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Thinning before Bloom Affects Fruit Size and Yield of Hardy Kiwifruit

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Abstract. **Five-year-old hardy kiwifruit [*Actinidia arguta* (Sieb. et Zucc.) Miq. 'Ananasnaya'] vines in a commercial vineyard were subjected to thinning before bloom in 1999. Flowers were thinned at four severities: 0% (control), 15%, 30%, and 50% flower bud removal (2-5 June). The average yield of vines thinned 50% was significantly less than that of control vines. However, marketable yield from vines thinned 15%, 30% and 50% was not significantly different from control vines. Thinning, regardless of severity, increased average fruit volume and king fruit volume by 18% and 27%, respectively, compared to control vines. King fruit were more affected by thinning than the two adjacent lateral fruit in the cluster. Thinning before bloom had no effect on percent soluble solids, seed number or total seed weight per fruit.**

Actinidia arguta (Sieb. & Zucc.) Miq., commonly known as the hardy kiwifruit, is commercially grown in Oregon, with planted hectarage estimated at 42 ha in 2002 (Tiyayon and Strik, 2003). The main cultivar grown in Oregon is 'Ananasnaya'.

Actinidia arguta is a vigorous, perennial, deciduous vine that is trained to a support structure. Shoots can have either terminating or nonterminating vegetative growth and are vegetative or mixed (producing both leaves and flowers). Flowers are borne in leaf axils either singly or in a small cyme (Tiyayon and Strik, 2003). The fruit of 'Ananasnaya' is an ovoid, green to red blushed berry with a smooth, edible epidermis. Fruit weight ranges fom 4.5 to 16 g (Strik, 2000) averaging 7 g (Tiyayon and Strik, 2003). Fruit mature in late summer to autumn, depending on region (Ferguson, 1990; Strik, 2000), with firmness decreasing slightly in the later stages of ripening (Kabaluk and Kempler, 1997). Fruit are generally once-over harvested at an average percent soluble solids, °Brix, of 9 to 14 (Strik, 2000; Tiyayon and Strik, 2003).

Fruit size and quality are the most important characteristics affecting price and marketing of kiwifruit. In *A. deliciosa* (A. Chev.) C.F. Liang & A.R. Ferguson 'Hayward', a high fruit number per vine was inversely correlated to average fruit weight (Burge et al., 1987; Cooper and Marshall, 1991; Lahav et al., 1989; Richardson and McAneney, 1990) and reduced flowering in the following season (Antognozzi et al., 1991; Burge et al., 1987; Cooper and Marshall, 1991).

Biennial bearing has not been observed in hardy kiwifruit, although there can be over 11,000 flowers produced on a mature vine (Tiyayon and Strik, 2003).

Variable fruit weight is a problem in hardy kiwifruit (Tiyayon and Strik, 2003). The highest quality fresh market fruit are uniform in size and weigh >6 g (Hurst, personal communication). Thinning to improve fruit size has not yet been reported in this species of kiwifruit. Fruit thinning of mature *A. deliciosa* 'Hayward' reduced yield but improved fruit size and quality (Antognozzi et al., 1991; Burge et al., 1987; Cooper and Marshall, 1991; Lahav et al., 1989; Richardson and McAneney, 1990). In contrast, Xiloyannis (1997) found no effect of fruit thinning in young vines. Early thinning of *A. deliciosa* flowers and fruit had little effect on yield, yet improved fruit quality depending on thinning severity (Antognozzi et al., 1991; Lahav et al., 1989; Vasilakakis et al., 1997). Thinning before bloom or at an early stage of cell division has been shown to be most effective at increasing fruit size in *A. deliciosa* (Antognozzi et al., 1991; Lahav et al., 1989), perhaps by increasing carbohydrate supply per individual fruit and thus augmenting fruit cell division (Richardson et al., 1997).

In 'Hayward' kiwifruit, seed number has been shown to be directly correlated to fruit weight (Grant and Ryugo, 1984). Tiyayon and Strik (2003) reported a linear relationship between seed number and fruit weight in 'Ananasnaya' hardy kiwifruit. It is not known if flower thinning impacts seed number of remaining fruit in hardy kiwifruit.

The objectives of this study were to 1) determine the effect of severity of flower thinning on fruit growth and quality, and 2) ascertain the relationship between fruit weight and seed number in *A. arguta* 'Ananasnaya'.

Materials and Methods

This study was carried out in 1999 in a 5-year-old *A. arguta* 'Ananasnaya' commercial vineyard in Wilsonville, Ore. The vines were trained to a pergola system and spaced at 4.5 × 4.5 m. The vineyard had a between row sod cover crop and was drip irrigated. Male vines were situated diagonally opposite the female study vines in adjacent rows. Beehives were introduced into the vineyard during bloom, but there was also additional artificial supplemental pollination using a commercial dry applicator (*Actinidia deliciosa* pollen). The vines were not summer pruned, but were dormant pruned and otherwise maintained according to standard commercial practices (Strik, 2004).

Four treatments were studied: a nonthinned control and thinned by removing 15%, 30%, or 50% of flowers before bloom (2–5 June). The experimental design was completely random with four single-vine replications. The 16 vines used were selected during the dormant period for uniformity in bud number. Subsequent counts of shoot number per vine confirmed no differences among treatments.

Thinning was done by hand. To achieve the desired thinning severities, every other inflorescence was removed for 50 % thinning;

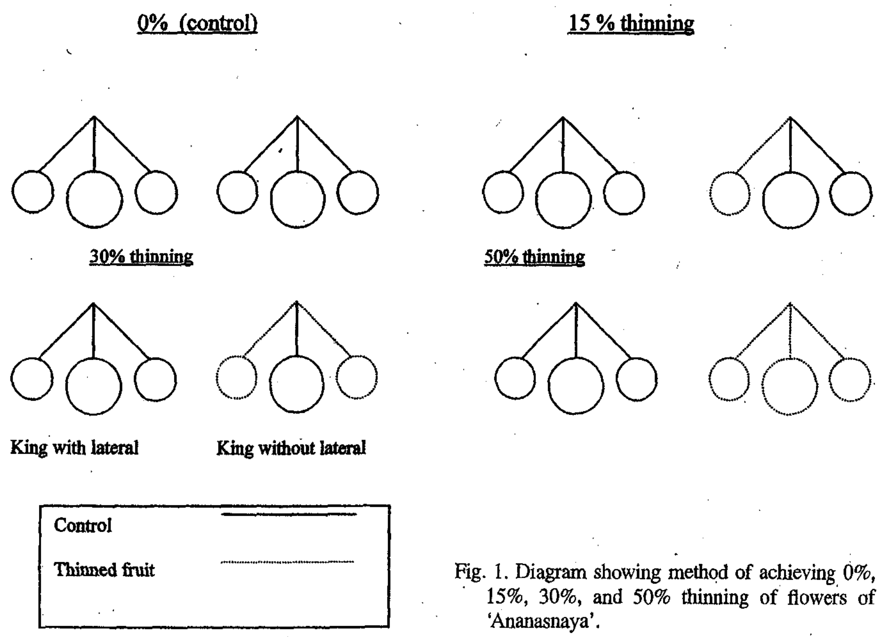

Fig. 1. Diagram showing method of achieving 0%, 15%, 30%, and 50% thinning of flowers of 'Ananasnaya'.

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Table 1. The effect of severity of flower thinning on yield and fruit quality of 'Ananasnaya' hardy kiwifruit in 1999.

Prebloom thinning (% removed)	Total yield (kg/vine)	Marketable yield (kg/vine)	Nonmarketable yield (kg/vine)	Fruit wt[z] (g)	Marketable fruit wt[y] (g)	King wt[x] (g)	Fruit vol[z] (cm^3)	King vol[x] (cm^3)	Soluble solids (%)
0	32.5 a[w]	27.2	3.8 a	6.03 b	6.9 c	6.1 b	4.4	4.3 b	15.1
15	31.3 a	26.4	3.5 a	6.86 a	7.4 bc	7.3 a	5.1	5.5 a	16.5
30	24.4 ab	20.9	2.7 ab	6.96 a	7.8 ab	7.2 a	5.3	5.5 a	15.4
50	18.7 b	16.2	1.6 b	7.14 a	8.3 a	7.3 a	5.2	5.4 a	15.5
Significance[v]	0.0372	0.074	0.039	0.015	0.016	0.040	0.061	0.025	0.27

[z]Average fruit volume and weight, 30 subsamples per vine, n = 4. $V = \pi L\,[(D1 + D2)/2]^2/6$.
[y]Average weight of 100 fruit per treatment vine, fruit diameter >12 mm.
[x]King fruit = center fruit in cluster, 20 subsamples per vine. n = 4
[w]Means followed by the same letter are not significantly different by protected LSD ($P \geq 0.05$).
[v]P values are adjusted and are from the analysis of covariance with flower number as the covariate.

two lateral flowers were removed from every other inflorescence for 30% thinning, and one lateral flower was removed from every other inflorescence for 15 % thinning (Fig. 1). The total number of flowers per vine was counted in the control vines. In the thinned vines, the number of flowers removed at thinning were counted and flowers left per vine were estimated.

Data on shoot number per vine (after bud break) and trunk diameter (at 15 cm) were collected. Fruit length (taken from the point of pedicel attachment to the end of the persistant stylar column) and diameter (in each of two directions) were measured biweekly during fruit development on each treatment vine as follows: 10 fruit in each position within the inflorescence (king with lateral, king without lateral and a lateral in an unthinned inflorescence) were subsampled per vine on each sample date (Fig. 1). At harvest, a subsample of 10 fruit in each inflorescence position per vine (Fig. 1) was collected and individual fruit fresh weight, percent soluble solids, seed number and seed dry weight measured. Fruit volume was calculated using the formula: $V = \pi L\,[(D1 + D2)/2]^2/6$, where L = length in mm, D1 and D2 are the two diameters (widest and narrowest directions at fruit midpoint; cm), and V= volume (cm^3).

Vines were harvested by hand on 5 Oct. 1999, when the average percent soluble solids reached commercial maturity. Total harvest per vine was weighed. Fruit were sorted into nonmarketable (<12 mm in diameter—a commercial standard—and overripe or soft fruit) and marketable (>12 mm), then counted and weighed by category. In addition, 100 marketable fruit were randomly subsampled and weighed for each vine and average weight of marketable fruit calculated. Two additional subsamples of 10 fruit per vine were collected to measure, in one subsample, fresh and dry weight and, in the second subsample, to determine percent soluble solids.

The seeds of 20 fruit (10 king fruit and 10 lateral fruit) from control vines and those thinned 50% were separated from the fruit pulp and dried (individually per fruit) at 16 °C until at a constant dry weight.

Data were subjected to analysis of variance (ANOVA) using SAS (SAS Inst., 1990). Initial flower number per vine, shoot number per vine, and trunk diameter were used as covariates. Linear regression was used to determine the relationship between thinning severity and yield, fruit volume and fruit weight.

Results and Discussion

There was a high variability in yield within treatments (among replications), especially in control vines. Yield variability amongst vines or reps was reduced by thinning (data not shown). Variability in vine performance has also been reported in *A. deliciosa* for yield and fruit size (Lai et al., 1989; Lawes et al., 1986; Woolley et al., 1988).

Shoot number per vine and trunk diameter were not effective covariates for yield or other variables. However, the initial number of flowers was an effective covariate to determine the effect of thinning severity on all variables except marketable fruit weight and percent soluble solids. The following results are presented with data analyzed using the number of flowers as a covariate.

The average yield per vine, percentage of marketable fruit (84%), and average marketable fruit weight on control vines (Table 1) were similar to those reported by Tiyayon and Strik (2003). Flower thinning vines by 50% reduced yield significantly from control vines and from those thinned 15% (Table 1). In *A. deliciosa,* Burge et al. (1987) found a significant reduction in yield (35%) in vines thinned 50% at full bloom. Lahav et al. (1989) reported the highest yield but lowest average fruit weight in control 'Hayward' vines. In our study, the response of vines to thinning severity was linear for yield ($y = 29.31x + 33.68$; $r^2 = 0.275$; $P = 0.0001$). Although thinning, on average, significantly reduced total yield, there was no significant effect on marketable yield ($P = 0.074$; Table 1). In general, thinning led to a reduction in nonmarketable yield or the quantity of fruit <12 mm in diameter (Table 1). There was no effect of thinning on the weight of overripe fruit ($P = 0.44$, data not shown).

There was a positive linear relationship between yield and fruit number per vine (Fig. 2; $y = 4.0976 + 0.0049\,x$; $r^2 = 0.9217$; $P = 0.0001$). However, as fruit number increased, average fruit weight decreased linearly (Fig. 2; $y = 7.3989 + 0.0003\,x$; $r^2 = 0.2981$; $P = 0.0441$). Tiyayon and Strik (2003) reported no effect of flower number in control vines on percent fruit set. The general relationships between fruit number and yield and fruit weight were similar to those found in *A. deliciosa* (Antognozzi et al., 1991; Burge et al., 1987; Cooper and Marshall, 1991; Lahav et al., 1989; Richardson and McAneney, 1990).

Thinning before bloom, on average, significantly increased marketable fruit weight (14%) and king fruit weight (19%) compared to control vines (Table 1). The highest fruit weight occurred in vines thinned 50%, which also had the lowest yield (Table 1). In *A. deliciosa*, Burge et al. (1987) reported a 5% and 14% increase in the mean fruit weight with 25% and 50% of the flowers removed, respectively. In 'Cox Orange Pippin' apple, thinning by 15%, 33%, and 53% resulted in 14%, 30%, and 19% fruit weight gain, respectively (Knight, 1980). Similar results were also found by Antognozzi et al. (1991) in *A. deliciosa*, where fruit thinning, regardless of

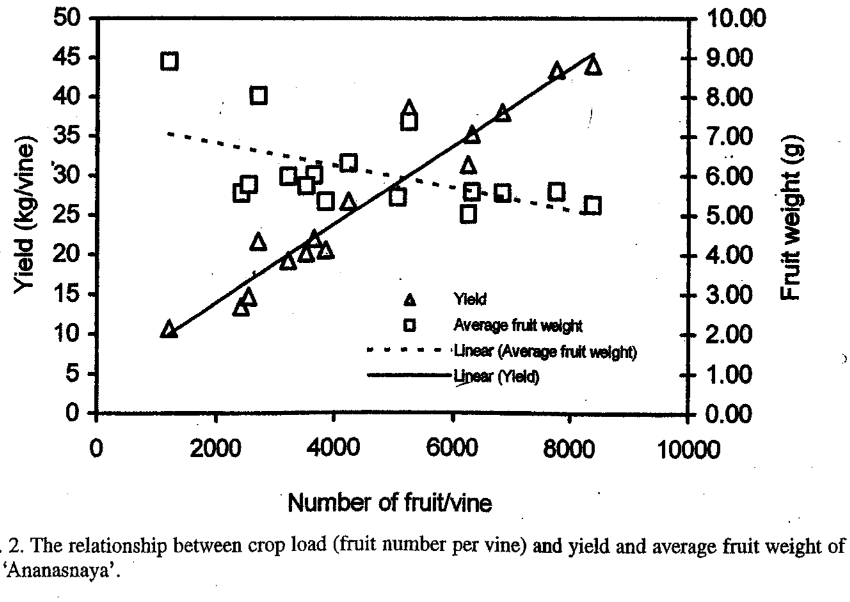

Fig. 2. The relationship between crop load (fruit number per vine) and yield and average fruit weight of 'Ananasnaya'.

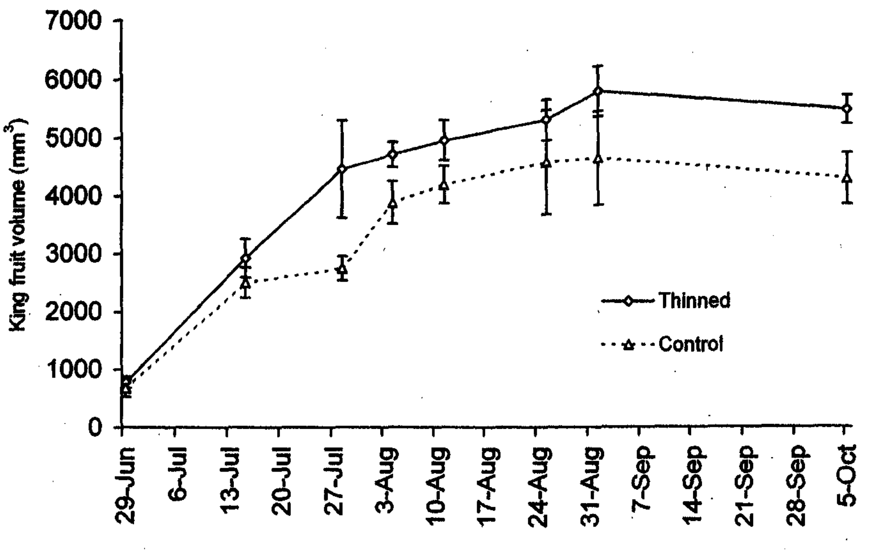

Fig. 3. Effect of flower thinning (average of 15 %, 30 %, and 50% thinning) on king fruit volume in 1999. Thinning was done on 2–5 June 1999. The bars represent ± SE of the mean, n = 4.

intensity and timing, had a positive effect upon fruit size, and thinning done at flower bud-swell stage improved fruit size more than that done after fruit set. Vasilakakis et al. (1997) also reported greater improvement in *A. deliciosa* fruit size with early thinning.

Thinning, increased average fruit volume (18%) and king fruit volume (27%; Table 1). In control vines, king fruit showed an initial phase (35 to 40 d after flowering) of rapid increase in fruit volume (Fig. 3). This was followed by a period of reduced growth, which may have coincided with seed hardening (from 35 to 50 d after flowering). Fruit thereafter increased in volume perhaps as a result of cellular expansion comparable with fruit development in *A. deliciosa* (Hopping, 1976). Fruit reached maximum size approximately one month prior to harvest (Fig. 3). In control vines, the initial phase of fruit growth appeared shorter in duration and the final fruit volume was less than in thinned vines.

Thinning severity did not significantly affect the weight or volume of fruit in the lateral position on the inflorescence (data not shown). In *A. deliciosa*, Davison and Sutton (1984) suggested that the lateral fruit in an inflorescence of three do not have the same capacity to size as does the terminal fruit, justifying in part the lack of sizing response of lateral fruit to thinning.

In *A. deliciosa*, the central (king) fruit is considered to be larger than the lateral fruit (Davison and Sutton, 1984). In this study in *A. arguta*, there was no significant difference between the volume of the king fruit (4.3 cm^3) and each of the two lateral fruit (4.5 cm^3) in control vines.

Thinning in many fruit crops results in earlier fruit maturity (for example: Reynolds, 1986, 1989; Samanci, 1997; Wells and Bukovac, 1978). In this study, there was no treatment effect on percent soluble solids of the fruit, a measure of fruit maturity (Table 1). This agrees with the results of Burge et al. (1987) on thinning of *A. deliciosa*.

At harvest, there was a positive correlation between percent soluble solids and fruit number per vine ($y = 14.84 + 0.0002$ x; $r^2 = 0.0991$; $P = 0.026$) and percent soluble solids and yield ($y = 14.64 + 0.031$ x; $r^2 = 0.1313$; $P = 0.018$). In contrast, a negative correlation between total soluble solids and yield has been reported in *A. deliciosa* (Samanci, 1997). Percent soluble solids was positively related to fruit size in 'Hayward' (Hopkirk et al., 1986; Richardson et al., 1997). In this study, there was a positive linear relationship between percent soluble solids and volume of the king fruit from whole inflorescences ($y = 12.48 + 0.0006$ x; $r^2 = 0.18$; $P = 0.0165$). However, there was no relationship between percent soluble solids and volume of lateral fruit or the king fruit with one or no laterals present (data not shown).

There was no significant thinning treatment effect on seed number or seed weight per fruit, agreeing with the findings of Lai et al. (1990) in *A. deliciosa*. Among the control and 50% thinned treatments, seed number per fruit ranged from 7 to 219, with a mean of 70 seeds and an average seed weight of 0.086 g. In *A. deliciosa*, assimilates are transported to fruit from vegetative and fruiting shoots, and are imported more strongly by fruits with a high seed number (Lawes et al., 1990). In this study, there was a quadratic relationship between fruit fresh weight and seed number, ($y = 1.34 + 0.69 x^2$; $r^2 = 0.69$; $P < 0.001$) and fruit weight and total seed weight ($y = 1.37 + 19.41 x^2$; $r^2 = 0.70$; $P = < 0.0001$). Tiyayon and Strik (2003) found a linear relationship between fruit weight and seed number per fruit. In their study, seed number per fruit averaged 151 and they had fewer fruit with a low seed number. A quadratic relationship between fruit weight and seed number has been reported in *A. deliciosa* (Lai et al., 1989, 1990; Vasilakakis et al., 1997). However, Lawes et al. (1990) found, within the same season, a linear, curvilinear and asymptotic relationship between fruit weight and seed dry weight depending on whether fruit from different single vines were assessed or fruit from many vines were pooled. They also found that mean seed weight tended to be higher at lower seed numbers per fruit. However, in this study, mean seed weight was not affected by seed number per fruit (data not shown).

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