Fruit Distribution and Early Thinning Intensity Influence Fruit Quality and Productivity of Peach and Nectarine Trees

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ABSTRACT. Peach [*Prunus persica* (L.) Batsch, Peach Group] tree productivity is improved if trees are thinned early, either in full bloom or when the fruit is recently set. Chemical thinning reduces the high cost of manual thinning and distributes the fruit irregularly on the shoots. The effect is similar to a late spring frost that mostly affects early flower buds on the tip of the shoot. To simulate frost damage (or chemical thinning) and evaluate the effect of fruit distribution on production, fruit growth of several peach cultivars—‘Catherine’, ‘Baby Gold 6’, ‘Baby Gold 7’, ‘O’Henry’, ‘Sudanel’ and ‘Miraflores’—and the nectarine [*Prunus persica* (L.) Batsch, Nectarine Group] ‘Queen Giant’ was studied in the central Ebro Valley (Spain) in 1999 and 2000. The factors investigated were the intensity of thinning and fruit distribution on the shoot (concentrated in the basal area or uniformly placed). The treatments were performed at 30 days after full bloom in 1999 and at bloom in 2000. For ‘Baby Gold 6’ and ‘Miraflores’ and when fruit load was high after thinning (over four fruit per shoot), a high concentration of fruit on the basal portion of the shoot had a negative influence on final yield and fruit size. The intensity of thinning (or simulated frost) greatly affected fruit diameter but was also strongly related to cultivar, tree size, and length of shoots. Thus, relationships between thinning intensity and fruit diameter varied, even among trees of the same cultivar.

Elimination of part of the potential production of peach and nectarine [*Prunus persica* (L.) Batsch] trees by thinning flowers or fruit is a common technique to increase fruit size and improve color and quality (Costa and Vizzotto, 2000). The effectiveness of the thinning increases with thinning intensity, although the response also depends on cultivar. Early ripening cultivars are more sensitive to the excess load than late-maturing ones and require more intense thinning (Costa and Vizzotto, 2000; Pavel and DeJong, 1993). The timing of thinning is also important. Many studies have shown that thinning during or soon after bloom increases final fruit size (Byers and Lyons 1984; Costa and Vizzotto 2000; Southwick et al., 1995), compared with late thinning (Pavel and DeJong, 1993). Nonetheless, in practice, thinning is not always performed early either for lack of manual labor, fear of late frosts or a high tendency for fruit of some cultivars to drop after fruit set (Blanco and Sociás, 1988).

Hand thinning is costly and takes between 100 to 500 h·ha⁻¹ depending on vigor and flower production, thinning intensity and season (Clanet et al., 1987; Hilaire and Guiauque, 1994; Southwick et al., 1996). In general, the cost of manual thinning is comparable to harvesting (Lichou et al., 1997). Chemical thinning agents can help reduce this cost. They can be either caustic agents used at bloom or other chemicals that reduce flower induction when applied the previous season. Several caustic agents, which partially destroy the flower buds or flowers by desiccation and reduce pollen or ovule viability have been tested (Byers and Lyons, 1985; Costa and Vizzotto, 2000; Myers et al., 1993; Southwick et al., 1996; Westwood, 1982). Flower induction can be decreased by applying gibberellic acid (GA) in the previous season, from one month after bloom until the beginning of autumn (Agustí et al., 1997; Byers et al., 1990; Southwick et al., 1995; Taylor and Geissler-Taylor, 1998). Since there is a gradient of flower buds opening from the apex to the base of each shoot (Corelli-Gappadelli and Coston, 1991; Spencer and Couvillon, 1975), flowers are usually thinned in a nonuniform manner. Caustic

products affect the most sensitive buds and gibberellic acid affects differentiating buds (Taylor and Geissler-Taylor, 1998).

Spring frosts may strongly reduce crops in many fruit growing regions. The damage caused by frost is similar to the effect of chemical thinning since it reduces the number of flowers or fruit, especially on the upper half of the shoots with the most sensitive buds or flowers (Byers et al., 1990). The remaining fruit are mostly concentrated at the base of the shoots.

Some researchers have studied the effect of fruit position on the shoot and fruit growth rate in peach. Marini and Sowers (1994) reported no differences in fruit size when they left three well distributed fruit per shoot, but when shoots were not thinned, the fruit left on the tip of the shoot were bigger than those left at the base. These same authors cite similar results by Blake et al. (1931) and Spencer and Couvillon (1975). On the other hand, Corelli-Gappadelli and Coston (1991) found that ‘Redglobe’ and ‘Redhaven’ peach fruit were smaller at the apical part of the shoot. An explanation for these contradictory results may be that Blake et al. (1931), Marini and Sowers (1994), and Spencer and Couvillon (1975) harvested all the fruit at the same time while Corelli-Gappadelli and Coston (1991) harvested the fruit at the same state of maturity. Thus, basal fruit (which generally ripen later), were harvested some time after those on the shoot’s tip. The effect of concentrating fruit in different areas of the shoot has not been studied in depth. Corelli-Gappadelli and Coston (1991) found that, under similar thinning intensities, ‘Redglobe’ and ‘Redhaven’ peach fruit were similar in size whether they were concentrated at the base or distributed uniformly, but were larger than those concentrated at the apical portion of the shoot. In this study we simulated damage caused by spring frost (or chemical thinning) and evaluated the effect of the intensity of manual thinning (or frost damage) and fruit distribution along the shoot on the yield of different cultivars that are widely grown in the Ebro Valley in Spain.

Materials and Methods

TREATMENTS. The research was conducted in 1999 and 2000 using commercial plots in full production in the townships of Tudela

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Table 1. Main agronomic characteristics (mean $\pm$ SD) of the plots and cultivars under study. Values for tree size, pruning level and shoot characteristics correspond to all trees in every plot ($n = 80$); values for fruit per shoot, fruit diameter and yield correspond to control trees ($n = 5$). Control trees were thinned uniformly at 50 d after full bloom (DAFB) for all cultivars except 'Miraflores' and 'Sudanell', for which the time is 80 DAFB.

Cultivar	Harvest			Pruning level ^y		Shoot characteristics ^y		Fruit/shoot (no.) ^x		Fruit	Fruit yield ^x	
	Year studied	date (DAFB)	PD ^z (m ² /tree)	Tree size ^y (cm ² TCA)	[shoots/ tree (no.)]	Length (cm)	Flower nodes (no.)	After thinning	At harvest	diam ^x (mm)	Fruit/ cm ² TCA	kg/tree
Queen Giant	1999	115	22	127.0 $\pm$ 13.3	162 $\pm$ 18.0	34.9 $\pm$ 5.4	9.9 $\pm$ 1.5	3.0 $\pm$ 0.6	2.6 $\pm$ 0.4	67.2 $\pm$ 7.3	3.7 $\pm$ 0.6	79.1 $\pm$ 12.8
	2000	117	24	190.4 $\pm$ 8.9	181 $\pm$ 14.2	42.4 $\pm$ 4.0	12.0 $\pm$ 1.2	2.9 $\pm$ 0.4	2.5 $\pm$ 0.3	65.5 $\pm$ 2.8	2.6 $\pm$ 0.4	75.3 $\pm$ 13.1
Catherine	2000	131	13	225.6 $\pm$ 12.5	120 $\pm$ 10.0	33.9 $\pm$ 3.3	13.1 $\pm$ 1.0	3.0 $\pm$ 0.2	2.5 $\pm$ 0.4	63.4 $\pm$ 1.5	1.4 $\pm$ 0.3	40.7 $\pm$ 7.3
Baby Gold 6	1999	143	22	113.0 $\pm$ 18.3	113 $\pm$ 19.5	30.4 $\pm$ 4.9	13.6 $\pm$ 2.1	3.9 $\pm$ 0.2	3.6 $\pm$ 0.4	57.4 $\pm$ 4.6	3.9 $\pm$ 0.4	46.3 $\pm$ 4.9
	2000	135	12	86.6 $\pm$ 14.0	76 $\pm$ 11.1	39.2 $\pm$ 5.0	13.7 $\pm$ 1.1	2.5 $\pm$ 0.5	2.3 $\pm$ 0.3	61.6 $\pm$ 2.0	2.2 $\pm$ 0.4	24.1 $\pm$ 4.4
Baby Gold 7	1999	143	24	227.0 $\pm$ 28.5	156 $\pm$ 28.4	42.2 $\pm$ 4.8	14.7 $\pm$ 1.8	3.2 $\pm$ 0.5	3.0 $\pm$ 0.5	73.1 $\pm$ 3.2	2.3 $\pm$ 0.3	105.5 $\pm$ 14.1
	2000	146	24	210.6 $\pm$ 22.4	101 $\pm$ 15.3	37.0 $\pm$ 3.4	13.0 $\pm$ 1.3	2.8 $\pm$ 0.3	2.1 $\pm$ 0.3	75.5 $\pm$ 1.4	1.1 $\pm$ 0.2	50.7 $\pm$ 13.2
O'Henry	1999	165	24	108.2 $\pm$ 19.4	157 $\pm$ 24.4	44.1 $\pm$ 4.8	13.6 $\pm$ 2.6	2.9 $\pm$ 0.2	2.8 $\pm$ 0.2	74.7 $\pm$ 6.6	4.5 $\pm$ 0.2	94.7 $\pm$ 4.8
	2000	165	22	147.5 $\pm$ 15.4	149 $\pm$ 19.6	39.5 $\pm$ 3.5	12.2 $\pm$ 0.8	2.8 $\pm$ 0.4	2.3 $\pm$ 0.5	74.9 $\pm$ 2.4	2.5 $\pm$ 0.3	76.3 $\pm$ 8.3
Sudanell	1999	160	22	123.0 $\pm$ 19.9	149 $\pm$ 31.2	40.1 $\pm$ 6.8	16.2 $\pm$ 3.1	3.2 $\pm$ 0.4	2.7 $\pm$ 0.5	64.7 $\pm$ 4.9	3.6 $\pm$ 0.6	64.9 $\pm$ 10.5
Miraflores	1999	193	22	107.0 $\pm$ 9.3	145 $\pm$ 29.6	31.2 $\pm$ 8.8	12.0 $\pm$ 4.3	3.8 $\pm$ 0.2	3.4 $\pm$ 0.5	69.6 $\pm$ 4.8	5.0 $\pm$ 0.8	82.8 $\pm$ 13.1
	2000	173	24	128.7 $\pm$ 8.2	145 $\pm$ 37.2	45.3 $\pm$ 3.6	15.4 $\pm$ 1.4	2.6 $\pm$ 0.4	2.2 $\pm$ 0.4	71.4 $\pm$ 2.9	2.7 $\pm$ 1.3	60.1 $\pm$ 17.5

^zPD = planting density.

^yAverages of all the trees used in the study ($n = 80$), for each cultivar.

^xAverage values for control trees ($n = 5$), which are those that were thinned uniformly at the usual time for the Ebro Valley area (50 DAFB for all cultivars except 'Miraflores' and 'Sudanell', for which it is 80 DAFB). Averages obtained taking into account every shoot in the tree.

and Alfaro, both in the central Ebro Valley (lat. 42.04°N long. 1.36°W, altitude 264 m). Clingstone peach cultivars Catherine, Baby Gold 6, Baby Gold 7, Sudanell and Miraflores were studied, as well as freestone peach cultivar O'Henry and the nectarine cultivar Queen Giant. A different plot was used for each cultivar and year, for a total of 12 plots used (Table 1), as the study was performed only one year for cultivars Catherine (2000) and Sudanell (1999). In each plot trees of similar vigor and pruning level (number of shoots per tree) were chosen.

The experimental design was completely random, studying two main variables: namely, fruit load and fruit distribution on the shoot. In 1999, manual thinning ^a30 days after full bloom (DAFB), between the stages 'jacket stage' and 'jacket split' was performed (Strand, 1999) and, for fruit load treatments, three, four or five fruit were left per shoot. In 2000, manual thinning at full bloom was performed, and for fruit treatments, two, three, four, five or six nodes with flowers were left per shoot. The 2000 treatments were checked in the jacket split stage so that there was at most one fruit per node. Fruit distribution treatments in both 1999 and 2000 consisted of fruit left at those nodes closest to the basal end of the shoot (basal distribution) and fruit left uniformly distributed along the shoot (uniform distribution). Each combination of fruit load and fruit distribution was performed on every shoot on the tree and replicated over five trees for each cultivar/plot combination. Five control trees per cultivar/plot combination were also chosen, picking specimens whose vigor was similar to that of experimental ones and hand thinning them 80 DAFB for 'Miraflores' and 'Sudanell' and 50 to 60 DAFB for the other cultivars. Fruit was distributed evenly over each shoot, for control trees. Thinning dates and crop density for control trees (Table 1) are common ones for commercial production of these cultivars in the central Ebro Valley.

DATA COLLECTION. At 30 DAFB, for basal treatments, the length of shoot occupied by fruit (length from insertion of the shoot in the branch to the most distal fruit) was measured on 15 shoots and in each one of five trees per cultivar, thus estimating separation between fruit on the shoot and the proportion of total shoot length occupied by fruit. At 50 DAFB (80 DAFB for 'Miraflores' and 'Sudanell'), 15 shoots per tree were tagged, and fruit number per

shoot was counted, for each treatment and the control. At harvest, this procedure was repeated and the diameter of the fruit on the same tagged shoots was also measured. The tagged shoots of each tree were located on one main branch to represent all positions (interior, exterior, superior, and inferior) proportional to their occurrence on the trees. Fruit were harvested when the firmness of the greenest part of the skin was 4.5 to 5 kg·cm⁻² for freestone and nectarine cultivars and 6 to 6.5 kg·cm⁻² for clingstones (Alavoine et al, 1988). To determine the weight of the fruit that were inspected for diameter, 100 fruit at the indicated state of maturity were chosen randomly and their diameters and weights were measured. After a series of inspections, crop density (no. of fruit/cm² trunk cross-sectional area, TCA), total shoot length per trunk cross-section (shoot m·cm⁻² TCA), fruit drop, production of the shoots, fruit diameter, and the marketable production, as the proportion of fruit with a diameter >56 mm (the minimum to be considered in the category of "extra", according to CEE directive 3596/90, Ministerio de Agricultura, Pesca y Alimentación, 1995), were estimated.

STATISTICAL ANALYSIS. Data were subjected to analysis of variance followed by Duncan's multiple range test by means of the SPSS (SPSS Inc., Chicago, Ill.) GLM procedure, where percentage values were arc-sin-transformed before statistical analysis. The data taken from shoots were averaged within each replication (tree) before being subjected to analysis of variance. When the interaction of distribution $\times$ fruit load was significant, each treatment combination was analyzed separately. To determine the weights of the fruit a regression analysis was performed between the diameters and the weights of 100 fruit samples by fitting curvilinear estimation models with the Curvilinear Regression Procedure of SPSS. The relationship between fruit diameter and crop density was determined with the Linear Regression Procedure of SPSS for each cultivar/crop combination. A multiple regression model was evaluated; its dependent variable was fruit diameter and independent ones were crop density, total shoot length per TCA and number of days between bloom and harvest. Data from all the different cultivars and plots were combined for this regression. Finally, for each plot the basal-distribution thinning rate which produced a yield similar to that of control samples was calculated. For this calculation, yield of those

Table 2. Analysis of variance for the proportion of the shoot length occupied by fruit [LEN (%), percentage of total shoot length] and the separation between fruit on the shoot [FSEP (cm)] at 30 d after full bloom (DAFB) for basal distribution treatments.

Year 2000 treatments			Year 1999 treatments		
Factor	LEN (%) ^z	FSEP (cm)	Factor	LEN (%)	FSEP (cm)
Fruit load (INT) ^y			Fruit load (INT)		
2	27.13 c ^x	6.08 a	3	40.41 c	5.64 a
3	33.19 b	5.08 b	4	53.05 b	5.28 ab
4	35.19 b	3.99 c	5	65.68 a	4.96 b
5	46.66 a	4.45 c			
6	49.52 a	3.92 c			
Cultivar			Cultivar		
Queen Giant	44.93 a	5.63 a	Queen Giant	60.65 b	5.31 b
Catherine	34.71 b	3.98 d	Baby Gold 6	58.70 b	4.47 b
Baby Gold 6	41.81 a	5.09 ab	Baby Gold 7	40.75 d	4.32 b
Baby Gold 7	37.56 b	4.46 bc	O'Henry	44.11 c	4.87 b
O'Henry	35.71 b	4.24 c	Sudanell	49.31 c	4.95 b
Miraflores	34.22 b	4.77 bc	Miraflores	64.77 a	7.82 a
Significance			Significance		
INT	***	***	INT	***	*
Cultivar	***	***	Cultivar	***	***
INT × cultivar	NS	NS	INT × cultivar	NS	NS

^zRatio between distance from shoot insertion to the most distal fruit in the shoot and total shoot length.

^yINT = number of flower nodes per shoot left at thinning (2000) or number of fruit per shoot left at thinning (1999).

^xMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

treatments with fruit concentrated at the base and control trees yield (all yields in g/shoot) were subjected to analysis of variance followed by Duncan's multiple range test by means of the SPSS GLM procedure.

Results and Discussion

FRUIT DISTRIBUTION AFTER BASAL THINNING. At similar fruit loads, the separation between fruit on the shoot depended on shoot length, separation between nodes, and on the number of flowers on the shoot. At low fruit loads, fruit at the base occupied 30% of the total shoot length, while at intermediate loads, fruit occupied 30% to 40% of the shoot length (Table 2). When more than four fruit were left

on the shoot, they occupied as much as 60% of the shoot length. At similar fruit loads left at thinning, fruit on 'Catherine' was the most concentrated, separated by 4 cm, while 'Miraflores' fruit (1999 treatments) was separated by 8 cm. The rest of the cultivars averaged 5 cm separation between fruit on a shoot.

EFFECT OF FRUIT DISTRIBUTION. There was no interaction between fruit distribution and fruit load on fruit drop. More fruit drop were recorded in 'Catherine' (Table 3) when the fruit were concentrated at the base, but this was not the case with the other cultivars. This seems contradictory since concentrating fruit in a reduced space should increase fruit drop as their short stem makes it difficult for them to stay on the shoot. This was observed only in 'Catherine' because the fruit were concentrated in a lower proportion of the

Table 3. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 50 d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and % fruit > 56 mm diameter, and yield/shoot on 'Catherine' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop (%)	Fruit diam (mm)	Fruit >56 mm (%)	Yield/shoot (g)
			50 DAFB	Harvest				
2000	DIS	B ^z	3.1	2.4 b	22.4 a	67.6	95.0	343.6
		U	3.1	2.7 a	14.8 b	66.5	93.1	372.5
	INT	2 ^y	1.7 e ^x	1.3 d	20.9	72.0 a	99.1 a	234.9 d
		3	2.5 d	2.1 c	15.2	68.3 b	97.8 ab	320.8 c
		4	3.3 c	2.8 b	17.2	66.2 b	95.6 bc	396.8 b
		5	4.0 b	3.0 b	24.3	65.5 b	92.0 c	407.2 ab
		6	4.6 a	3.8 a	16.1	61.9 c	83.1 d	460.8 a
	DIS		NS	*	*	NS	NS	NS
	INT		***	***	NS	**	**	**
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of nodes with flowers left per shoot at bloom.

^xMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

shoot and were closer together than in the other cultivars (Table 2). From these results it can be deduced that basal fruit concentration did not affect drops if the distance between fruit was at least 5 to 6 cm.

There was no interaction between fruit distribution and fruit load on fruit diameter or diameter distribution in any cultivar except 'Baby Gold 6' and 'Miraflores' (both in 1999, Tables 4 and 5, respectively). For 'Baby Gold 6' in 1999 (Table 4), at the lower fruit load (three fruit per shoot treatments), the diameter was similar in both distributions but the proportion >56 mm diameter was significantly more when concentrated at the base. There were no differences at intermediate fruit load (four fruit per shoot treatments), but at higher fruit loads, basal fruit were smaller, mostly <56 mm in diameter. For 'Miraflores' in 1999 (Table 5) the situation was similar. At higher fruit load, fruit were larger when distributed homogeneously along the shoot (but always >56 mm in diameter). Fruit from 'Queen Giant' (Table 6), 'O'Henry' (Table 7) and 'Baby Gold 7' (Table 8) had greater diameter in both years when they were concentrated at the base.

Concentrating fruit at the base delayed maturity 2 to 5 d, depending on the cultivar (data not presented). Fruit continued to grow in the last stages of maturation (Blake et al., 1931, as cited by Marini and Sowers, 1994), increasing by as much as 3% in early cultivars and 1% in later ones (personal observation). This could explain why our results agree with Corelli-Grapadelli and Coston (1991) who studied 'Redglobe' and 'Redhaven' peach.

They concentrated fruit at the base and middle of the shoot and harvested at the same stage of maturity and found that fruit were similar or larger than when distributed uniformly. Opposite results were reported by Spencer and Couvillon (1975) who, after harvesting 'Sullivan's Elberta' on the same date, found smaller fruit at the base.

There was no interaction between fruit distribution and fruit load on shoot production in any cultivar except 'Baby Gold 6' and 'Miraflores' in 1999. For 'Baby Gold 6' (1999) and 'Miraflores' (1999), shoots with five fruit left were more productive when the fruit were distributed uniformly along the shoot, whereas in treatments with three or four fruit left, yields for uniform and basal distributions were similar. Shoot production in 'Baby Gold 6' (2000), 'Queen Giant', and 'Baby Gold 7' (1999) (Tables 4, 6, and 8, respectively) was higher when fruit were concentrated at the base.

In general, fruit distribution on the shoot had little or no influence over either final diameter or yield. Nevertheless, for 'Baby Gold 6' and 'Miraflores', diameter and yield were negatively affected by excess fruit concentration if a high fruit load was left after thinning (over five fruit per shoot).

EFFECT OF THINNING INTENSITY. More fruit dropped when fruit load was high in 'Miraflores' in 2000 (Table 5), 'Baby Gold 7' in 2000 (Table 8) and 'Sudanell' (Table 9), whereas in the other cultivars fruit load did not affect fruit drop. For 'Queen Giant', 'O'Henry', 'Baby Gold 6', and 'Baby Gold 7' (1999) about 10%

Table 4. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 50d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and % fruit > 56 mm diameter, and yield/shoot on 'Baby Gold 6' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop (%)	Fruit diam (mm)	Fruit >56 mm (%)	Yield/shoot (g)
			50 DAFB	Harvest				
1999	DIS	B ^z	3.7	3.2	12.1	58.4	68.9	334.5
		U	3.6	3.1	14.2	60.5	77.8	360.4
	INT	3 ^y	2.5 c ^w	2.1 c	14.2	62.7 a	85.0 a	276.8 b
		4	3.8 b	3.2 b	15.3	61.1 a	88.3 a	385.3 a
		5	4.5 a	4.1 a	9.9	54.6 b	46.7 b	380.3 a
		3B				63.8 a	93.3 a	288.4 c
		3U				61.5 ab	76.7 b	265.3 c
		4B				61.5 ab	90.0 a	387.4 ab
		4U				60.6 b	86.7 ab	383.1 ab
		5B				49.9 c	23.3 c	327.7 a
		5U				59.3 b	70.0 b	432.9 bc
	DIS		NS	NS	NS	NS	NS	NS
	INT		***	***	NS	***	***	***
	INT × DIS		NS	NS	NS	***	**	*
2000	DIS	B	3.1	2.9	4.9	65.4	93.4	428.0 a
		U	2.9	2.7	6.7	64.4	91.6	382.3 b
	INT	2 ^x	1.6 d	1.5 d	7.8	67.5 a	99.2 a	240.2 d
		3	2.3 c	2.2 c	3.7	66.4 a	96.6 ab	347.1 c
		4	3.1 b	2.9 b	5.2	65.2 ab	92.2 bc	430.1 b
		5	3.9 a	3.8 a	2.0	62.0 c	85.9 c	494.8 a
		6	4.2 a	3.7 a	10.3	63.5 bc	88.6 c	513.4 a
	DIS		NS	NS	NS	NS	NS	*
	INT		***	***	NS	***	***	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xNumber of nodes with flowers left per shoot at bloom.

^wMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 5. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 80d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and % fruit > 56 mm diameter, and yield/shoot on 'Miraflores' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop (%)	Fruit diam (mm)	Fruit >56 mm (%)	Yield/ shoot (g)
			80 DAFB	Harvest				
1999	DIS	B ^z	3.2 a ^w	2.6	18.9	69.1	100.0	397.8 b
		U	3.9 b	3.1	19.2	70.5	100.0	511.7 a
	INT	3 ^y	2.3 c	1.9 c	17.1	74.8 a	100.0	365.8 b
		4	3.5 b	2.9 b	17.3	68.5 b	100.0	453.3 ab
		5	4.9 a	3.8 a	22.8	66.1 c	100.0	545.2 a
		3B				75.5 a		358.2 b
		3U				74.1 a		373.5 b
		4B				68.2 b		444.4 b
		4U				68.8 b		462.2 b
		5B				63.7 c		390.8 b
		5U				68.6 b		699.6 a
	DIS		*	NS	NS	NS	NS	*
	INT		***	***	NS	***	NS	**
	INT × DIS		NS	NS	NS	**	NS	*
2000	DIS	B	2.1	1.4	28.8	74.2	99.3	261.3
		U	2.0	1.5	19.5	73.4	100.0	274.3
	INT	2 ^x	1.1 d	0.9 d	11.6 b	75.4 a	100.0	178.6 d
		3	1.6 c	1.3 c	18.4 ab	73.2 b	99.3	235.0 c
		4	2.2 b	1.3 c	36.1 a	74.5 ab	100.0	242.8 c
		5	2.4 b	1.7 b	27.2 a	72.9 b	100.0	304.8 b
		6	3.0 a	2.1 a	27.4 a	73.1 b	99.0	377.9 a
	DIS		NS	NS	NS	NS	NS	NS
	INT		***	***	*	*	NS	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xNumber of nodes with flowers left per shoot at bloom.

^wMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 6. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 50 d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and percentage of fruit >56 mm diameter, and yield/shoot on 'Queen Giant' nectarine.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop (%)	Fruit diam (mm)	Fruit >56 mm (%)	Yield/ shoot (g)
			50 DAFB	Harvest				
1999	DIS	B ^z	2.9	2.5	13.7	63.2 a	82.2	366.9 a
		U	2.7	2.4	9.8	60.9 b	83.3	324.4 b
	INT	3 ^y	2.1 c ^w	1.9 b	10.5	65.5 a	98.3 a	300.5 b
		4	2.9 b	2.7 a	9.1	61.1 b	80.0 b	366.4 a
		5	3.4 a	2.9 a	15.6	59.5 b	70.0 c	370.1 a
	DIS		NS	NS	NS	*	NS	*
	INT		***	***	NS	***	***	*
	DIS × INT		NS	NS	NS	NS	NS	NS
2000	DIS	B	3.0	2.6	11.7	65.3 a	84.7	375.9
		U	3.1	2.8	8.1	63.0 b	81.1	360.4
	INT	2 ^x	1.7 e	1.4 e	13.1	69.1 a	98.6 a	247.2 c
		3	2.3 d	2.1 d	9.5	66.7 ab	91.8 ab	328.5 b
		4	2.8 c	2.6 c	7.1	64.7 b	84.7 bc	370.3 b
		5	4.0 b	3.5 b	11.6	61.5 c	74.5 cd	446.5 a
		6	4.4 a	4.0 a	8.1	58.7 c	64.9 d	448.3 a
	DIS		NS	NS	NS	**	NS	NS
	INT		***	***	NS	***	***	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xNumber of nodes with flowers left per shoot at bloom.

^wMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 7. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 50d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and % fruit > 56 mm diameter, and yield/shoot on 'O'Henry' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop	Fruit diam	Fruit >56 mm	Yield/shoot
			50 DAFB	Harvest	(%)	(mm)	(%)	(g)
1999	DIS	B ^z	3.1	2.6	14.5	80.4 a	100.0	619.0
		U	2.8	2.6	9.5	77.3 b	100.0	545.8
	INT	3 ^y	2.5 b ^w	2.2 b	11.5	82.4 a	100.0	553.3
		4	2.7 b	2.4 b	12.5	78.6 b	100.0	540.9
		5	3.7 a	3.2 a	12.0	75.6 c	100.0	653.1
	DIS		NS	NS	NS	***	NS	NS
	INT		***	***	NS	***	NS	NS
	INT × DIS		NS	NS	NS	NS	NS	NS
	DIS	B	2.4	2.1	10.9	78.3 a	97.1	479.3
		U	2.5	2.2	10.0	75.0 b	94.2	468.0
2000	INT	2 ^x	1.4 e	1.4 d	3.2	82.3 a	100.0 a	377.9 c
		3	2.0 d	1.8 c	8.9	77.4 b	97.0 ab	423.6 bc
		4	2.5 c	2.0 c	16.1	77.3 b	96.1 abc	460.3 b
		5	2.9 b	2.6 b	10.0	75.4 b	94.1 bc	553.1 a
		6	3.6 a	3.0 a	14.1	70.9 c	91.1 c	553.4 a
	DIS		NS	NS	NS	***	NS	NS
	INT		***	***	NS	***	**	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xNumber of nodes with flowers left per shoot at bloom.

^wMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 8. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 50 d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and % fruit > 56 mm diameter, and yield/shoot on 'Baby Gold 7' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop	Fruit diam	Fruit >56 mm	Yield/shoot
			50 DAFB	Harvest	(%)	(mm)	(%)	(g)
1999	DIS	B ^z	2.6 a ^w	2.2	12.5	77.2 a	100.0	518.0 a
		U	2.2 b	2.0	9.6	73.1 b	100.0	409.8 b
	INT	4 ^y	2.1 b	1.9 b	7.9	73.9	100.0	407.0 b
		5	2.7 a	2.3 a	14.2	76.3	100.0	520.8 a
	DIS		*	NS	NS	*	NS	**
	INT		***	*	NS	NS	NS	**
	INT × DIS		NS	NS	NS	NS	NS	NS
2000	DIS	B	2.9	2.1	25.1	77.8 a	100.0	502.9
		U	2.9	2.1	23.4	74.9 b	100.0	455.6
	INT	2 ^x	1.5 d	1.3 d	14.7 b	77.4	100.0	298.7 d
		3	2.3 c	1.8 c	18.5 ab	77.5	100.0	430.9 c
		4	2.9 b	2.2 bc	24.4 ab	76.3	100.0	503.0 bc
		5	3.9 a	2.6 ab	32.9 a	75.2	100.0	566.9 ab
		6	4.1 a	2.7 a	31.8 a	75.5	100.0	608.0 a
	DIS		NS	NS	NS	**	NS	NS
	INT		***	***	*	NS	NS	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xNumber of nodes with flowers left per shoot at bloom.

^wMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 9. Analysis of variance for effects of fruit distribution (DIS) and fruit load (INT) on fruit number/shoot at 80 d after full bloom (DAFB) and harvest, fruit drop, fruit diameter and percentage of fruit >56 mm diameter, and yield/shoot on 'Sudanell' peach.

Year	Factor	Treatment	Fruit/shoot (no.)		Fruit drop	Fruit diam	Fruit >56 mm	Yield/shoot
			80 DAFB	Harvest	(%)	(mm)	(%)	(g)
1999	DIS	B ^z	3.3	2.3	28.0	69.2	100.0	392.0
		U	3.3	2.5	24.8	68.4	100.0	416.4
	INT	3 ^y	2.1 c ^x	1.7 c	20.3 b	69.2 a	100.0	289.3 b
		4	3.2 b	2.4 b	25.3 ab	70.0 a	100.0	429.0 a
		5	4.6 a	3.1 a	33.7 a	67.2 b	100.0	494.2 a
	DIS		NS	NS	NS	NS	NS	NS
	INT		***	***	*	*	NS	***
	INT × DIS		NS	NS	NS	NS	NS	NS

^zBasal (B) or uniform (U) distribution of the fruit on the shoot.

^yNumber of fruit left per shoot at 30 DAFB.

^xMeans in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects or interactions that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 10. Relationships between crop density (x, fruit/cm² TCA) and fruit diameter (y, mm) in the trees tested.

Cultivar	Year	Fruit distribution ^z	y = b ₀ + b ₁ x		R ²
			b ₀	b ₁	
Queen Giant	1999	BU	70.44 cd ^{***y}	-2.42 ab ^{***}	0.41 ^{***}
	2000	BU	74.40 bc ^{***}	-3.97 abc ^{***}	0.73 ^{***}
Catherine	2000	BU	73.57 bc ^{***}	-4.55 a ^{***}	0.44 ^{***}
Baby Gold 6	1999	B	75.50 b ^{***}	-4.85 a ^{***}	0.73 ^{***}
		U	63.01 d ^{***}	-0.74 d ^{***}	0.62 ^{***}
	2000	BU	70.57 cd ^{***}	-2.15 bc ^{***}	0.39 ^{***}
Baby Gold 7	1999	BU	74.58 bc ^{***}	0.34 d ^{NS}	0.03 ^{NS}
	2000	BU	79.49 ab ^{***}	-2.80 abc [*]	0.14 ^{**}
O'Henry	1999	BU	93.89 a ^{***}	-4.27 a ^{***}	0.69 ^{***}
	2000	BU	85.78 ab ^{***}	-3.71 abc ^{***}	0.51 ^{***}
Sudanell	1999	BU	71.95 bcd ^{***}	-0.99 d [*]	0.19 [*]
Miraflores	1999	B	77.24 ab ^{***}	-2.09 bcd [*]	0.36 [*]
		U	75.21 bc ^{***}	-1.01 d ^{**}	0.52 ^{**}
	2000	BU	76.05 ab ^{***}	-1.26 d [*]	0.15 ^{**}

^zBU = data from basal and uniform distributions were pooled when no significant interaction between fruit load and distribution appeared, otherwise basal (B) or uniform (U) distribution were taken separately.

^yCoefficients in columns followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Equation coefficients or regression that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Table 11. Analysis of variance for effect of basal distribution on yield per shoot. Control trees' shoots were uniformly thinned at 50 d after full bloom (DAFB) (80 DAFB for 'Miraflores' and 'Sudanell').

Year	Cultivar	Yield/shoot (g)					Control
		2 ^z	3	4	5	6	
1999	Queen Giant		320 b ^y	390 ab	390 ab		440 a [*]
	Baby Gold 6		290 b	390 a	330 ab		370 a [*]
	Baby Gold 7		440 b	590 a			610 a [*]
	O'Henry		580	580	690		550 ^{NS}
	Sudanell		280 b	400 a	490 a		400 a ^{**}
	Miraflores		390	440	390		520 ^{NS}
2000	Queen Giant	264 c	333 bc	361 b	460 a	470 a	379 b ^{***}
	Catherine	234 d	291 cd	362 b	430 a	436 a	309 bc ^{***}
	Baby Gold 6	269 d	359 c	451 b	489 b	572 a	288 d ^{***}
	Baby Gold 7	337 d	420 cd	506 bc	582 ab	669 a	459 c ^{***}
	O'Henry	379 b	447 b	415 b	565 a	590 a	460 b ^{***}
	Miraflores	174 c	232 bc	239 bc	308 ab	353 a	375 a ^{***}

^zNumber of fruit left at 30 DAFB (1999) or number of flower nodes left at bloom (2000).

^yMeans in rows followed by different letters are significantly different at $P < 0.05$ (Duncan's multiple range test).

NS, *, **, *** Factor effects that are nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

fruit drop occurred, while in 'Catherine', 'Sudanell' and 'Miraflores', fruit drop varied between 12% and 36%. Drop intensity appeared to depend more on cultivar than on the amount of fruit left after thinning.

As expected, there was a positive relationship between fruit load and final fruit diameter for all cultivars. Table 10 summarizes results of the regression analysis of these relationships for each cultivar and year of study. Except for 'Baby Gold 7' in 1999, the linear relationship was significant but the slope depended on the cultivar. Fruit diameters of 'Queen Giant', 'Catherine', 'Baby Gold 7' in 2000, and 'O'Henry' were much more sensitive to fruit load than other cultivars. For 'Baby Gold 6' in 1999, the slope for the relationship between crop load and fruit diameter was much steeper for basally distributed fruit than for uniformly distributed fruit.

Many researchers have reported a negative relationship between fruit load and fruit size in plots with homogeneous trees (i.e., similar tree size and pruning level) (Blanco et al. 1995; Johnson and Handley, 1989; Marini and Sowers, 1994; Pavel and DeJong, 1993; Rowe and Johnson, 1992; Westwood, 1982). Cultivar also influences this relationship. Johnson and Handley (1989) and Pavel and DeJong (1993) reported that early ripening cultivars are more sensitive to excess load than late ripening cultivars. Our results are similar although 'O'Henry', which is a mid season ripening cultivar, was just as sensitive as earlier ripening cultivars. Similarly, Pavel and DeJong (1993) found that 'O'Henry' is more sensitive to fruit load than 'May Crest', 'June Lady' and 'Elegant lady', which are earlier ripening cultivars. As concluded by Grossman and DeJong (1995), the response of a cultivar does depends not only on precocity but also on other internal factors of the fruit, such as the demand capacity for photoassimilates.

Since fruit load explains only between 3% and 73% of the variability in fruit diameter, other factors must influence diameter, as indicated by Faust (1989). These factors include available photoassimilates and their distribution between vegetative and reproductive structures, i.e., tree size and the leaf per fruit ratio (Costa and Vizzotto, 2000; Faust, 1989; Pavel and DeJong, 1993). Using our data, a mathematical relationship was established between fruit diameter (as the independent variable), and precocity (expressed in days elapsed from full bloom to harvest), pruning load (expressed as the total length of tree shoots per TCA) and crop density (expressed as the total number of fruit on the tree per TCA), as the dependent variables. The following formula was obtained: $\text{diameter (mm)} = 48.84 + 8.34 \times \text{pruning load} - 3.16 \times \text{crop density} + 0.17 \times \text{days bloom-harvest}$ ($R^2 = 0.55$ $P < 0.001$), all with significant coefficients. Fruit diameter for a specific tree size was higher when there was greater shoot length (pruning load) for a late-maturing cultivar and it decreased if more fruit were left. This relationship may be a useful tool to determine the thinning intensity needed to obtain desired fruit size. Our data indicate that yield increased if more fruit were left on the trees but the relationship between fruit number and yield was conditioned by the influence of the thinning intensity on fruit drop during the season and on the diameter of fruit that are harvested.

MINIMAL NUMBER OF FRUIT REQUIRED FOR COMMERCIAL PRODUCTION AFTER EARLY BASAL THINNING. For each cultivar and year, calculations were performed to find what thinning intensity for basally distributed fruit produced the same yield as the control samples (Table 11). The results were similar when thinning was performed 30 DAFB (1999 treatments) or in full bloom (2000 treatments); when three to four fruit were left (or three to four

nodes with flower), the production was the same as in control trees. In addition, fruit diameter was similar or higher as fruit on shoots which had been uniformly thinned (data not presented). In other words, production did not decrease if the number of nodes with flowers or the number of fruit 30 DAFB was at least 30% more than in the normal thinning season. 'Miraflores' was an exception to this. To achieve normal yield with this cultivar, the number of flower nodes that had to be left when thinning during bloom was twice as high as the amount of fruit required when thinning 30 DAFB. This result is explained in part by the high tendency of drops in this cultivar, which increased with early thinning. For thinning at 80 DAFB, fruit drop was about 15%. When four fruit per shoot were left 30 DAFB (1999 treatments), about 27% abscised. When five nodes with flower were left (2000 treatments), about 68% of the nodes did not bear fruit at harvest. This higher tendency to abscise with early thinning was also reported by Blanco and Sociás (1988) in 'Sudanell'. This should be taken into account when estimating the convenience of early thinning in this cultivar.

In conclusion, when thinning of peach fruit takes place between bloom and 30 DAFB and if less than four to five fruit per shoot are left, the concentration of fruit at the base of the shoot does not seem to decrease fruit yield or fruit diameter. Nevertheless, when thinning intensity is low, an excessive concentration of basal fruit can negatively affect diameter and final production in certain cultivars. To a large degree, the desired fruit diameter determines thinning intensity, but it is also related to cultivar, tree size and total shoot length.

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