Journal of Horticultural Science & Biotechnology (2009) **84** (5) 505–509

Effects of crop load and time of thinning on the incidence of split pits, fruit yield, fruit quality, and leaf mineral contents in 'Andross' peach

By P. D. DROGOUDI*, C. G. TSIPOURIDIS and G. PANTELIDIS
Pomology Institute, National Agricultural Research Foundation, P.O. Box 122, 38 R.R. Station, 59200 Naoussa, Greece
(e-mail: drogoudi@otenet.gr)
(*Accepted 4 April 2009*)

SUMMARY
The effects of light, moderate, or heavy thinning (5, 10, or 20 cm between fruit, respectively), conducted before (7 d or 15 d), during, or after (7 d or 15 d) pit hardening (PH), on the incidence of split pits, fruit yield, fruit quality characteristics, and leaf mineral contents, were studied in the canning peach (*Prunus persica* L. Batsch.) cultivar 'Andross' over two growing seasons. The percentage of fruit with split pits increased by 58.2% in heavily-thinned trees compared with moderately- or lightly-thinned trees, and by 22.9% for the earliest time of thinning (15 d before PH) compared with thinning during, or after PH. Fruit fresh weight (FW) was greater in moderately- and heavily-thinned trees compared with lightly-thinned trees, but yields were similar among the different crop-load treatments. The latest time of thinning (15 d after PH) also had a negative impact on yield at first harvest and on total yield, fruit FW, and delayed fruit ripening compared to thinning during, and 15 d before PH. Total anti-oxidant capacities and phenolic contents were usually greater in fruit from heavily-thinned compared with lightly- or moderately-thinned trees only when thinning was conducted during, or 15 d after PH. Moreover, anti-oxidant levels were highest in fruit from the earliest-thinned trees. There was no significant effect of crop load, or of time of thinning application treatment on fruit colour, or on the K, P, Fe, Mn, and Cu contents of leaf tissues. In conclusion, light or moderate thinning during PH resulted in minimal split pits during processing, and in optimal yields and fruit quality characteristics in the canning peach cultivar 'Andross'.

The cultivation of canning peach (*Prunus persica* L. Batsch.) is of significant economic importance to Greece, with a total annual production of 505,000 tonnes. Canning peaches also represent a high proportion (60.2%) of total production in Greece compared with other European countries (e.g., 38.1% in Spain, 6.5% in Italy, and 1.2% in France; "EUROPECH", 2007). Peaches grown for canning have a non-melting flesh, are known to maintain their integrity during storage and high-temperature treatment, have higher fruit firmness, soluble solids contents, and total carotene and xanthophyll contents, although they lack the red pigmentation, acidity, and aroma of commonly-grown dessert-type melting-flesh peaches (Karakurt *et al*., 2000).

A significant problem in the peach canning industry is the presence of split pits when fruit are cut in half during processing. The split pits have to be removed carefully, by hand, increasing production costs as this would pose a danger to consumers if swallowed. Split pits appear 2 – 4 weeks after pit hardening (PH) when lignin is formed in the two halves of the pit. The incidence of split pits is a cultivar-specific characteristic, and breeding programmes aim to develop resistant cultivars (O'Malley and Proctor, 2002). There is evidence that the incidence of split pits is related to the growth rate of the peach fruit. A high incidence of split pits was found when peach trees were placed in growth chambers at high temperatures (12°C day/6°C night) before PH, followed by high temperatures (20°C day/12°C night) after PH (Monet and Bastard, 1979). Girdling of branches may also increase the frequency of split pits in peach (Kubota *et al*., 1993). Little is known about the effects of crop load and time of application of thinning on the incidence of split pits in peach.

Thinning can be applied during flowering or post-bloom (i.e., removing fruit/fruitlets). It is known that the time of thinning can affect peach tree productivity. Early thinning (i.e., during flowering) reduces both fruit set and yield (Byers and Marini, 1994; Ebel *et al*., 1999; Greene *et al*., 2001). The optimum time to thin is considered to be during Stage I of fruit growth, which covers a 45- to 60-day period in the early development of fruit. However, even this period may be too late, because it is well into the first source-limiting period of growth, which begins 3 – 4 weeks after bloom (Grossman and DeJong, 1995). Njoroge and Reighard (2008) found that thinning at 20 d after full bloom (DAFB) was better than thinning at 0, 10, 30, or 40 DAFB, with respect to its effects on fruit yield and fruit size.

Crop load also affected shoot growth, root growth, and fruit fresh weight (FW), all of which were reduced by increasing levels of cropping (Blanco *et al*., 1995; Williamson and Coston, 1989; Inglese *et al*., 2002; Gordon and Dejong, 2007). The effects of crop load on the mineral nutrient contents of leaves were also documented by Blanco *et al*. (1995), although only minor differences were shown by Wright (1989).

*Author for correspondence.

The objectives of this work were to study the effects of fruit load and time of thinning on the incidence of split pits, fruit yield, fruit anti-oxidant contents, other fruit quality characteristics, and leaf mineral nutrient contents in a canning peach cultivar. The peach cultivar used was 'Andross', the most widely-cultivated peach for the canning industry in Greece.

MATERIALS AND METHODS

The experiment was conducted in a commercial peach (*Prunus persica* L. Batch. cv. Andross) orchard located in Imathia, central Macedonia, Greece, during 2006 and 2007. The trees were 10 years-old, trained in an open vase shape, and planted at a spacing of 5 m × 5 m. All trees received routine horticultural care, except for thinning, which varied according to our treatments.

Thirty-six trees were selected for vegetative and crop-load uniformity. The treatments applied were: i) fruit load, where fruits were hand-thinned and spaced at approx. 5, 10, or 20 cm throughout the whole canopy; and ii) time of thinning, which included thinning 7 d before, during, or 7 d after PH in 2006 (62, 69, and 75 DAFB, respectively), and 15 d before, during, or 15 d after PH in 2007 (57, 72, and 88 DAFB, respectively).

The contents of K, P, Fe, Mn, and Cu were measured in leaf samples collected at random from the middle part of current year shoots from the middle of the tree canopy. Fifty leaves were collected per experimental tree, washed with a liquid soap solution, rinsed twice with distilled water to eliminate all surface contamination, left to dry in ambient air, then dried to constant weight at 80°C. Approx. 0.5 g of finely ground leaf material was dried for 2 h at 80°C. The sample was reweighed and dried at 550ºC for 8 h, then 10 ml 2 M HCl was added and heated at 80°C for 30 min. The digest was sieved and diluted with 50 ml deionised water prior to analyses. Potassium, P, Fe, Mn and Cu contents were determined by atomic absorption spectroscopy (Model AAnalyst 300; Perkin Elmer Ltd., Beaconsfield, UK).

Fruits from each tree were harvested at the commercial maturity stage in two harvests, and yields were measured. The number of fruit in the first harvest was counted and mean fruit FWs were calculated. Thirty fruit from the first harvest of each tree were transferred to the laboratory for fruit quality measurements. The skin fruit colour parameters, L*, a* and b* were measured on the surface (i.e., skin ground colour) using a Minolta Chromatometer (Model CR-200; Minolta, Ramsey, NJ, USA). Soluble solid contents (SSC) were analysed in the juice from six fruit using a digital refractometer (Model PR-1; Atago, Tokyo, Japan) and total acidity (TA) was assessed for the same samples by titration with 0.1 M NaOH and expressed as malic acid contents (g 100 ml^{-1}). Pit lengths and widths were measured, and the presence of split pits was recorded.

In 2007, a further 50-fruit sample from each treatment was transferred to a fruit-canning facility and placed into the cutting machine on the peach processing conveyor belt. The number of split pits in the resulting fruit halves was recorded, and the percentage of split pits was calculated.

Total phenolics contents and anti-oxidant capacities were measured in nine replicate fruit per treatment, in 2007. Fruits were rinsed with distilled water, dried on tissue paper, and stored at –20°C. Flesh samples were removed using a sharp knife and used directly for analyses, in triplicate. All chemicals were purchased from the Sigma Chemical Co. (St. Louis, MO, USA). Assays were performed using an automated UV/visible spectrophotometer (Model U-2001 UV/Vis; Hitachi Instruments Inc., San Francisco, CA, USA).

Anti-oxidant capacity and total phenolics assay

Frozen samples (approx. 1 g) of flesh from three replicate fruit were homogenised as a pooled sample in 10 ml 80% (v/v) methanol (MeOH) in H_2O in a micro-dismembrator (Micro-Dismembrator U.B.; Braun Biotech International GmbH, Melsungen, Germany) for 3 min at 2,000 rpm. The extract was centrifuged at 5,000 × *g* for 10 min, and the supernatant was recovered.

Anti-oxidant capacities were measured using the stable 1,1-diphenyl-2-picryl hydrazyl (DPPH) free radical (Blois, 1958), which has an intense violet colour, but turns colourless as unpaired electrons are sequestered by anti-oxidants. Reaction mixtures containing 0 or 10 µl extract, 2.3 ml 106.5 µM DPPH in MeOH and 690 µl H_2O were vortexed, then kept at room temperature in the dark for 4 h. The absorbance of each reaction mixture was measured at 517 nm and the concentration of ascorbate-equivalent anti-oxidant capacity (AEAC; in mM) was extrapolated from a standard curve prepared using 0 – 2.7 mM ascorbate.

Total soluble phenolics contents were determined according to the Folin-Ciocalteu procedure (Singleton and Rossi, 1965) and the results were expressed as mg gallic acid equivalent 100 g^{-1} FW.

Experimental design and statistical analyses

The experiment was a randomised complete block design with a factorial treatment structure (i.e., three crop loads and three thinning times). Each tree in a block was treated as an experimental unit and was randomly assigned to be thinned to a specific crop load and time. All treatment combinations were replicated four-times.

Statistical analyses were conducted using multi-factor ANOVA (SPSS Inc., Chicago, IL, USA). Percentage data were arcsine transformed before analyses.

RESULTS AND DISCUSSION

Time of thinning treatment altered fruit yield and some fruit quality characteristics only in 2007, when thinning was conducted at 15-d intervals, but not in 2006, when thinning was conducted at 7-d intervals (Table I; Table II). This may be attributed to the greater time interval between treatments that made the effects more pronounced. It is possible, however, that environmental differences between experimental years may also have altered fruit growth rates and influenced the treatment effects (Lopez and DeJong, 2007).

The percentage of fruit with split pits increased by 58.2% in heavily-thinned (20 cm distance) compared with moderately- (10 cm) or lightly- (5 cm) thinned trees, and by 22.9% at the earliest time of thinning (15 d before PH), compared with thinning during or after PH (Tables I – III). It is noteworthy that the above effects were found only when fruit were cut into two halves at

TABLE I
P values for the effects of time of thinning and crop load on peach fruit yield, fruit quality, and leaf mineral nutrient contents

	2006			2007		
Parameter	Time of thinning	Crop load	Time × Crop load	Time of thinning	Crop load	Time × Crop load
Yield						
Yield 1st harvest	0.311	0.784	0.539	**0.046**	0.587	0.646
Yield 2nd harvest	0.324	0.594	0.866	0.319	0.213	0.560
Total yield	0.325	0.795	0.540	**0.008**	0.456	0.370
Fruit quality						
Fruit weight	0.551	**0.010**	0.066	**0.014**	**0.003**	0.828
Stone length	0.277	**0.022**	0.177	0.170	0.977	0.752
Stone width	0.118	0.063	0.651	0.485	0.284	0.333
Split pits (visually)	0.615	0.161	0.337	0.435	0.250	0.320
Split pits (industry)	–	–	–	**0.043**	**0.001**	0.777
Soluble solid content	0.987	0.200	0.465	0.099	0.222	0.889
Total acidity	0.100	0.531	0.594	**0.041**	0.926	0.418
Firmness	0.180	0.115	0.727	**0.005**	0.089	0.606
Total anti-oxidant capacity	–	–	–	< **0.001**	0.281	< **0.001**
Total phenolics content	–	–	–	< **0.001**	**0.035**	< **0.001**
L* skin colour	0.542	0.190	0.150	0.192	0.383	0.341
a* skin colour	0.345	0.240	0.540	0.182	0.735	0.552
b* skin colour	0.230	0.140	0.580	0.233	0.466	0.253
Leaf mineral content						
K	0.425	0.210	0.523	0.764	0.357	0.229
P	0.199	0.249	0.448	0.523	0.532	0.217
Fe	0.801	0.857	0.224	0.815	0.777	0.263
Mn	0.456	0.273	0.396	0.168	0.519	0.213
Cu	0.119	0.807	0.945	0.142	0.433	0.719

Significant *P* values are shown in bold.

the peach canning facility, whereas there was no difference between treatments when the incidence of split pits was assessed visually. Monet and Bastard (1979) found that the incidence of split pits increased when peach trees were placed in growth chambers with higher, rather than lower temperatures before PH, suggesting that the incidence of split pits may be related to the fruit growth rate prior to PH. Moreover, girdling lateral branches in peach trees was shown to increase the frequency of split pits, probably due to increased photosynthetic carbon-partitioning to the fruit (Kubota *et al*., 1993). In the present study, the higher incidence of split pits in fruit from heavily-, compared to moderately- or lightly-thinned trees, may also be due to increased photosynthetic carbon-partitioning, as there were fewer fruits in the former trees. Early thinning, before PH, also increased the incidence of split pits, probably because the fruit were at a more sensitive stage of growth (before PH), which made them more prone to split.

Time of thinning and crop load treatments altered mean fruit FWs, with higher values in heavily- and moderately-thinned trees compared to lightly-thinned trees (increased by 19.9% in 2006, and 30.2% in 2007), and when thinning occurred 15 d before, compared with 15 d after PH (149.2 g *vs*. 133.2 g, respectively; Tables I – III). Pit length and pit width did not differ between treatments, probably because thinning was applied near to PH, by which time most pit growth had already occurred. Therefore, changes in fruit FW were probably due to changes in the FW of the flesh and the increased availability of photosynthates from source leaves (DeJong and Grossman, 2005). Similar results have been reported in other studies (Blanco *et al*., 1995; Berman and DeJong, 1996; Naor *et al*., 1999; Inglese *et al*., 2002; Bussi *et al*., 2005). Moreover, Njoroge and Reighard (2008) found that fruit FW decreased quadratically with increasing time before hand-thinning.

In the present study, the different crop load treatments did not alter yields, although fruit FW was greater in moderately- and heavily-thinned trees compared with lightly-thinned trees (Table I; Table III), suggesting that the increased mean fruit FW in moderately- and heavily-thinned trees compensated for the lower numbers of fruits per tree. Bussi *et al*. (2005) found that, in an early-maturing peach cultivar, increasing fruit load increased fruit yield; but, at the highest fruit load, no significant

TABLE II
Effect of time of thinning‡ on fruit yield and fruit quality in the peach cultivar 'Andross'

	2006			2007		
Parameter	7 d before	During	7 d after	15 d before	During	15 d after
Yield						
Yield 1st harvest (kg)	61.8	71.9	57.9	50.4a	51.2 a	33.6 b
Yield 2nd harvest (kg)	39.8	27.6	31.3	25.4	32.2	31.1
Total yield (kg)	101.7	99.5	89.1	75.8 a	83.3 a	64.7 b
Fruit quality						
Fruit weight (g)	171.0	182.7	169.2	149.2 a	142.7 ab	133.2 b
Stone length (mm)	32.2	32.5	32.9	32.0	31.3	31.9
Stone width (mm)	25.6	25.8	26.4	24.4	24.1	24.4
Split pits (visually) (%)	2.2	1.8	2.8	4.7	4.8	3.4
Split pits (industry) (%)	–	–	–	21.5 a	18.1 b	16.9 b
Soluble solids content (%)	10.3	10.3	10.3	12.1	11.8	12.7
Total acidity (g 100^{-1} ml)	5.1	5.0	5.9	3.8 b	3.9 b	4.8 a
Firmness (kg)	6.2	7.1	7.6	5.5 b	5.8 b	6.6 a

Means separation within a year and a row was by Duncan's multiple range test ($P \leq 0.05$).
‡Fruit thinning was conducted 7 d before, during, or 7 d after pit hardening in 2006; and 15 d before, during, or 15 d after pit hardening in 2007.

TABLE III
Effect of crop load‡ on fruit yield and fruit quality in the peach cultivar 'Andross'

	2006			2007		
Parameter	Light thinning	Medium thinning	Heavy thinning	Light thinning	Medium thinning	Heavy thinning
Yield						
Yield 1st harvest (kg)	60.4	65.1	66.1	39.4	45.0	50.7
Yield 2nd harvest (kg)	34.3	35.3	29.1	31.6	33.9	23.2
Total yield (kg)	94.7	100.4	95.2	71.0	78.9	74.0
Fruit quality						
Fruit weight (g)	145.1 b	182.0 a	195.7 a	125.1 b	146.9 a	153.1 a
Stone length (mm)	31.9 b	32.9 a	32.8 a	31.8	31.8	31.6
Stone width ((mm)	25.5	26.1	26.2	24.4	24.0	24.4
Split pits (visually) (%)	0.6	3.6	2.5	4.6	6.0	1.7
Split pits (industry) (%)	–	–	–	12.4 b	19.2 b	25.0 a
Soluble solids content (%)	10.4	10.0	10.4	12.4	11.8	12.3
Total acidity (g 100^{-1} ml)	5.3	5.5	5.1	4.1	4.1	4.2
Firmness (kg)	7.9	6.2	6.8	5.8	6.4	5.8

Means separation within a year and a row was by Duncan's multiple range test ($P \leq 0.05$).
‡Fruits were thinned and spaced at approx. 5 cm (light), 10 cm (medium), or 20 cm (heavy thinning) throughout the whole canopy, in 2006 and 2007.

yield enhancement was detected compared with an intermediate fruit load.

First-harvest yield and total yield decreased by 34.4% and 22.3%, respectively, when thinning was conducted 15 d after PH, compared with during PH (Table I; Table II). Thinning 15 d after PH also increased flesh firmness and TA, compared with thinning during or before PH, suggesting that fruit ripening was delayed in late-thinned trees. Soluble solids contents (Table II) and the colour parameters L*, a*, and b* (data not shown) did not differ between treatments. Considering that late thinning reduced fruit yield, while early thinning increased the percentage of split pits, we recommend that the optimum thinning time for the peach cultivar 'Andross' is during PH.

Mean values of total phenolics contents (37.9 – 64.1 mg gallic acid equivalent 100 g^{-1} FW) were similar to those in other reports on non-melting-fleshed peaches, and were positively correlated with total anti-oxidant capacity (r = 0.727), suggesting that phenolic compounds act as a major source of potential anti-oxidants in peach fruit (Chang *et al.*, 2000; Drogoudi and Tsipouridis, 2007; Figure 1). Moreover, total phenolics contents were two- to 12-fold greater than in melting-fleshed peaches and nectarines (Drogoudi, unpublished data), suggesting that non-melting-fleshed (canning) peaches provide more health benefits compared to melting-fleshed peaches.

The total phenolics contents and total anti-oxidant capacities of fruit were greater (by 58.8% and 63.6%, respectively) in trees thinned 15 d before PH compared to those thinned 15 d after PH (Table I; Figure 1). Kubota *et al.* (1993) found that girdling lateral peach branches increased total phenolics contents, and the proportion of higher molecular weight phenols, suggesting that the greater accumulation of photosynthates in girdled branches may facilitate phenolics accumulation. In the present study, early thinning may have reduced the competition for photosynthetic products (Grossman and DeJong, 1995) and favoured the synthesis of anti-oxidant compounds.

Total phenolics contents and total anti-oxidant capacities were usually greater in fruit from heavily-thinned trees compared to lightly- or moderately-thinned trees only when thinning was conducted during or after PH. Minor effects of crop load on the anti-oxidant contents of peach were found only in a study on peach by Buendia *et al.* (2008), where fruit from a commercial crop load (thinned to 25 cm) were compared with a low crop load (thinned to 50 cm). The former had a slightly higher content of anti-oxidant compounds in their peel, but not in their flesh tissues.

There was no significant effect of crop load or time of thinning on the K, P, Fe, Mn, or Cu contents of leaf tissues (Table I; data not shown). Similarly, Blanco *et al.* (1995) found that the P, Fe, Cu, K, Ca, Mg, and Zn contents of

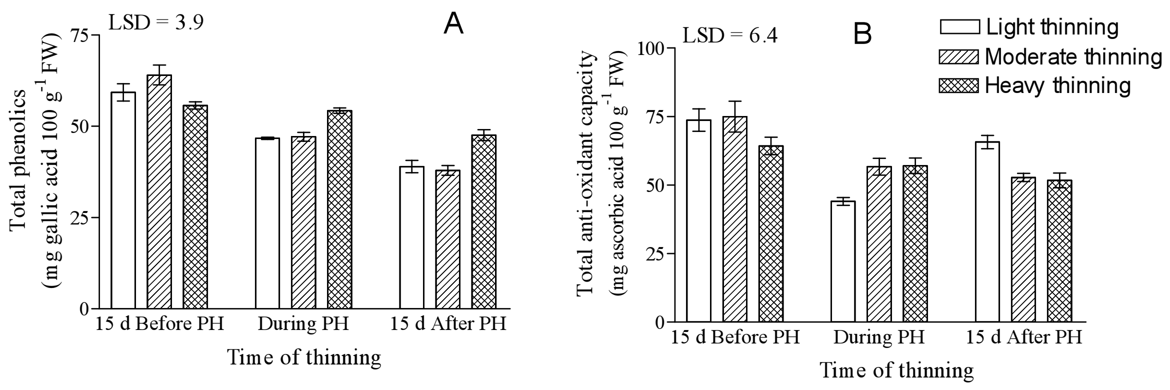

FIG. 1
Effects of light (open columns), moderate (hatched columns), or heavy (chequered columns) hand-thinning (where the remaining fruits were spaced at approx. 5, 10, or 20 cm, respectively) and different times of thinning [15 d before pit hardening (PH), during, or 15 d after pit hardening] on total phenolics contents (means ±SE) (Panel A), and total anti-oxidant capacity (Panel B), in the peach cultivar 'Andross', in 2007.

peach leaves did not differ from trees with different fruit loads; however, Mn contents decreased with increasing crop load. Minor differences in peach leaf nutrient contents due to crop load were also documented by Wright (1989).

In conclusion, the results from the present study suggest that light or moderate thinning during PH results in the lowest incidence of split pits during processing, and in optimal yields and fruit quality characteristics in the peach cultivar, 'Andross'.

The authors are grateful to the General Secretariat for Research and Technology for financial support through Project TR14.

REFERENCES

BERMAN, M. E. and DEJONG, T. M. (1996). Water stress and crop load effects on fruit fresh and dry weights in peach (*Prunus persica*). *Tree Physiology*, **16**, 859–864.

BLANCO, A., PEQUERUL, A., VAL, J., MONGE, E. and GOMEZ APARISI, J. (1995). Crop-load effects on vegetative growth, mineral nutrient concentration and leaf water potential in 'Catherine' peach. *Journal of Horticultural Science*, **70**, 623–629.

BLOIS, M. S. (1958). Antioxidant determination by the use of stable free radicals. *Nature*, **181**, 1199-1200.

BUENDÍA, B., ALLENDE, A., NICOLÁS, E., ALARCÓN, J. J. and GIL, M. I. (2008). Effect of regulated deficit irrigation and crop load on the antioxidant compounds of peaches. *Journal of Agricultural and Food Chemistry*, **56**, 3601–3608.

BUSSI, C., LESCOURRET, F., GENARD, M. and HABIB, R. (2005). Pruning intensity and fruit load influence vegetative and fruit growth in an early-maturing peach tree (cv. Alexandra). *Fruits*, **60**, 133–142.

BYERS, R. E. and MARINI, R. P. (1994). Influence of blossom and fruit thinning on peach flower bud tolerance to an early spring freeze. *HortScience*, **29**, 146–148.

CHANG, S., TAN, C., FRANKEL, E. N. and BARRETT, D. M. (2000). Low-density lipoprotein antioxidant activity of phenolic compounds and polyphenol oxidase activity in selected clingstone peach cultivars. *Journal of Agricultural and Food Chemistry*, **48**, 147–151.

DEJONG, T. M. and GROSSMAN, Y. L. (2005). Quantifying sink and source limitations on dry matter partitioning to fruit growth in peach trees. *Physiologia Plantarum*, **95**, 437–443.

DROGOUDI, P. D. and TSIPOURIDIS, C. GR. (2007). Effects of cultivar and rootstock on the antioxidant content and physical characters of clingstone peaches. *Scientia Horticulturae*, **115**, 34–39.

EBEL, R. C., CAYLOR, A., PITTS, J. and HIMELRICK, D. G. (1999). "Surfactant WK" for thinning peach blossoms. *Fruit Varieties Journal*, **53**, 184–188.

EUROPECH (2007). *Actualisation des Prévisions de Récolte Pêche au 15 Juin 2008*. www.europech.com/fr/previsions.cfm.

GORDON, D. and DEJONG, T. M. (2007). Current-year and subsequent-year effects of crop-load manipulation and epicormic-shoot removal on distribution of long, short and epicormic shoot growth in *Prunus persica. Annals of Botany*, **99**, 323–332.

GREENE, D. W., HAUSCHILD, K. I. and KRUPA, J. (2001). Effect of blossom thinners on fruit set and fruit size of peaches. *HortTechnology*, **11**, 179–183.

GROSSMAN, Y. L. and DEJONG T. M. (1995). Maximum fruit growth potential and seasonal patterns of resource dynamics during peach growth. *Annals of Botany*, **75**, 553–560.

INGLESE, P., CARUSO, T. and GUGLIUZZA, G. (2002). Crop load and rootstock influence on dry matter partitioning in trees of early and late ripening peach cultivars. *Journal of the American Society for Horticultural Science*, **127**, 825–830.

KARAKURT, Y., HUBER, D.J. and SHERMAN, W. B. (2000). Quality characteristics of melting and non-melting flesh peach genotypes. *Journal of the Science of Food and Agriculture*, **80**, 1848–1853.

KUBOTA, N., NISHIYAMA, N. and SHIMAMURA, K. (1993). Effects of girdling lateral bearing branches on astringency and phenolic contents of peach fruits. *Journal of the Japanese Society for Horticultural Science*, **62**, 69–73.

LOPEZ, G. and DEJONG, T. M. (2007). Spring temperatures have a major effect on early stages of peach fruit growth. *Journal of Horticultural Science & Biotechnology*, **82**, 507–512.

MONET, R. and BASTARD, Y. (1979). Split-pit of peaches. The effect of temperature. *Annales de l'Amelioration des Plantes*, **29**, 535–543.

NAOR, A., KLEIN, I., HUPERT, H., GREENBLAT, Y., PERES, M. and KAUFMAN, A. (1999). Water stress and crop load interactions in relation to nectarine yield, fruit size distribution and water potentials. *Journal of the American Society for Horticultural Science*, **124**, 189–193.

NJOROGE, S. M. C. and REIGHARD, G. L. (2008). Thinning time during stage I and fruit spacing influences fruit size of 'Contender' peach. *Scientia Horticulturae*, **115**, 352–359.

O'MALLEY, C. and PROCTOR, J. T. A. (2002). Split pits in Canadian peaches. *Journal of the American Pomological Society*, **56**, 72–75.

SINGLETON, V. L. and ROSSI, J. A. (1965). Calorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagent. *American Journal of Enology and Viticulture*, **16**, 144–158.

WILLIAMSON, J. G. and COSTON, D. C. (1989). The relationship among root growth, shoot growth, and fruit growth of peach. *Journal of the American Society for Horticultural Science*, **114**, 180–183.

WRIGHT, C. J. (1989). Interactions between vegetative and reproductive growth. In: *Manipulation of Fruiting*. (Wright, C. J., Ed.). Butterworths, London, UK. 15–27.