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To cite this article: M. Agust, V. Almela & J. Pons (1992) Effects of girdling on alternate bearing in citrus, *Journal of Horticultural Science*, 67:2, 203-210, DOI: [10.1080/00221589.1992.11516238](https://doi.org/10.1080/00221589.1992.11516238)

To link to this article: <http://dx.doi.org/10.1080/00221589.1992.11516238>



Published online: 27 Nov 2015.



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## Effects of girdling on alternate bearing in citrus

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### SUMMARY

Girdling branches increased flowering in citrus. The number of buds sprouted increased following treatment but the response markedly depends on the time of girdling, summer being most effective. All types of shoots, except vegetative ones, are increased in number but with no differences in its characteristics. The alternate bearing cultivars, such as 'Salustiana' sweet orange and, in some cases, 'Satsuma' mandarin, were improved in productivity by girdling in the following year to one of a high crop. The increase in number of leafy inflorescences was particularly important as this can contribute up to 70% of the total fruit crop.

FLOWERING is an essential component of productivity in citrus. In most cultivars the number of flowers per tree is more than sufficient to obtain a heavy crop; in others, flowering is profuse but competition between growing organs and other factors greatly reduces fruit set and a very low percentage of flowers develop into fruit (Agusti *et al.*, 1982). Some cultivars, mainly seedless ones, scarcely flower at all and the crop is very slight (Moss, 1971). In this last case the absence of flowers does not occur every year but is a characteristic of years following heavy fruiting. The presence of fruit then largely reduces flowering (Moss, 1971) and, therefore, the next crop, through alternate bearing. This phenomenon appears to be a result of within-plant competition for carbohydrate reserves and macronutrients (Monselise *et al.*, 1981; 1983; Monselise and Goldschmidt, 1982).

Girdling has been used in citriculture to obtain several responses (Cohen, 1981) including the improvement of fruit set (Lewis and McCarty, 1973), fruit enlargement (Hochberg *et al.*, 1977; Cohen, 1984a; 1984b; Agusti *et al.*, 1990) and increased flowering (Furr and Armstrong, 1956; Erner, 1988). The influence of girdling on the interrelationships between flowering and fruiting and the improvement of cropping during the 'off' years of alternate bearing citrus cultivars has, however, received little attention.

This paper examines the effectiveness of girdling, and its timing, on the flowering and subsequent yield in the 'off' years of 'Salustiana' sweet orange (*Citrus sinensis* (L.), Osbeck), an alternate bearing variety very appreciated in Spain, and on the flowering of 'Satsuma' mandarin (*Citrus unshiu*, Marcovitch).

### MATERIALS AND METHODS

The experiments were done in two commercial groves, one of sweet orange and the other of mandarin, their behaviour differing with respect to alternate bearing. Trials were conducted on 18 year old 'Salustiana' sweet orange trees, a cultivar with a strong tendency to alternate bearing, and 12 year old 'Satsuma' mandarin trees, a cultivar that, in some cases, tends toward alternate bearing, grafted onto citrange Troyer rootstock. In both cases high yielding trees (about 35 tonnes ha<sup>-1</sup>) were used in the experiments.

From the beginning of the summer (7 July) until 30 days before sprouting (19 January) seven girdling dates were used for the 'Satsuma' mandarin. In the 'Salustiana' sweet orange there were four dates of girdling, from 26 August to 26 December. Trials were on a randomized block design, with single-tree plots and seven replications for each date of girdling in both cases.

The girdling was carried out with sharp scis-

sors, making a cut of ca. 1 mm of effective width, without reaching the xylem. All secondary branches (5–7 cm in diameter) were girdled and no ring of bark was removed.

Four branches per tree of three ages (late spring, summer and autumn sprouts), with some 1200 nodes per branch, were previously selected. During the following spring, the number of sprouted nodes and the number of sprouts per node were counted. In this way data on the percentage sprouting and the number of nodes with one or more sprouts would be obtained. These sprouts were classified into five types according to the number of flowers and leaves (Table I), following the criteria of Guardiola *et al.* (1977), giving the average number of flowers and leaves per sprout and the total number of flowers per branch.

At harvest, the numbers of fruits finally formed on each recorded branch were counted. In the 'Salustiana' sweet orange these fruits were classified according to the sprout in which each was formed, with the objective of assessing the relative importance of the different kinds of inflorescence for the crop.

The values for sprouting, and the number of fruits formed, is expressed per 100 nodes, allowing for better and easier handling of measurements and giving a good estimate of the total number of flowers per tree ( $r \geq +0.94$ ) (Agustí *et al.*, 1985).

Analysis of variance and regression were performed on the data, using Keul's multiple range test for mean separation.

## RESULTS

### *The influence of girdling date on bud sprouting and flowering*

Girdling branches of 'Satsuma' mandarin

increased flowering the following spring. Quantitatively the response depended on the date of girdling (Figure 1), the maximum occurring in those trees girdled at the end of July. Girdling after this date, up to the middle of November, proved progressively less effective. From this date until two weeks before sprouting, girdling did not modify the number of flowers in the trees compared with the controls. Likewise, girdling of trees in early July, before the optimum date, proved ineffective.

The response of 'Salustiana' sweet orange (Figure 2) indicates that the differences between the trees girdled in summer (August and September) and the controls were greater than those found in the 'Satsuma' mandarin. Rather than a differential effect of girdling on floral stimulation in the 'Salustiana' sweet orange, these differences appear due to the low level of flowering in the controls (1.8 flowers per 100 nodes as opposed to 20.5 flowers per 100 nodes in 'Satsuma' mandarin). This is a consequence of the greater depressive effect of the preceding crop on this characteristically alternate bearing variety.

In both cases the flowering response appears to be a stimulating effect of girdling on sprouting. The number of nodes with several shoots, and in particular those with two shoots, is increased by girdling with the same temporal sensitivity and the number of nodes which sprout (Figures 1 and 2). Both effects were almost directly proportional to the variations observed in flowering.

This increase in sprouting affects in a different manner the distribution of distinct types of shoots. In 'Salustiana' sweet orange the unifloral ones, with or without leaves, are more sensitive to girdling (Table I) and the sensitivity

TABLE I

*The influence of girdling date on shoot type in 'Salustiana' sweet orange trees Results expressed in shoots per 100 nodes  $\pm$  SE*

Girdling date	Leafless shoots		Leafy shoots		
	FS	RF	FC	BM	BV
Ungirdled	0.4 $\pm$ 0.1a	0.1 $\pm$ 0.01a	0.9 $\pm$ 0.2a	0.1 $\pm$ 0.02a	19.7 $\pm$ 2.9
26 August	4.0 $\pm$ 0.3b	1.1 $\pm$ 0.3b	4.5 $\pm$ 0.3b	2.7 $\pm$ 0.1b	15.2 $\pm$ 2.5
5 September	2.0 $\pm$ 0.1ab	1.0 $\pm$ 0.2b	2.9 $\pm$ 0.2a	2.2 $\pm$ 0.3b	17.4 $\pm$ 1.8
23 November	1.7 $\pm$ 0.4a	1.1 $\pm$ 0.3b	1.0 $\pm$ 0.2a	0.9 $\pm$ 0.2a	15.0 $\pm$ 1.7
26 December	0.8 $\pm$ 0.2a	0.1 $\pm$ 0.03a	0.6 $\pm$ 0.1a	0.3 $\pm$ 0.1a	16.6 $\pm$ 2.3
Significance	*	*	*	*	n.s.

FS = Shoots with one flower. FC = Shoots with one terminal flower RF and BM = Shoots with several flowers. BV = Vegetative shoots, without flowers.

\*: Significant at  $P \leq 0.05$ , n.s. = not significant.

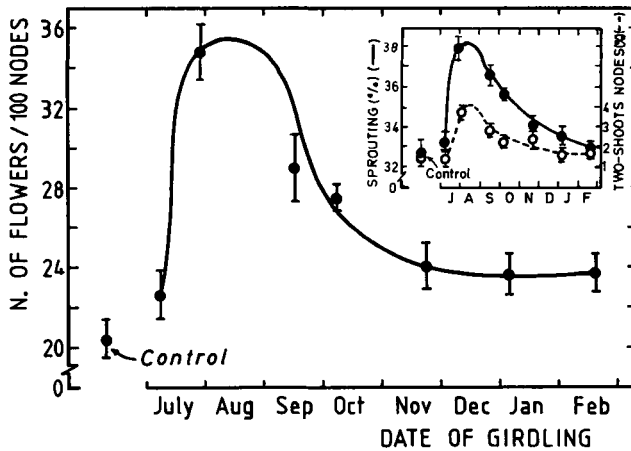


FIG. 1  
Effect of girdling date on flower number and sprouting in 'Satsuma' mandarin trees. The standard errors are given as vertical bars.

of multifloral shoots with leaves is also greater than those multifloral shoots without leaves. In all cases the variations observed corresponded with those found for sprouting and flowering. No differences in the number of vegetative shoots was observed.

Similar results were obtained with the 'Satsuma' mandarin (Table II). In this cultivar the almost total absence of multifloral shoots restricted analysis to the unifloral and vegetative shoots. While the number of unifloral shoots without leaves is almost tripled by girdling at the end of July, the number of vegetative ones is halved. The variations in these two types of shoots relative to the time of girdling are almost parallel (increasing with floral shoots and decreasing with vegetative ones) to those observed over the sprouting and flowering (Figure 1). The number of unifloral leafy shoots is not altered by girdling regardless of when it is done.

The characteristics of the shoots in both cultivars, defined by their numbers of flowers and

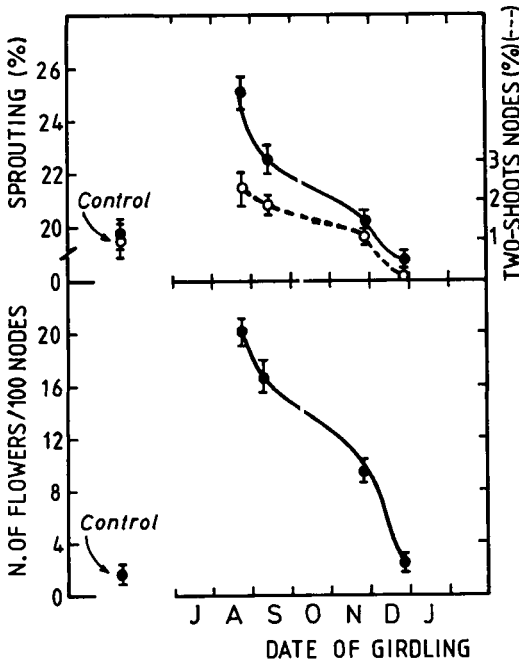


FIG. 2  
Effect of girdling date on flower number and sprouting in 'Salustiana' sweet orange trees. The standard errors are given as vertical bars.

TABLE II  
The influence of girdling date on shoot type in 'Satsuma' mandarin. Results and shoot types as in Table I

Girdling date	Leafless shoots	Leafy shoots	
	FS	FC	BV
Ungirdled	9.6 ± 0.7a	10.8 ± 1.2	15.4 ± 1.5a
7 July	12.0 ± 1.6a	10.3 ± 1.0	13.1 ± 1.5a
28 July	24.7 ± 2.1b	9.8 ± 2.3	9.1 ± 1.9b
16 September	17.7 ± 2.9ab	11.0 ± 1.7	11.5 ± 0.6ab
7 October	13.9 ± 2.1a	12.8 ± 0.9	12.6 ± 1.7ab
23 November	13.8 ± 2.1a	9.9 ± 1.1	13.3 ± 1.2a
5 January	11.1 ± 1.5a	11.7 ± 1.8	12.9 ± 1.0a
19 February	9.0 ± 0.8a	13.7 ± 0.5	13.2 ± 0.6a
Significance	*	n.s.	*

\*. Significant at  $P \leq 0.05$ , n.s. = not significant.

TABLE III  
Effect of girdling date on the number of leaves (L) and flowers (F) per shoot ( $\pm$  SE). Shoot types as in Table I

Girdling date	Shoot types				
	RF F	FC L	BM F	BM L	BV L
<i>'Satsuma' mandarin</i>					
Ungirdled	—	3.1 $\pm$ 0.1	—	—	3.3 $\pm$ 0.2
7 July	—	2.9 $\pm$ 0.1	—	—	3.2 $\pm$ 0.2
28 July	—	2.9 $\pm$ 0.1	—	—	3.5 $\pm$ 0.2
16 September	—	3.1 $\pm$ 0.1	—	—	3.6 $\pm$ 0.2
7 October	—	2.9 $\pm$ 0.1	—	—	3.1 $\pm$ 0.1
23 November	—	3.2 $\pm$ 0.1	—	—	3.5 $\pm$ 0.2
5 January	—	3.1 $\pm$ 0.2	—	—	3.4 $\pm$ 0.2
19 February	—	3.0 $\pm$ 0.1	—	—	3.2 $\pm$ 0.1
Significance		n.s.			n.s.
<i>'Salustiana' sweet orange</i>					
Ungirdled	3.2 $\pm$ 0.7	3.4 $\pm$ 0.2	2.8 $\pm$ 0.1	3.4 $\pm$ 0.5	4.6 $\pm$ 0.2
26 August	3.0 $\pm$ 0.1	3.5 $\pm$ 0.3	3.0 $\pm$ 0.2	3.3 $\pm$ 0.2	4.7 $\pm$ 0.2
5 September	3.2 $\pm$ 0.3	3.4 $\pm$ 0.3	3.1 $\pm$ 0.2	3.3 $\pm$ 0.3	5.1 $\pm$ 0.3
23 November	3.0 $\pm$ 0.2	3.1 $\pm$ 0.5	3.0 $\pm$ 0.3	3.8 $\pm$ 0.3	4.6 $\pm$ 0.2
26 December	3.5 $\pm$ 0.4	3.0 $\pm$ 0.4	3.2 $\pm$ 0.3	3.2 $\pm$ 0.4	4.7 $\pm$ 0.3
Significance	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. = not significant.

leaves, were not altered by girdling at any of the treatment dates (Table III).

#### The effect of flowering variations on crop

The increase in flower number by girdling does not modify the subsequent crop in 'Satsuma' mandarin (Table IV). The number of flowers in the control trees (20.5 per 100 nodes) was enough to obtain an optimum crop (4.37 fruits per 100 nodes) so that an increase in flowering did not increase the crop. This is because fruit set (the determining factor for the crop load) is regulated by the plant through competition between developing fruits. Therefore, the percentage of flowers which set decreases as flowering increases, compensating

TABLE IV  
The influence of girdling date on fruit set and number in 'Satsuma' mandarin

Girdling date	Fruit set (% of flowers)	Fruits (per 100 nodes)
Ungirdled	21.2 $\pm$ 2.3a	4.37 $\pm$ 0.56
7 July	20.4 $\pm$ 2.8a	4.58 $\pm$ 0.34
28 July	13.7 $\pm$ 1.1b	4.75 $\pm$ 0.22
16 September	16.4 $\pm$ 0.8b	4.47 $\pm$ 0.29
7 October	17.6 $\pm$ 0.8ab	4.60 $\pm$ 0.33
23 November	23.9 $\pm$ 2.5a	4.41 $\pm$ 0.44
5 January	21.3 $\pm$ 1.9a	4.83 $\pm$ 0.60
19 February	21.9 $\pm$ 2.1a	5.32 $\pm$ 0.59
Significance	*	n.s.

\*: Significant at  $P \leq 0.05$ ; n.s. = not significant.

this increase and maintaining the same crop on all the trees. Trees girdled from the end of July to the beginning of October showed a greater increase in flower number and the percentage of those that set was greatly reduced (Table IV).

In the 'Salustiana' sweet orange, however, the increase in flowering through girdling led to an increase in subsequent fruit yield (Table V). After a year of heavy fruit production, such as the one before our experiment, poor flowering in the control trees (1.8 flowers per 100 nodes) gives very low yield (1.02 fruits per 100 nodes), reflecting alternate bearing. The increase of flowering through girdling in early August (20.3 flowers per 100 nodes) leads to a heavy crop (up to 5 fruits per 100 nodes). As in 'Satsuma' mandarin, the trees regulate their fruit

TABLE V  
Crop load of 'Salustiana' sweet orange trees. Effect of date of girdling

Girdling date	Fruit set (% of flowers)	Fruits (per 100 nodes)
Ungirdled	56.5 $\pm$ 5.4a	1.02 $\pm$ 0.25a
26 August	24.1 $\pm$ 2.6b	5.00 $\pm$ 0.97b
5 September	33.8 $\pm$ 3.5ab	3.43 $\pm$ 0.83ab
23 November	44.0 $\pm$ 5.5ab	2.61 $\pm$ 0.59ab
26 December	52.2 $\pm$ 5.6a	1.06 $\pm$ 0.37a
Significance	*	*

\*: Significant at  $P \leq 0.05$ .

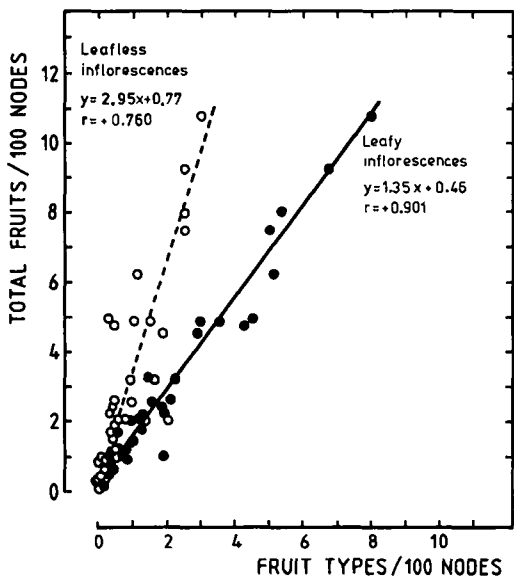


FIG. 3

Contribution of the fruits located on leafless and leafy inflorescences to the total number of fruits cropped per tree in 'Salustiana' sweet orange

number to their capacity to support them, so that the percentage of flowers set falls as flowering increases (Table V).

The increase in the number of leafy inflorescences (Table I) is the reason for the increased yield of the 'Salustiana' sweet orange. The number of fruits of the leafy and leafless inflorescences and the total number of fruits picked, both show a linear relationship (Figure 3). For shoots with leaves, 80% of the variability in this relationship is explained by the shoot type ( $r = +0.901$ ) and its slope (1.35) indicates that 75% of the fruits harvested come from this type of inflorescence.

#### DISCUSSION

Alternate bearing is a frequent phenomenon in many woody species and *Citrus spp.* are no exception. This phenomenon has been widely studied and reviewed (Davies, 1957; Jonkers, 1979; Monselise and Goldschmidt, 1982; Agustí, 1987). In citrus, fruit can modify the hormonal balance through the synthesis of gibberellins, which inhibits flower formation the following spring in some cultivars (Moss, 1971), and this is an essential factor of alternate bearing because it is the lack of flowers that reduces the crop.

The reduction of carbohydrate and nitrogenous reserves in roots of trees with a heavy crop, has also been put forward as a cause of reduced flowering and, therefore, directly linked to alternate bearing (Golomb and Goldschmidt, 1981; Goldschmidt and Golomb, 1982). Finally, the possibility that hormonal and nutritional interactions partially control flowering seems to have been discarded; Goldschmidt *et al.* (1985) indicate that both factors act independently on flower regulation in citrus.

In the alternate bearing cultivars of sweet orange, the relationship between flowering and yield follows a curve in two phases; the first with between 0 and 20 flowers per 100 nodes in which the yield increases with the number of flowers, and a second with above 20 flowers per 100 nodes in which the yield is independent of flower intensity (Becerra and Guardiola, 1984; Agustí *et al.*, 1985). Therefore, raising the rate of flowering above this threshold is essential to correct alternate bearing.

This stimulating effect of girdling on flowering in citrus has been clearly shown in several studies (Furr and Armstrong, 1956; Cohen, 1981; 1984b; Goldschmidt *et al.*, 1985; Erner, 1988), but almost none has previously related the increase in flowering obtained to the subsequent yield of strongly alternate bearing cultivars. On the other hand, girdling by these authors involved peeling off a ring of bark 2–3 cm wide, causing a prolonged interruption of phloem transport, accumulating high quantities of carbohydrates in the leaves which may then abscise (Cohen, 1981) and disturb next year's crop.

In contrast with the results of Erner (1988), girdling in summer proved to be most effective in increasing flowering in our experiments, by stimulating bud sprouting (Figures 1 and 2). These results show that girdling can affect the buds' capacity to develop, a process determined during summer (Guardiola, 1981), coinciding with the period of greatest sensitivity to girdling. Despite this, stimulation of budding is not enough to explain the increased flowering. When bud sprouting is under glass forced *in vitro*, flowers are not obtained (Guardiola *et al.*, 1982) except when trees have been previously girdled (García-Luis *et al.*, 1989), and even so, under these conditions they never reach the same level of flowering as obtained outdoors.

The presence of a substance which promotes flowering in the plant and whose synthesis (Monselise, 1979) and/or transport can be modified by girdling, appears to be the explanation for the increased flowering.

Stimulation of sprouting by girdling does not affect all types of shoots equally (Tables I and II). Differential sensitivity of shoots demands alterations in the buds, previous to sprouting, caused by girdling, and also impedes any attempt to explain increased flowering in terms, exclusively, of increased sprouting. A similar response can be found when studying inhibition of flowering by exogenous applications of gibberellic acid (Monselise and Halevy, 1964; Ohgaki, 1966; Guardiola *et al.*, 1982). In this case there is always less sprouting (Guardiola *et al.*, 1977) but with unequal distribution according to the different types of shoots (Guardiola, 1981; Guardiola *et al.*, 1982; García-Luis *et al.*, 1986). The results of Erner (1988) cannot be interpreted in this way since his evaluations were made in terms of the percentage of each type of shoot. The increment of the total number of sprouts that he obtained by autumn girdling could carry an increase in the number of some shoots per 100 nodes, the unit that we use. Differences in location, cultivar and in the method of girdling can explain, however, not only these different results on the distribution of the type of spring-flush shoots, but the effect of treatment date on sensitivity to girdling.

The parallel between sprouting and flowering in our experiment is explained, in 'Salustiana' sweet orange, mainly by the increase obtained in multifloral shoots with leaves. In the 'Satsuma' mandarin the increase in the number of leafless shoots is sufficient explanation, since in this cultivar there are only two types of inflorescences and the number of leafy ones does not vary. Therefore, whatever the increase in sprouting, it is transformed into a parallel increase in flowering.

Despite changes in the distribution of the different types of shoots by summer girdling, the number of leaves or flowers present in each does not vary (Table III). This characteristic resembles the plant's response to temperature (Moss, 1969), as well as to the inhibitory effect of the fruit (Moss, 1971) and exogenous applications of gibberellic acid (Guardiola *et al.*,

1980) on flowering. None of these factors, or the changes which their application or modification provokes, can alter shoot development, although they can promote or inhibit its initiation.

The importance which the increase in flowering, promoted by girdling, has on the subsequent yield depends on cultivar. In 'Satsuma' mandarin, a heavy crop does not usually reduce the next flowering to below 20 flowers per 100 nodes (Figure 1) so that the subsequent crop is not reduced (Becerra and Guardiola, 1984; Agustí *et al.*, 1985). The increase in flowering following girdling is not transformed here into increased yield, given that the plant controls fruit number. This process is regulated by internal competition between developing organs (Agustí *et al.*, 1982; Guardiola *et al.*, 1984) with more abscission as flowering increases, giving progressively smaller fruit sets (Table IV).

However, in the 'Salustiana' sweet orange, when the previous crop load is high, flowering is drastically reduced to fewer than 2 flowers per 100 nodes (Figure 2) with a consistent reduction in the next crop. This interdependence, marked by the previous yield, establishes strict alternate bearing. Stimulation of flowering to more than 20 flowers per 100 nodes (a ten-fold increase), provoked by girdling in August (Figure 2), increases yield five-fold. The differences between the increase in flowering and the increase in yield is due to the variations in the percentage of the fruit set (Table V) which, as in 'Satsuma' mandarin, is regulated by the internal competition between developing flowers. In this case the increase in the number of leafy inflorescences causes the increase in crop load, seeing that these give rise to approximately 75% of the fruits (Figure 3), similar to non-forced flowering (Agustí *et al.*, 1985).

Girdling of branches between the end of July and the end of August increased flowering in citrus to more than 20 flowers per 100 nodes in both cultivars tested. With 'Salustiana' sweet orange alternate bearing was eliminated, increasing yields to optimum levels. In some cases girdling could be needed every year to avoid the depressive effect that increased yield can have on the following year's blossoming.

In Spain the repeated use of this technique (at other times of year and with different objectives) has not shown depressive effects on

either the development of the trees or their longevity. The economic cost must be assessed but it should always be less than the losses incurred by a reduced crop.

## REFERENCES

- AGUSTI, M. (1987). La alternancia de cosechas en los agríos. *Fruticultura Profesional*, **8**, 20–6.
- AGUSTI, M., ALMELA, V. and GUARDIOLA, J. L. (1985). Interrelaciones floración-fructificación en el naranjo dulce Salustiana (*Citrus sinensis* (L.) Osb.). *VI Reunión Nacional SEFV. Resúmenes*, No. 195.
- AGUSTI, M., ALMELA, V. and AZNAR, M. (1991). Rayado y tamaño final del fruto en los agríos. *I Congreso Ibérico de Ciencias Hortícolas*, **216** (abstract).
- AGUSTI, M., GARCIA-MARI, F. and GUARDIOLA, J. L. (1982). The influence of flowering intensity on the shedding of reproductive structures in sweet orange. *Scientia Horticulturae*, **17**, 343–52.
- BECERRA S. and GUARDIOLA, J. L. (1984). Inter-relationship between flowering and fruiting in sweet orange, cultivar Navelina. *Proceedings of the International Society of Citriculture*, **1**, 190–4.
- COHEN, A. (1981). Recent developments in girdling of citrus trees. *Proceedings of the International Society of Citriculture*, **1**, 196–9.
- COHEN, A. (1984a). Citrus fruit enlargement by means of summer girdling. *Journal of Horticultural Science*, **59**, 119–25.
- COHEN, A. (1984b). Effect of girdling date on fruit size of Marsh Seedless grapefruit. *Journal of Horticultural Science*, **59**, 567–73.
- DAVIES, L. D. (1957). Flowering and alternate bearing. *Proceedings of the American Society for Horticultural Science*, **70**, 545–56.
- ERNER, Y. (1988). Effects of girdling on the differentiation of inflorescence types and fruit set in Shamouti orange trees. *Israel Journal of Botany*, **37**, 173–80.
- FURR, J. R. and ARMSTRONG, W. W. (1956). Flower induction in grapefruit in the Coachella Valley, California. *Proceedings of the American Society for Horticultural Science*, **67**, 176–82.
- GARCIA-LUIS, A., ALMELA, V., MONERRI C., AGUSTI, M. and GUARDIOLA, J. L. (1986). Inhibition of flowering “in vivo” by existing fruits and applied growth regulators in *Citrus unshiu*. *Physiologia Plantarum*, **66**, 515–20.
- GARCIA-LUIS, A., SANTAMARINA, P. and GUARDIOLA, J. L. (1989). Flower formation from *Citrus unshiu* buds cultured *in vitro*. *Annals of Botany*, **64**, 515–9.
- GOLDSCHMIDT, E. E., ASCHKENAZI, N., HERZANO, Y., SCHAFFER, A. and MONSELISE, S. P. (1985). A role of carbohydrate levels in the control of flowering in citrus. *Scientia Horticulturae*, **26**, 159–66.
- GOLDSCHMIDT, E. E. and GOLOMB, A. (1982). The carbohydrate balance of alternate-bearing citrus trees and the significance of reserves for flowering and fruiting. *Journal of the American Society for Horticultural Science*, **107**, 206–8.
- GOLOMB, A. and GOLDSCHMIDT, E. E. (1981). Mineral balance of alternate bearing Wilking mandarin. *Alon Hanotea*, **35**, 639–47.
- GUARDIOLA, J. L. (1981). Flower initiation and development in citrus. *Proceedings of the International Society of Citriculture*, **1**, 242–6.
- GUARDIOLA, J. L., AGUSTI, M., BARBERA, J. and GARCIA-MARI, F. (1980). Influencia de las aplicaciones de ácido giberélico durante la brotación en el desarrollo de los agríos. *Revista de Agroquímica y Tecnología de Alimentos*, **20**, 139–43.
- GUARDIOLA, J. L., AGUSTI, M. and GARCIA-MARI, F. (1977). Gibberellic acid and flower bud development in sweet orange. *Proceedings of the International Society of Citriculture*, **2**, 696–9.
- GUARDIOLA, J. L., GARCIA-MARI, F. and AGUSTI, M. (1984). Competition and fruit set in the Washington navel orange. *Physiologia Plantarum*, **62**, 297–302.
- GUARDIOLA, J. L., MONERRI C. and AGUSTI, M. (1982). The inhibitory effect of gibberellic acid on flowering in citrus. *Physiologia Plantarum*, **55**, 136–42.



- HOCHBERG, R. S., MONSELISE, S. P. and COSTO, J. (1977). Summer girdling and 2,4-D effects on grapefruit sizes. *HortScience*, **12**, 228.
- JONKERS, H. (1979). Biennial bearing in apple and pear: a literature survey. *Scientia Horticulturae*, **11**, 303–17.
- LEWIS, L. N. and McCARTY, D. (1973). Pruning and girdling of citrus. In: *The citrus industry, Vol III* (Reuther, W., Ed.). University of California, Berkeley, USA, 211–29.
- MONSELISE, S. P. (1979). The use of growth regulators in citriculture. A review. *Scientia Horticulturae*, **11**, 151–62.
- MONSELISE, S. P. and GOLDSCHMIDT, E. E. (1982). Alternate bearing in fruit trees. *Horticultural Reviews*, **4**, 128–73.
- MONSELISE, S. P., GOLDSCHMIDT, E. E. and GOLOMB, A. (1981). Alternate bearing in citrus and ways of control. *Proceedings of the International Society of Citriculture*, **1**, 239–42.
- MONSELISE, S. P., GOLDSCHMIDT, E. E., GOLOMB, A. and ROLF, R. (1983). Alternate bearing in citrus: Long-term effects of a single girdling treatment on individual “Michal” tangerine branches. *Journal of the American Society for Horticultural Science*, **108**, 373–6.
- MONSELISE, S. P. and HALEVY, A. H. (1964). Chemical inhibition and promotion of citrus flower bud induction. *Proceedings of the American Society for Horticultural Science*, **84**, 141–6.
- MOSS, G. I. (1969). Influence of temperature and photoperiod on flower induction and inflorescence development in sweet orange (*Citrus sinensis* (L.) Osbeck). *Journal of Horticultural Science*, **44**, 311–20.
- MOSS, G. I. (1971). Effect of fruit on flowering in relation to biennial bearing in sweet orange (*Citrus sinensis*). *Journal of Horticultural Science*, **46**, 177–84.
- OHGAKI, C. (1966). Control of citrus flower bud formation. I. The effect of gibberellic acid spraying on flower bud formation in Satsuma orange trees. *Chemical Regulation of Plants*, **1**, 183–5.

(Accepted 7 August 1991)