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Girdling of early season 'Mayfire' nectarine trees

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SUMMARY

The effect of four times of limb girdling on fruit and tree response was examined on 'Mayfire' nectarine (*Prunus persica* (L.) Batsch). Girdling prior to Stage II of fruit growth reduced the lag phase associated with Stage II, and caused peak fruit growth rates to occur earlier in the season than on later girdled or ungirdled trees. Optimum response was obtained by girdling prior to Stage II, when fruit seed length was approximately 10 mm. Girdling at this time increased fruit weight by 22.5% and more than doubled the percentage of fruit in the largest three size categories. Maturity, measured as soluble solids concentration, was increased by 42%. Shoot extension growth was reduced only by early girdling. Leaf weight per unit area was increased, and leaf nutrient concentrations were decreased by all girdling treatments. Leaf conductance to water vapour (g_1) was not affected when measured 8 days prior to and 78 days after harvest. Fifteen days after harvest, g_1 was decreased in all girdling treatments.

SMALL fruit size and low yield are common problems in the production of early-season stonefruit cultivars. These characteristics are tolerated by growers because the returns for such fruit are initially high, with large fruit commanding premium prices. However, the market is volatile and can change rapidly. Because of this, growers of early-season cultivars are interested in harvesting their fruit as quickly as possible to take advantage of favourable market conditions.

Girdling has been effective in advancing maturity and increasing the size of grapes (Winkler *et al.*, 1974) citrus fruits (Lewis and McCarthy, 1973), apricots (Crane and Campbell, 1957; Lilleland and Brown, 1936) and peaches and nectarines, (Fernandez-Escobar, 1987; Weinburger and Cullinan, 1932). While often performed on early-season stone fruit trees, girdling is by no means universal owing to the associated adverse effects. Lilleland and Brown (1936) demonstrated that girdling apricots increased maturity by as much as 14 days while also increasing fruit size. However, fruits on some branches showed initial shrinkage and wilting, and while most recovered, some never did. In further work with apricot, Crane and Campbell (1957) reported that some girdled branches showed little or no increased fruit growth, leaf chlorosis, and severe gumming.

Such responses are caused in part by slow healing of the girdled area. If the girdle is made too wide or deep, the healing process can be slow (Fernandez-Escobar *et al.*, 1987; Lavee *et al.*, 1983) and root carbohydrate depletion and injury can occur (Cohen, 1987; Priestly, 1976). Girdled tress often also show other symptoms of root injury such as decreased leaf size, premature senescence, and autumnal leaf coloration (Noel, 1970). The situation is complicated since healing of girdles is not only species dependent (Noel, 1970) but also cultivar dependent (Fernandez-Escobar *et al.*, 1987).

Determining the optimum date of girdling, to reduce the dangers and increase the effectiveness, is a major problem for growers. Fernandez-Escobar *et al.* (1987) reported that date of girdling does not affect fruit size in peaches. However grower experience in Central San Joaquin Valley does not substantiate this and previous work has indicated that date of girdle application can affect fruit size (Beutel, pers. comm.).

Stone fruit growth exhibits what has become known as the double-sigmoid growth curve with three stages; an initial phase of exponential growth (Stage I), a lag phase (Stage II) and a second exponential phase (Stage III) (Con-

TABLE I
Summary of treatments of 1988 girdling experiment of Mayfire nectarine

Treatment	Seed length (mm ± SE)	Days after full-bloom
Girdled 24 March	7.1 ± 0.4	23
Girdled 31 March	9.6 ± 0.3	30
Girdled 7 April	13.9 ± 0.3	37
Girdled 18 April	17.6 ± 0.3	48

ners, 1919). Lilleland and Brown (1936) girdled apricot trees at the beginning of Stage II of fruit growth, but suggested that girdling seven to ten days earlier may have been even more effective. However, the date of this developmental stage is difficult to predict since within cultivars, the beginning of Stage II will vary from year to year because of differences in chilling response, date of bloom, and post-bloom temperatures.

It has been noted that many peach and nectarine cultivars have a seed length of 12 to 15 mm at the onset of stage II of fruit growth (Beutal, pers. comm.). Therefore the use of seed length may have merit as a fruit-based method to determine the optimum time of girdling.

The following experiment was designed to determine how the timing of girdling affects fruit size, quality, and tree response; and to evaluate the potential of seed length for use in determining optimum timing of girdling.

MATERIALS AND METHODS

Plant materials

The plants used in this experiment were four year old nectarine trees (*Prunus persica* (L.) Batsch cv. Mayfire) growing in a commercial orchard in Southern Fresno County, California. These trees were planted at a spacing of 2.76 × 5.50 m, trained to a modified four-scaffold vase system, and received routine horticultural care suitable for early-season fresh-shipping nectarines. Trees were hand-thinned on 1 April to crop loads standard for the cultivar.

Treatments

Girdling was done on: 24 March, 31 March, 7 April and 18 April. All four scaffolds were girdled with a 6 mm double-bladed girdling knife. On each girdling date seed length was determined from ten fruits collected from ungirdled trees. A randomized block design with six blocks and with single tree plots was used to compare five treatments, namely four times of girdling and an ungirdled control, using 30 trees in all.

Fruit measurements

Following thinning on 1 April, four fruits on each tree were tagged, one in each quadrant, in similar height locations. Cheek to cheek fruit caliper was measured twice weekly on these fruits. Fruit were harvested according to ground colour on 7 and 11 May. Following harvest all fruit from each tree were weighed, commercially sized, and sorted for visual split pits. Soluble solids concentration (SSC) was determined on juice samples obtained by macerating two, one-eighth fruit sections from each of the tagged fruits.

Plant measurements

Leaf conductance to water vapour (g_l) calculated as the inverse of leaf resistance was measured on 29 April, 26 May, and 28 July using a LI-1600 steady state porometer (model #LI-190s, LI-COR). Measurements were made between 0900 and 1100 hours PST. For each treatment, mean g_l was calculated from measurements on five individual well-exposed leaves from the mid to upper canopy level on each tree.

Leaf samples for nutrient analysis were obtained on 16 May by collecting two mid-shoot leaves from each quadrant. All current season shoot growth above the girdle was measured on 17 and 18 May on a single scaffold oriented in a southwesterly position.

RESULTS AND DISCUSSION

Fruit responses

Mean seed length ranged from 7.1 mm on 29 March to 17.6 mm on 18 April (Table I). Girdling was most effective in increasing fruit size and maturity when performed on March 31 (Table II). Only the 31 March treatment had significantly greater mean fruit weight than ungirdled trees. Distribution of fruit within various size ranges indicated that the 31 March treatment had the greatest percentage of fruit (Table III) in the largest three size categories.

Girdling also advanced fruit maturity. The percentage of fruit picked in the first harvest and SSC were significantly greater in all girdled

TABLE II
The effect of date of girdling on mean (± SE) fruit yield, number, size, soluble solids, percent split-pit fruits, and percent of total fruit yield harvested in the first pick

Treatment	Fruit yield kg tree^{-1}	Fruit number per tree	Fruit size g fruit^{-1}	Percent SSC	Percent split-pit	Percent first pick
Girdled 24 March	12.31 ± 1.22	136.7 ± 15.2	91.5 ± 4.9	14.1 ± 0.06	4.8 ± 0.9	79.8 ± 5.6
Girdled 31 March	12.94 ± 1.07	132.7 ± 10.4	97.8 ± 4.9	14.2 ± 0.05	4.7 ± 0.6	89.6 ± 2.8
Girdled 7 April	14.22 ± 0.95	156.6 ± 18.6	94.2 ± 3.3	13.7 ± 0.06	6.6 ± 1.3	79.0 ± 4.1
Girdled 18 April	13.25 ± 1.83	158.0 ± 21.7	84.3 ± 3.0	12.2 ± 0.04	8.2 ± 1.3	75.6 ± 7.1
Ungirdled	11.67 ± 1.54	146.0 ± 17.4	79.5 ± 1.8	10.0 ± 0.30	5.7 ± 0.9	67.9 ± 6.9

TABLE III
The effect of time of girdling on fruit size distribution of 'Mayfire' Nectarine harvested on 7 May and 11 May. Data represent the mean (± SE) percent of the total number of fruit in a given category (number of fruit per 10 kg box) harvested from each of six trees

	Size categories					
Treatment	undersize	108	96	84	72	64
Girdled 24 March	21.5 ± 5.3	7.9 ± 1.5	33.1 ± 2.6	31.6 ± 4.7	6.0 ± 3.0	0
Girdled 31 March	13.1 ± 3.5	4.5 ± 1.2	29.3 ± 5.8	38.1 ± 4.3	12.2 ± 5.7	2.9 ± 2.0
Girdled 7 April	22.7 ± 4.7	8.0 ± 2.2	40.6 ± 2.6	25.6 ± 5.6	3.2 ± 1.4	0
Girdled 18 April	26.2 ± 6.5	8.4 ± 1.2	37.1 ± 0.9	25.1 ± 7.1	2.4 ± 1.1	0
Ungirdled	31.2 ± 6.4	9.8 ± 1.5	38.3 ± 2.1	17.9 ± 4.4	2.2 ± 1.2	0

treatments compared with the control (Table II). Mean SSC of fruit from the 31 March treatment tended to be the highest of the girdled treatments. The total yield per tree and percentage of split-pit fruit were unaffected by girdling (Table II).

Seasonal patterns of fruit size shows that early girdling (24 March, 31 March) almost eliminated Stage II of fruit growth (Figure 1). Such a response is consistent with the results obtained on apricot by Lilleland and Brown (1936). Because fruit growth rate is a function of fruit size (DeJong and Goudriaan, 1989) the effects of this initial increase in fruit size lasted through harvest.

The early girdling treatments stimulated peak growth rates earlier in the season than the late girdles (7 April, 18 April) and ungirdled trees. From Figure 2 it appears that early girdling reduces the final growth swell of the fruit. While the late girdles stimulated greater fruit growth rates during the final dates of Stage III, fruits on early girdled trees maintained higher growth rates for longer periods so fruit size at harvest was larger. The 24 March treatment tended to have a quicker fall in fruit growth rate than the 31 March treatment. This may be due to the healing of the girdle and an increased competition for photosynthates by tree organs below the girdle.

Plant responses

Preharvest and postharvest measurements of g_1 showed no differences between treatments except when measured 15 days after harvest on 26 May (Table IV). The differences in g_1 at this time may have been due to feedback inhibition of photosynthesis. The utilization of available photosynthates by the developing crop on 29 April (prior to harvest) may have allowed stomata to remain open. After harvest (on 26 May), feedback inhibition may have caused stomatal closure as photosynthates accumulated above the girdle (DeJong, 1986; Neals and Incoll, 1968). The separation of response on this date was such that reduction of g_1 was

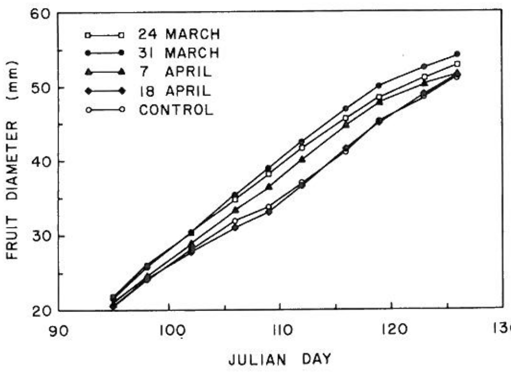

FIG. 1
The effect of date of girdling on cheek to cheek fruit diameter of 'Mayfire' nectarine.

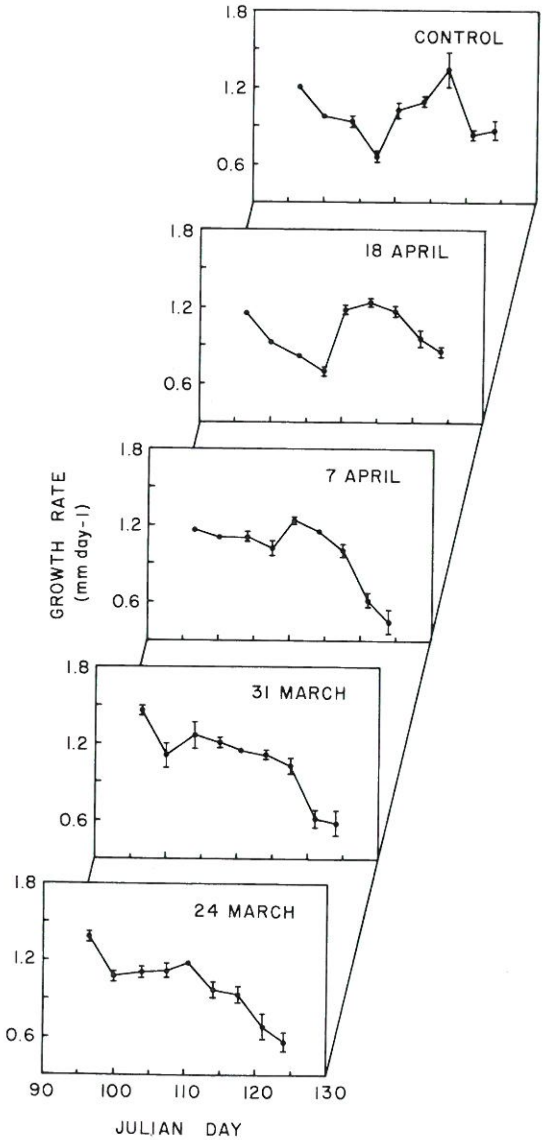

FIG. 2
The effect of date of girdling on fruit growth rate of 'Mayfire' nectarine. Vertical bars indicate ± SE.

related to girdling date, or more likely, the degree of wound healing. As the girdles healed, photosynthates were probably able to again pass downward to the root system, lessening feedback inhibition. On 28 July, after all wounds had healed, g_l was again similar for all treatments.

Early girdling treatments reduced shoot extension growth, while the 18 April treatment caused no such reduction (Table V). Fernandez-Escobar *et al.* (1987) reported similar results for other nectarine cultivars. This is probably because shoot growth rates of peach are greatest during late March and early April (DeJong *et al.*, 1987) and vegetative growth is cumulative. Therefore early decreases in shoot growth will be compounded as the season progresses. Leaf weight per unit area (W_a) was increased by all girdling treatments (Table V). This would be expected where feedback inhibition would cause carbohydrate accumulation above the girdle (DeJong, 1986; Neals and Incoll, 1968).

Leaf nutrient concentrations were decreased by all girdling treatments (Table VI). These differences may be partially due to the different W_a between treatments. However, this cannot account for all of the differences, especially with Mg and Mn, the elements most affected. Indeed, girdled trees exhibited leaf symptoms common to these deficiencies. Decreased leaf NPK concentrations have also been observed in girdled orange trees (Wallerstein *et al.*, 1978). Priestly (1978) reported that lower nutrient concentrations in the leaves of girdled trees may be caused by reduced root activity. Such a response might also explain the reductions in vegetative growth of girdled trees (Table V).

Previous research has shown that girdling increases fruit size and maturity (Fernandez-

TABLE IV
Seasonal pattern of morning (1000–1200 hours PDT) leaf conductance (cm s^{-1}) in response to girdling treatment. Values indicate means ± SE, n = 6

	Stomatal conductance (cm s^{-1}) on		
	29 April	26 May	28 July
Girdled 24 March	0.75 ± 0.03	0.60 ± 0.08	0.90 ± 0.06
Girdled 31 March	0.65 ± 0.06	0.51 ± 0.07	0.93 ± 0.02
Girdled 7 April	0.77 ± 0.06	0.42 ± 0.03	0.88 ± 0.05
Girdled 10 April	0.69 ± 0.04	0.39 ± 0.04	0.88 ± 0.04
Ungirdled Control	0.82 ± 0.08	0.82 ± 0.02	0.94 ± 0.02

TABLE V
Mean (± SE) extension shoot growth (m $scaffold^{-1}$) and leaf weight per unit area (mg cm^{-2}) of girdled and ungirdled trees measured on 17 and 18 May

Treatment	Shoot growth (m)	W_a (mg cm^{-2})
Girdled 24 March	41.1 ± 1.2	6.71 ± 0.13
Girdled 31 March	42.1 ± 1.9	7.01 ± 0.13
Girdled 7 April	44.5 ± 3.5	6.77 ± 0.40
Girdled 18 April	53.4 ± 3.3	6.69 ± 0.24
Ungirdled	53.1 ± 3.8	5.84 ± 0.22

TABLE VI
Leaf nutrient concentrations of girdled and ungirdled 'Mayfire' nectarine trees. Values are means (± SE) of five exposed mid-shoot leaves from each of the six treatment trees sampled on 16 May

	Percent				PPM		
Treatment	N	P	K	Mg	Zn	Mn	Fe
Girdled 24 March	3.11 ± 0.14	0.21 ± 0.01	1.21 ± 0.10	0.30 ± 0.03	22.8 ± 1.4	37.3 ± 3.5	152.3 ± 2.6
Girdled 31 March	2.88 ± 0.07	0.20 ± 0.01	1.07 ± 0.10	0.24 ± 0.01	23.2 ± 2.1	27.2 ± 0.9	128.0 ± 3.9
Girdled 7 April	2.84 ± 0.12	0.20 ± 0.01	0.95 ± 0.05	0.25 ± 0.01	20.7 ± 1.2	30.8 ± 1.8	128.0 ± 7.5
Girdled 18 April	2.88 ± 0.05	0.20 ± 0.01	0.96 ± 0.04	0.24 ± 0.01	19.2 ± 0.7	29.3 ± 2.4	132.5 ± 11.6
Ungirdled	3.78 ± 0.09	0.28 ± 0.01	1.64 ± 0.05	0.47 ± 0.01	27.3 ± 0.6	65.3 ± 3.9	172.7 ± 7.3

Escobar *et al.*, 1987; Lilleland and Brown, 1936). The present research indicates that the timing of girdling is critical and the fruit were more responsive to girdling date than vegetative growth. Girdling too early or late reduced or eliminated benefits. Optimum fruit response was obtained by girdling on 31 March, 30 days after full-bloom. This corresponded to a seed length of about 10 mm. The data presented here and elsewhere (Lilleland and Brown, 1936) support the concept that girdling is most effective at the beginning of Stage II. A fruit-based method to aid in the prediction of this occurrence takes into account annual variations in environmental conditions. Further research is necessary to determine if seed length can be used to predict accurately the optimum date of girdling for other cultivars.

REFERENCES

COHEN, A. (1984). Citrus fruit enlargement by means of summer girdling. *Journal of Horticultural Science,* **55,** 119–25.

CONNERS, C. H. (1919). Growth of fruits of peach. *Annual Report of the New Jersey Agricultural Experiment Station,* **40,** 82–8.

CRANE, J. C. and CAMPBELL, R. C. (1957). The comparative effectiveness of girdling and 2,4,5-Trichlorophenoxyacetic acid for increasing size and hastening maturity of apricots. *Proceedings of the American Society for Horticultural Science,* **69,** 165–9.

DEJONG, T. M. (1986). Fruit effects of photosynthesis in *Prunus persica. Physiologia Plantarum,* **66,** 149–53.

DEJONG, T. M., DOYLE, J. F. and DAY, K. R. (1987). Seasonal patterns of reproductive and vegetative sink activity in early and late maturing peach *(Prunus persica)* cultivars. *Physiologia Plantarum,* **71,** 83–88.

DEJONG, T. M. and GOUDRIAAN, J. (1989). Modelling peach fruit growth and carbohydrate requirements; re-evaluation of the double sigmoid growth pattern. *Journal of the American Society for Horticultural Science,* **114,** 800–4.

FERNANDEZ-ESCOBAR, R., MARTIN R., LOPEZ-RIVARES, P. and PAZ SUAREZ, M. (1987). Girdling as a means of increasing fruit size and earliness in peach and nectarine cultivars. *Journal of Horticultural Science,* **62,** 493–8.

LAVEE, S., HASKAL, A. and BEN TAL, Y. (1983). Girdling olive trees, a partial solution to biennial bearing. I. Methods, timing and direct tree response. *Journal of Horticultural Science,* **58,** 209–18.

LEWIS, L. N. and MCCARTY, C. D. (1973). Pruning and girdling of citrus. In: *The citrus industry Vol. III* (Reuther, W., Ed.), University of California, Berkeley, USA.

LILLELAND, O. and BROWN, J. G. (1936). Growth study of the apricot fruit. III. The effect of girdling. *Proceedings of the American Society for Horticultural Science,* **34,** 264–71.

NEALS, T. F. and INCOLL, I. D. (1968). The control of leaf photosynthesis rate by the level of assimilate concentration in the leaf: A review of the hypothesis. *Botanical Review,* **34,** 107–25.

NOEL, A. R. A. (1970). The girdled tree. *Botanical Review,* **36,** 162–95.

PRIESTLY, C. A. (1976). Some effects of ringing branches on the distribution of dry matter in young apple trees. *Journal of Experimental Botany,* **27,** 1313–24.

WEINBURGER, J. H. and CULLINAN, F. P. (1932). Further studies on the relation between leaf area and size of fruit, chemical composition, and fruit bud formation in Elberta peaches. *Proceedings of the American Society for Horticultural Science,* **29,** 23–7.

WINKLER, A. J., COOK, J. A., KLIEWER, W. M. and LIDER, L. A. (1974). *General viticulture.* University of California Press, Berkeley, USA.

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