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Thinning of Peach Trees Using High-Pressure Water

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Abstract

Peach trees (*Prunus persica* [L.] Batsch) annually produce an over-abundance of flowers that often set to produce an excessive number of unmarketable, small fruit. Hand-thinning fruits following natural fruit abscission in June is a costly but essential management practice growers undertake to ensure remaining fruits are marketable at harvest. Past thinning methods have focused on chemical and mechanical approaches to removing flowers or fruitlets. The focus of this two-year study was to outline a method using high-pressure water and demonstrate its proof of concept to thin peach trees non-chemically at bloom. 'Harrow Beauty' and 'Harrow Diamond' peach trees trained using a central leader spindle system were subjected to one of three high-pressure water spray treatments at full bloom based on amount of time spraying each tree: 1) 'LOW'- 45 s tree^{-1} (5.7 L water tree^{-1}); 2) "MED" - 60 s tree^{-1} (7.6 L water tree^{-1}), and; 3) "HIGH" -75 s tree^{-1} (9.5 L water·tree^{-1}). An unsprayed hand-thinned ("HAND") treatment served as a control. All treatments, including HAND, were hand-thinned after 'June' drop. In year one, high-pressure water treatments reduced fruit set, the requirement for hand-thinning, crop load, total fruit per tree and yield at harvest and increased fruit weight of 'Harrow Beauty' by 27%. In year two, treatments reduced fruit set, the total number of fruit per tree and increased the fruit weight of 'Harrow Beauty' at harvest. Effects on the early ripening cultivar 'Harrow Diamond' were less pronounced; although, there was an increase in fruit weight at harvest in response to high-pressure sprays. Overall, increasing the duration of spraying resulted in greater treatment effects compared with the HAND treatment. High-pressure water treatments increased the percentage of fruit in the 2.25" (57 mm) and larger fruit diameter categories. In comparison with HAND and based on final crop load, the ideal rate of thinning using high-pressure water was in the range of 60-70s per tree requiring 7.6 – 9.5 L water per tree. The merits of this novel thinning approach and design factors for commercialization are discussed.

Apple, peach, nectarine, plum and pear producers often hand thin immature fruit (fruitlets) four to six weeks after bloom following natural fruit abscission (Havis 1962; Byers and Lyons 1984; Webster and Andrews 1986; Byers 1989a). Fruit thinning by hand has become a standard cultural practice to enhance fruit size and quality at harvest, to increase return bloom of biennially bearing species (eg. *Malus*), and to prevent scaffold limbs from breaking under the weight of excess fruit. Hand thinning is most effective when performed as early as reasonably possible (Day and DeJong, 1999; Jiménez and Díaz, 2002). Thinning of peaches at bloom has several advantages over hand thinning, including reduced labour costs, increased flowering the following season by up to sixty percent and a greater number of shoots per tree (Byers, 1989a).

Labour costs for hand-thinning peaches in Ontario are approximately $C 1,729/ha based on 124 trees/ha labour and 2010 labour rates (OMAFRA, 2010). While bloom thinning may increase peach fruit size and yields by 20-30% compared to hand thinning 40-50 days later (Byers, 1989a), hand-thinning remains the most effective method to regulate peach crop load. Alternative thinning methods have been sought, including robotics (Lyons et al, 2015) and mechanical thinning at bloom using a 'string' thinner (Schupp et al, 2008; Sauerteig and Cline, 2013) in order to offset this time-consuming and expensive practice. Chemical thinning sprays, such as carbaryl, 1-naphthalene acetic acid or 6-ben-

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zyl adenine, are for use on apple; however, there are no chemical thinners currently registered for many stone fruit crops including peaches and cherries.

Our previous research at the University of Guelph investigated three approaches to reduce the requirement for hand-thinning peach trees: flower inhibition, blossom thinning, and chemical fruitlet thinning. All three approaches were successful with 'Redhaven', 'Harrow Diamond', and 'Harrow Beauty' and further studies are ongoing to refine the methodology for other cultivars and to ensure the results are repeatable annually (Coneva and Cline, 2006).

The primary objective of this study was to investigate a non-chemical approach to thinning peaches at bloom. Thinning early offers a distinct advantage in comparison with fruitlet thinning by providing earlier allocation of limited photosynthates and assimilates to fewer sinks. Although blossom thinning peaches with various chemical products has been studied extensively since the 1940s (Larsen, 1947), an approach that does not rely on chemicals and that is consistent across cultivars, weather conditions, and phenological stages of flower development would be ideal. A high-pressure water stream, directed at the peach inflorescence at or near full bloom, may reduce fruit set and result in less hand-thinning at 'June' drop. Furthermore, thinning at this early stage would result in larger fruit at harvest and in contrast to hand-thinning would also provide more predictable results.

Material and Methods

Experiment 1: Thinning of 'Harrow Beauty' in 2008. A 5-yr old research orchard of ''Harrow Beauty' (*Prunus persica*) located at the University of Guelph, Vineland (lat. 43°10'55.1" N, long. 79°23' 23.1" W) planted at a spacing of 2.5 m x 5.0 m (500 trees ha^{-1}) was used for this study. 'Harrow Beauty' ripens around 2 Sept. in the Niagara Peninsula of Southern Ontario.

Experiment 2: Thinning of 'Harrow Beauty' and 'Harrow Diamond' in 2009. A 6-yr old research orchard of 'Harrow Diamond'/Bailey and 'Harrow Beauty'/Bailey (*Prunus persica*) (different trees from those used in 2008) located at the University of Guelph, Vineland (lat. 43°10'55.1" N, long. 79°23' 23.1" W) and planted at a spacing of 2.5 m x 5.0 m was used for this study.

'Harrow Diamond' is an early maturing cultivar with a ripening date around 27 July in Southern Ontario. Because the fruit is small-to-medium sized, this cultivar must be thinned early and adequately to obtain suitable size, making it a good candidate cultivar for early bloom thinning.

Both cultivars were planted in individual rows and trained using an 'Italian Fusetto' (central leader) spindle system with individual tree supports and fastened to wire trellis (Caruso et al., 1989; Miles et al., 1999). Trees and pests were managed according to conventional practices for Ontario (Anonymous, 2012).

Experiments 1 and 2. On 12 May 2008, and 6 May 2009 at full bloom, treatments were applied using a commercial gasoline-powered pressure washer (Model PE2055-HWSCOM, BE Pressure, Inc., Cambridge, ON) equipped with a 0° nozzle (direct spray) on a hand-wand at a working pressure of 1 378 KPa and discharge rate of 7.6 l per min (Fig. 1-3). The stream of high-pressure water was directed at individual limbs (Fig. 2) at a distance of ~1.5 m. If the stream was within 1 m of the limb, removal of bark was possible (Fig. 3); although, this occurred infrequently. Fresh, clean municipal water was supplied to the pressure washer via a 10 mm (i.d.) high-pressure rubber hose connected to commercial air blast sprayer (GB Irrorazione Diserbo, Model Laser P7, Italy) acting as a 'nurse' tank and operating with a supply pressure of 500 KPa.

For experiment one, a randomized complete block (RCBD) with four treatments and ten replications was used as the experimental design. For experiment two, a RCBD with four treatments and nine replications for the

Fig. 1. Treatments being applied on May 12, 2008 to 'Harrow Beauty' peach trees in full bloom. Approximately only 5% of flowers are required to set a commercial crop. [J. Cline photo]

Fig. 2. It was necessary to direct the high-pressure water at the shoot limbs at a set distance to avoid damaging the tree bark whilst also dislodging the flower. [J. Cline photo]

Fig. 3. Bark injury as a result of excessive water pressure on the peach shoot. Generally, a distance of 1.5 m or greater from the branch was maintained to prevent injury. [J. Cline photo]

'Harrow Beauty' and five replications for the 'Harrow Diamond' was used as the experimental design. To minimize treatment interference, experimental units were separated by at least one 'guard' tree in the orchard. Treatments consisted of three levels of thinning based on amount of time spraying each tree: 'LOW'- 45 s per tree (5.7 L water per tree); "MED" - 60 s per tree (7.6 L water per tree), and;) "HIGH" - 75 s per tree (9.5 L water per tree); and a hand-thinned control ('HAND').

In early June after flowering, five primary scaffold limbs per tree were selected randomly between 1.0 – 2.0 m above the ground to determine initial fruit set after treatment application but before 'June drop'. Shoot length of 1-yr-old wood and the number of flower buds were recorded to evaluate flower density. The number of fruitlets were counted on these shoots after 'June drop' but before hand-thinning. All treatments, including hand-thinned control treatments, were hand-thinned between 3-5 July 2008 (52-54 DAFB) and 29 June-4 July 2009 (54-59 DAFB) to approximately 15-20 cm between fruits (5-7 fruits per m shoot length). The total number of fruit thinned per tree was counted and weighed (2008 only).

'Harrow Beauty' fruit were harvested on 9 Sept. 2008 and 1 Sept. 2009 while 'Harrow Diamond' were harvested over a period of 5 days beginning 31 Jul 2009, all based on uniform background colour and full suture swelling. The yield and total number of fruit harvested per tree was recorded. All fruit were then graded into one of the following six size categories based on minimum diameter: <57 mm, 57-62 mm; 63-69 mm; 70-75 mm; 76-81 mm and > 81 mm. A diameter greater than 57 mm is the commercial target for marketable fruit, hence, the category "> 57" mm (which combined all but the fruit with a 57 mm minimum fruit diameter) was also chosen for analyses of fruit size distribution. Fruit were counted and weighed in each category.

Tree trunk circumference 30 cm above the soil line was measured and recorded in Sept. of each year to calculate trunk cross-sectional area.

Data were analyzed by ANOVA using PROC MIXED (version 9.4, SAS Institute, Inc., Cary, NC) and Tukey's HSD was used to separate means with treatments as the fixed effect, and blocks as the random effect. To investigate the relationship between the response variables and thinning timing (rate), linear regression was conducted on the LOW, MED, and HIGH treatments only; the HAND treatment was excluded because it was not an untreated control. Linear regression of yield and crop load was conducted using Sigma Plot (ver. 13.0, Systat Software, Chicago, IL). A Shapiro-Wilk test was used to test the assumption that the residuals were normally distributed. Scatterplots of studentized residuals were visually observed to test the assumption that the errors were not heterogeneous. Lund's test of outliers with studentized residuals indicated whether outliers were present and, if so, they were removed from the analysis (Bowley, 2008). In cases where there were large deviations from the assumptions, data were corrected by log- or square root-transformation prior to analysis.

Results and Discussion

In 2008, high-pressure water thinning treatments reduced fruit set, the requirement for follow-up hand-thinning, crop load, total number of fruit per tree and mean fruit weight at harvest of 'Harrow Beauty' compared to the hand thinned control (Table 1). Overall, the LOW and MED treatments reduced fruit set and there was little additional benefit from the HIGH treatment. Treatments reduced yield per tree based on the Tukey's HSD test, but not based on the ANOVA F test ($P=0.058$). When mean fruit weight was adjusted for crop-load (Marini et al, 2002) using ANCOVA, treatments were similar. Fruit set was unaffected by the amount of time applying the thinning treatments (from 45 to 75 seconds per tree). The LOW, MED, and HIGH treatments resulted in 26, 58 and 57% (252, 143, and 146 fruits removed) reductions in the amount of hand-thinning required after 'June drop', respectively compared with the untreated hand-thinned trees (343 fruits removed) ($P<0.0001$). Similar levels of hand-thinning were needed for MED and HIGH treatments ($P>0.05$). At the time of thinning, not only was there a greater number of fruit thinned per tree for the 'HAND' treatments, but the fruitlet size at thinning was 16-25% smaller than the MED and LOW treatments, respectively (data not shown). These data are consistent with studies by Redman (1952)

Table 1. The effect of thinning treatments on follow-up hand thinning, fruit set, weight of thinned fruit, crop load, tree yield and mean fruit weight at harvest. 'Harrow Beauty'/Bailey. University of Guelph, Vineland, Ontario. 2008 data.

Treatment	Number of fruit thinned per tree		Initial set (number of fruit/m shoot length)[y]		Final crop load at harvest (frt/cm² tcsa)		Total fruit per tree (number)		Total fruit weight (kg/tree)		Crop load adjusted mean fruit weight (g)	Mean fruit weight (g)	
Hand thinned control	343	a	35	a	11.5	a	337	a	40.6	a	138.1	125.3	c
Low	252	b	19	b	7.9	b	221	b	31.8	b	144.7	148.1	b
Medium	143	c	20	b	8.7	b	247	b	34.2	ab	144.1	143.8	b
High	146	c	17	b	6.5	b	193	b	29.7	b	150.1	159.9	a
P value	<0.0001		<0.0001		0.0008		0.0017		0.0577		0.445	0.0006	
Regression of Low, Med, High[z]	L*		ns		ns		ns		ns		ns	ns	

[y] set was determined on June 17, prior to hand thinning in early July.

[y] Values within columns not followed by common letters differ at the 5% level of significance, by Tukey's HSD

[z] ns, *, **, ***, indicates not significant, and significant differences at P = 0.06, P = 0.01 respectively

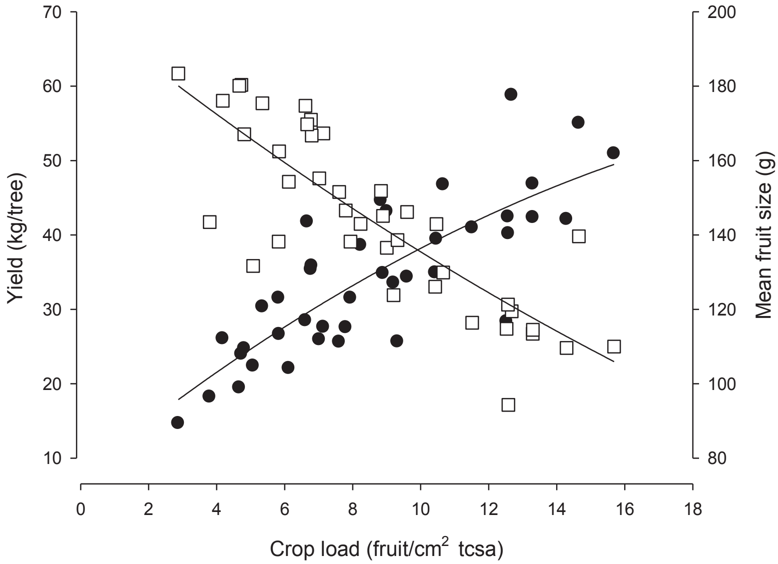

Fig. 4. Scatter plot of fruit size (□) and yield (●) plotted against crop load (per tree) at harvest for 'Harrow Beauty' in 2008. Yield and mean fruit size followed a curvilinear relationship when plotted against crop load. The linear regression for yield $=0.084x^2$ -7.3x + 200.5, *and* mean fruit size = $-0068x^2$ + 3.7x + 7.71, where x = crop load (r^2 = 0.683 for both equations

who reduced flowers using high pressure water spray. In an anecdotal study in New Zealand, Larsen (1947) discovered serendipitously that spraying peach trees with high pressure spray water reduced thinning by 75%, however no data on yield or fruit size were provided. In a study on 'Redhaven', 'Cresthaven', and 'Loring' using a three nozzle spray boom, closed stream spray pattern, 3447 KPa pressure, 45 L permin, Byers (1989) successfully removed 34-70% of flowers at bloom. However, no data on fruit size, efficiencies in reduced hand thinning or effects on yield were presented.

At harvest in early Sept., spray treatments resulted in a 24-44% (6.5 - 7.9 fruit/cm^2 tcsa) reduction in crop load in comparison with the HAND treatment 11.5 fruit/cm^2 tcsa). Again, differences were greater between the hand-thinned control and spray treatments than within the level (duration) of spray treatment. Regression analyses failed to show a linear or quadratic rate effect (time of spraying, 45, 60, 75 seconds) on crop load . Yield per tree was negatively related to crop load; that is, when the thinning treatments reduced crop load, yield was also reduced. Fruit size increased when thinning treatments reduced crop load, however, the compensatory effect of early thinning on fruit size failed to translate into treatment differences in yield per tree (P=0.0577) in part, because of high tree-tree variation (Fig. 4). Trees which are thinned often have lower yields but profitability is improved by improved fruit size. There was a significant increase (P=0.0006) in mean fruit size for the high pressure water treatments compared with the HAND treatment. The adjustment in crop load by thinning at 'June' drop was intended to provide a uniform level of cropping for comparison purposes. In retrospect, the level of hand-thinning in the HAND treatment was insufficient to bring the crop load (11.5 frt/cm^2 tcsa) in line with the LOW, MED, and HIGH treatments (6.5-7.9 frt/cm^2 tcsa), even though a greater number of fruit were removed from the trees receiving the HAND treatment.

Table 2. The effect of thinning treatments on commercial grade out of 'Harrow Beauty'/Bailey peaches in 2008. University of Guelph, Vineland, Ontario.[y]

	Weight of fruit (kg)										
Treatment	<2.25" < 57 mm		2.25-2.4" 57-62 mm		2.5-2.74" 63-69 mm		2.75-2.9" 70-75 mm	3.0-3.24" 76-81 mm		3.25+" 82+ mm	>= 2.5" 57 mm
Hand thinned control	4.8	a	11.2	a	16.6	a	6.1	1.9	b	0.1	35.9
Low	1.0	b	4.3	b	13.2	ab	9.1	3.7	ab	0.6	30.8
Medium	1.0	b	5.6	b	14.6	ab	9.6	3.4	ab	0.1	33.2
High	1.3	b	3.4	b	9.6	b	8.4	6.1	a	0.9	28.5
P value	0.0118		0.0008		0.0170		ns	0.0172		0.0421	0.2944
Regression of Low, Med, High[z]	ns		ns		ns		ns	ns		Q*	ns

[y] Values within columns not followed by common letters differ at the 5% level of significance, by Tukey's HSD
[z] ns, *, **, ***, indicates not significant, and significant differences at P = 0.05, P = 0.01 and P = 0.001 respectively.

Commercial grade-out of the fruit into seven size categories indicated that all spray treatments increased the weight of fruit in the less than 2¼ (57 mm), 2¼ - 2.4“ (57-62 mm), and 2½ -3¾ (63-69 mm) fruit diameter categories (Table 2). Fruit smaller than 57 mm are not sold on the fresh (retail) market in Canada and therefore commercial orchard practices aim to minimize production of fruit in this size category. The LOW, MED, and HIGH treatments resulted in greater weights of fruit in the 3.0-3.24” (76-81 mm) (P=0.01) and ≥ 3.25” (82 mm) (P=0.04) size categories. Overall, however, no significant treatment difference in the weight of fruit in the ≥ 2.5” (58 mm) size category was observed. In 2009, high-pressure water thinning treatments had a significant effect on the percentage of flowers removed for 'Harrow Beauty' (P=0.0006) but not for 'Harrow Diamond' trees (Table 3). Treatments removed approximately 40 to 57% of flowers, which increased with the time of spraying. Fruit set was also significantly affected for 'Harrow Beauty' (P=0.0003) but not for 'Harrow Diamond' trees. Fruit set ranged from 25%

Table 3. The effect of thinning treatments on flower thinning, fruit set, crop load, tree yield and mean fruit size at harvest of 'Harrow Diamond' and 'Harrow Beauty' peaches in 2009.

Treatment	Percent of flowers removed[x,y]		Percent fruit set[x]		Final crop load at harvest (frt/cm^2 tcsa)	Total fruit per tree (number)		Total fruit weight (kg/tree)	Crop load adjusted mean fruit weight (g)		Mean fruit weight (g)	
Harrow Diamond												
Hand thinned control	-		21.5		3.6	168		21.7	153.3		147.4	ab
Low	40.5		19.7		4.1	189		24.0	150.1		136.8	b
Medium	45.8		19.8		2.6	126		17.7	148.5		155.5	a
High	51.6		15.6		2.2	113		17.4	147.8		160.1	a
P value	0.3327		0.5649		0.2676	0.372		0.4103	0.9109		0.0549	
Regression of Low, Med, High[z]	L*		ns		ns	ns		ns	ns		ns	
Harrow Beauty												
Hand thinned control	-		26.0	c	4.3	186	ab	23.7	132.2	b	132.1	b
Low	36.8	c	38.7	a	5.6	216	a	24.5	125.0	b	116.9	c
Medium	48.1	b	32.7	b	3.5	145	ab	18.7	128.8	b	133.5	b
High	57.0	a	27.6	bc	3.7	139	b	20.1	149.1	a	152.5	a
P value	0.0006		0.0003		0.1429	0.0959		0.2589	0.0079		0.0002	
Regression of Low, Med, High[z]	L**		L*		ns	L*		ns	L**		L***	

[x] set was determined on June 17, prior to hand thinning in early July.
[y] Values within columns not followed by common letters differ at the 5% level of significance, by Tukey's HSD Test
[z] ns, *, **, ***, indicates not significant, and significant differences at P = 0.05, P = 0.01 and P = 0.001 respectively. NE indicates not estima

for the hand-thinned controls to 39% for the LOW rate of thinning. Fruit set decreased with increasing intensity of thinning. Fruit set of the HIGH treatment was equivalent to HAND treatment. Final crop load, total fruit per tree and total yield at harvest were unaffected by thinning treatments. Based on regression analyses, crop load was not linearly or quadratically related to spray time (rate). However, number of fruit per tree decreased in a linear fashion with increasing time of spraying (P=0.032) (data not shown). Compared to the control treatment for 'Harrow Diamond' fruit weight increased at the

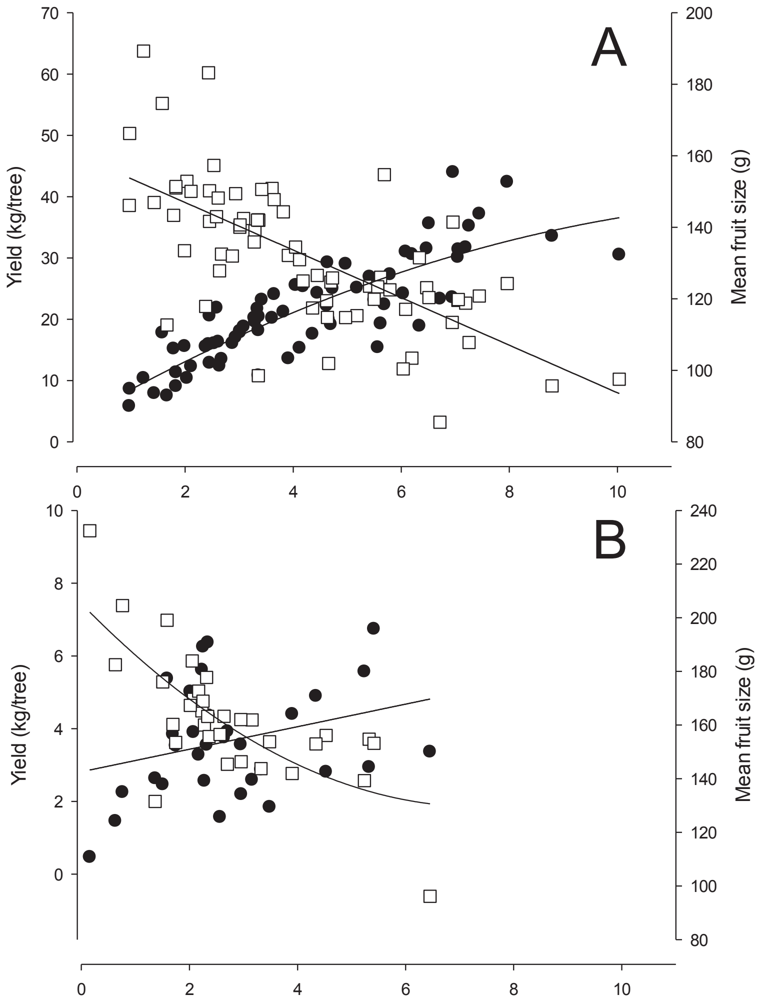

Fig. 5. Scatter plot of fruit size (□) and yield (●) plotted against crop load (per tree) at harvest for 'Harrow Beauty' (A) and 'Harrow Diamond' (B) in 2009. 'Harrow Diamond' yield and mean fruit size followed a curvilinear relationship when plotted against crop load. The linear regression for 'Harrow Diamond' (B) yield =3.640x^2 -4 x 10e-17x + 2.81 (r^2=0.65), and mean fruit size = 1.26x^2 - 0.146x + 159 (r^2=0.153), where x = crop load (r^2 = 0.683 for both equations). The linear regression for 'Harrow Beauty' (A) yield =5.08x^2 -0.179x + 3.6 (r^2+0.483), and mean fruit size = -11.43-0.502x^2 + 169.0 (r^2 = 0.712), where x = crop load.

0.055 level of significance for the MED and HIGH treatments and was significantly greater for the HIGH treatment (P=0.002) for ‘Harrow Beauty’. In both instances, fruit weight was equivalent to or greater than the HAND treatments. As was observed in 2008, fruit size and yield per tree were influenced by the thinning treatments, likely by crop load (Fig. 5). With increasing crop load up to approximately 10 fruit/cm^2 TCSA, ‘Harrow Beauty’ yields increased from 10 to 40 kg/tree (Fig 5A). A similar relationship was observed for ‘Harrow Diamond’, but yields per tree were considerably less than those of ‘Harrow Beauty’ (Fig. 5B). Fruit size of ‘Harrow Beauty’ (Fig. 5A) and ‘Harrow Diamond’ (Fig. 5B) increased in a linear fashion with decreasing crop loads.

Commercial grade-out of ‘Harrow Beauty’ fruit in 2009 indicated that the weight of fruit in the <2¼” (57 mm), 2¼-2.4” (57-62 mm), 2½ -2.74” (63-69 mm), and 2¾ -2.9” (70-75 mm) size categories were similar among all treatments (Table 4). Trees treated with the HIGH treatment had more fruit (by weight) in the 3.0-3.24” (76-81 mm) size category. As in 2008, no significant treatment difference in the weight of fruit in the ≥ 2.5” (57 mm) size category was observed. For ‘Harrow Diamond’ fruit, no significant treatment effects on grade distribution was observed.

The results of this study indicate that the overall crop load reduction from high-pressure spraying would directly reduce the labour requirement to thin the crop, thereby lowering the financial burden to producers. A 60% and greater reduction in thinning was achieved in this study. This is a conservative estimate given that the HAND-thinning treatments were, in retrospect under-thinned in comparison with commercial standards, offering a $C 628 per ha immediate cost saving. In Ontario, with an estimated 2,500 ha of peaches and nectarines (OMAFRA, 2010), the annual cost savings could be in the magnitude of $C 1.5 million per annum. Additionally, in part because the thinning is done at bloom, 40-50 days earlier than when hand-thinning is normally conducted, there would be additional treatment benefits in fruit size (Asteggiano et al., 2015) liklely resulting in greater yields compared to thinning at ‘June drop’. Other advantages of bloom thinning included less dependence on weather for

Table 4. The effect of thinning treatments on commercial grade out of ‘Harrow Diamond’ and ‘Harrow Beauty’ peaches in 2009.

	Weight of fruit (kg)						
Treatment	<2.25" < 57 mm[y]	2.25-2.4" 57-62 mm	2.5-2.74" 63-69 mm	2.75-2.9" 70-75 mm	3.0-3.24" 76-81 mm	3.24+" 82+ mm	>= 2.5" 57 mm
Harrow Diamond							
Hand thinned control	4.0	10.6	5.0	1.0	0.3	0.0	17.0
Low	3.9	13.7	4.2	0.9	0.6	0.0	19.4
Medium	1.5	13.1	4.2	0.4	0.3	0.0	18.7
High	0.8	8.9	5.5	0.8	0.9	0.0	16.1
P value	0.554	0.778	0.452	0.862	0.497	-	0.554
Regression of Low, Med, High[z]	ns	ns	ns	ns	ns	-	ns
Harrow Beauty							
Hand thinned control	2.1	7.9	9.2	3.4	1.1 b	0.1	21.6
Low	4.4	8.8	6.9	3.3	1.0 b	0.1	20.1
Medium	1.5	5.3	8.1	2.9	0.9 b	0.0	17.2
High	1.0	4.0	7.1	4.2	3.5 a	0.2	19.0
P value	0.0564	0.0726	0.3972	0.6143	0.0055	0.4889	0.4603
Regression of Low, Med, High[z]	L*	L*	ns	ns	L**	ns	ns

[y] Values within columns not followed by common letters differ at the 5% level of significance, by Tukey's HSD Test

[z] ns, *, **, ***, indicates not significant, and significant differences at P = 0.05, P = 0.01 and P = 0.001 respectively.

Table 5. Estimated theoretical requirements for a prototype sprayer based on 1 to 5 nozzle configuration.

Treatment	L/Tree	Water Volume/ha^z		Water Volume/acre^z		Thinning time (secs) required/tree based on 1-5 nozzles					Tractor ground speed based on 1-5 nozzles (km/hr) and 2.5 m in-row spacing				
						No. spray nozzles					No. spray nozzles				
		Litres	Gallons	Litres	Gallons	1	2	3	4	5	1	2	3	4	5
not tested	3.8	1900	502	769	203	30	15	10	7.5	6	0.30	0.60	0.90	1.20	1.50
Low	5.7	2850	753	1154	305	45	22.5	15	11.3	9	0.20	0.40	0.60	0.80	1.00
Med	7.6	3800	1004	1538	406	60	30	20	15	12	0.15	0.30	0.45	0.60	0.75
High	9.5	4750	1255	1923	508	75	37.5	25	18.8	15	0.12	0.24	0.36	0.48	0.60
not tested	11.4	5700	1506	2308	610	90	45	30	22.5	18	0.10	0.20	0.30	0.40	0.50

z - based on 500 trees/ha (202 trees/acre), trees spaced 2.5 m apart, and a water discharge rate of 7.6 L/min per nozzle

pollination and applications can be made irrespective of weather compared to chemical thinning.

The high variability in treatment responses are likely due to a number of factors. First, the method of application is based on manual application of the high pressure water and directing toward flowering shoots. It is conceivable that the high pressure water treatments were not applied uniformly between replicates. Also, blocking on flower density per tree prior to treatment application may have reduced this variability if the trees did not have a similar number of flowers per tree. If high-pressure water thinning technology is to be commercialized, building a prototype sprayer with multiple nozzles and a tractor-driven delivery system would be required. Calculations of the range of water discharge rates and water volumes per area are indicated in Table 5. For the current experiment, spraying between the MED and HIGH rate would require 3,800-4,700 L ha^{-1} at planting densities of 500 trees per ha. In addition, and perhaps not immediately apparent, a single plane (hedgerow) tree architecture, such as a 'V' or 'Y' trellis training system would lend itself to automation. The distance from the nozzle to the flower is likely very important in obtaining desirable flower removal without causing bark injury. Automating the process would probably require multiple (5 or more) spray nozzles as well, which would directly influence the total water discharge rate and sprayer pump requirements. Estimated ground speed and thinning time per tree is also indicated in Table 5 based on a 1 to 5 nozzle prototype. This example is based on a density of 500 trees per ha, 2.5 m between trees, and 7.6 L per min water discharge rate per nozzle. With a sprayer configured with five nozzles, the thinning time would be reduced from 60-75 seconds to 12-15 seconds per tree and a minimum ground speed of 0.60-0.75 km hr^{-1}. These preliminary calculations support the feasibility of a delivery system that will work based on a 5 nozzle application system. Further refinements in nozzle discharge rates and efficacy will be required to maintain travel speeds within minimum acceptable levels (e.g., > 1 km per hr). Increasing water discharge rates would allow greater travel speed; however, the effectiveness of thinning would need to be evaluated. Optimization of high-pressure nozzle efficacy (e.g., rotating turbo nozzles) and methods to make the most effective use of water (i.e., water conservation techniques or nozzles that use less water) should be explored in prototype engineering development.

Canada ranks 45th in world production of peaches and nectarines based on land area (FAO, 2016). China accounts for 712,800 ha of production; more than North, Central and South America and Europe combined (500,000 ha). The countries who will most benefit from this technology are the top ten producers of peaches and nectarines (with the exception of China): Italy, Spain, USA, Greece, Turkey, the Islamic Republic of Iran, Chile, France, Argentina, and Egypt (FAO, 2016). These markets should be considered if this technology is further developed and commercialized.

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