie Warner looking on

Figure 29. Sieglinde Betz observing the apple thinning

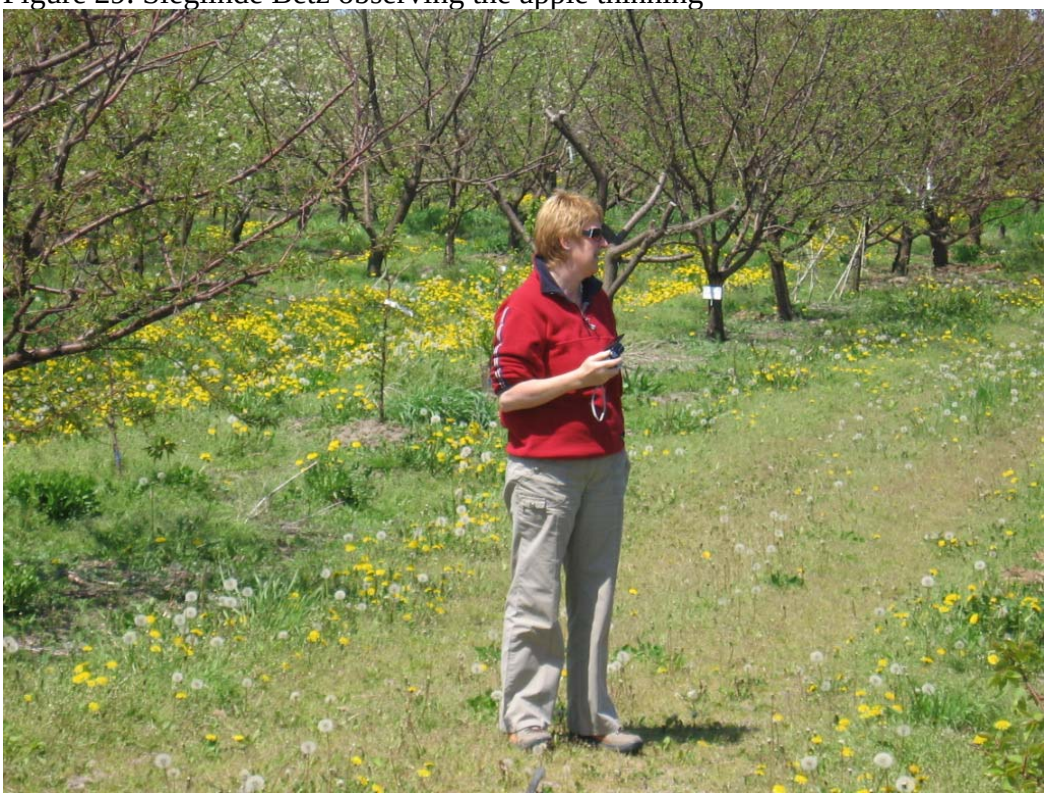

Figure 30. Adolf Betz thinning apple trees