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Some factors influencing flowering and fruit-set of clementine mandarin (1)

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Flowering process and fruit-setting in citrus can be affected by several internal or external factors. Among the first ones, the main tree factor influencing flowering is the maturing fruit (21, 26), while vegetative growth and rootstocks may influence the number of inflorescences and of flowers formed (26).

Many external factors also affect citrus flowering; they are temperature (5, 10, 12, 18, 31), photoperiod (10, 18), and growth substances (4, 7, 13, 14, 16, 20, 22, 25, 27, 28, 30, 32) during flower differentiation.

Fruit-setting, on the other hand, is strongly related to flower density (26) and inflorescence type (6, 8, 9, 19, 24), while temperature and growth substances may have some influence (3, 23, 26, 29).

From a practical view-point this information could be of great importance in the control of some factors affecting productive behaviour of the trees, but many aspects need further studies.

This paper describes several experiments conducted in Sardinia on clementine mandarin. Studies were carried out at the « Istituto di Coltivazioni arboree » experimental station, near Oristano (Sardinia), from 1973 to 1976, and were investions about effects of growth substances, light and temperature on flowering process and subsequent fruit-setting.

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MATERIAL AND METHODS

a - *1973 Trials* - Five-year-old clementine trees on sour orange rootstocks were sprayed with gibberellic acid at different times.

The treatments were:

1 - 20 p.p.m. GA on 10 and 30 Nov. 1972,
2 - 20 p.p.m. GA on 30 Nov. and 20 Dec. 1972,
3 - 20 p.p.m. GA on 20 Dec. 1972 and 9 Jan. 1973,
4 - 10 p.p.m. GA on 10 and 30 Nov., 20 Dec. 1972, and 9 Jan. 1973,
5 - control, no spray.

A complete randomized block design was used, with 7 replications of a single-tree-plot.

Observations were made in the following spring on flowering and fruit-setting. Fruit-set was recorded one month after the anthesis.

b - *1974-1975 Trials* - A factorial experiment was established on 7-year-old clementine trees grafted on sour orange. The following main treatments were compared:

1 - trees artificially shaded, beginning on October 1973,
2 - trees not shaded.

For each of the main treatments three secondary treatments were made as follows:

1_a - 20 p.p.m. GA at 20 days interval from 30 Nov. to 20 Feb.,
2_a - 2,000 p.p.m. Alar at 20 days interval for the same period,
3_a - control, no spray.

Shading was made by surrounding trees over and around with large cages covered with nets of black nylon. The reduction of light intensity under the cages was about 50%. Three trees for each cage were arranged. A split-plot design was used with three replications of a single-tree plot. Observations were made the next spring as in 1973 experiment.

c - *1976 Trials* - To evaluate residual effects of the treatments made in the previous years the same trees were not sprayed with GA and Alar in this year, but shade-frames were removed at different times, as follows:

1 - trees shaded until 15 Nov. 1975,
2 - trees shaded until 30 Dec. 1975,
3 - trees shaded until 15 Feb. 1976.

The same experimental design as in 1975 was used, and the same observations were recorded in the following spring. Air temperature was also recorded during all the experiments above decribed.

RESULTS

a - *1973 Trials* - The number of flowers per m² of canopy was drastically reduced by GA treatments. Flowering reduction was greater in treatments 1 and 4 and less effective in treatment 3, depending on the spraying period (Table 1).

Table 1 - *The effects of gibberellic acid sprays on flowering and subsequent fruit-set of clementine mandarin* (1973 Trials).

Tabella 1 - *Effetti dell'acido gibberellico sulla fioritura e l'allegagione del clementine* (anno 1973).

GA Treatments	Flowers / m²	Leafy inflor. / m²	Leafless inflor. / m²	Fruits / m²	% Fruit-set
20 p.p.m.					
1 - Nov. 10 - Nov. 30	495 a	102 c	40 a	32.5 b	6.6 c
2 - Nov. 30 - Dec. 20	590 b	86 b	100 b	23.5 a	4.0 b
3 - Dec. 20 - Jan. 9	692 c	64 a	121 c	25.7 a	3.7 ab
10 p.p.m.					
4 - Nov. 10/30 - Dec. 20 - Jan. 9	465 a	112 c	48 a	35.0 b	7.5 c
5 - Control	855 d	55 a	156 d	25.0 a	2.9 a
Significance level (1)	**	**	**	**	**

(1) * Significance of F at the 5% level.

** Significance of F at the 1% level.

Means followed by the same letter or letters in each column do not differ significantly at the 5% level.

GA treatments resulted in more leafy inflorescences and fruit number per m² of canopy. The reduced flower density resulted in a higher fruit-set

percentage. GA increased leafy inflorescences and the fruit-set percentage mainly in treatments 1 and 4, the same treatments where a higher decrease in flower number was observed.

b - *1974-1975 Trials* - In the 1974 experiments, as shown in Table 2, it has been observed that flower density in the canopy was reduced by shading, and by GA treatments too. Alar, on the contrary, increased flower number per unit area of canopy.

Table 2 - *Effects of artificial shading, gibberellic acid, and Alar sprays on flowering, and subsequent fruit-set of clementine mandarin* (1974 Trials) (1).

Tabella 2 - *Effetti dell'ombreggiamento, dell'acido gibberellico e dell'Alar sulla fioritura e l'allegagione del clementine* (anno 1974).

Treatments	Flowers / m²	Leafy inflor. / m²	Leafless inflor. / m²	Fruits / m²	% Fruit-set
Shading	2,548	331	630	16.9	0.7
No-shading	3,829	324	469	41.2	1.1
Significance level	**	NS	**	**	**
GA	2,809 a	539 b	408 a	21.7 a	0.8 a
Alar	3,553 c	206 a	579 b	39.2 b	1.1 b
Control	3,203 b	238 a	602 b	26.3 b	0.8 a
Significance level	**	**	*	**	*
Interaction	NS	NS	NS	NS	NS

(1) See table 1, foot note (1), for meaning of statistical symbols and interpretation.

No significant effect by shading was recorded on leafy inflorescences per m², but leafless inflorescence number was greater in shaded trees. GA sprays, as in the previous year, increased leafy inflorescence number compared to the control, while no effect was found from Alar treatment. A reduction in number of leafless inflorescences was also found in the GA treatment. The fruit number per m² was drastically reduced by shading. GA sprays also reduced fruit number, which on the other hand was increased by Alar sprays. A reduction in fruit-set percentage was found in shaded trees, while no difference occurred between GA treatment and control. Alar treatment on the other hand slightly increased fruit-set percentage.

No interaction effects were found between the main and the secondary treatments.

In the 1975 experiment the effect of shading on flower number has been rather evident (Table 3): in shaded trees the number of flowers per m^2 of canopy was drastically reduced.

Table 3 - *Effects of artificial shading, gibberellic acid, and Alar sprays on flowering, and subsequent fruit-set of clementine mandarin* (1975 Trials) (1).

Tabella 3 - *Effetti dell'ombreggiamento, dell'acido gibberellico e dell'Alar sulla fioritura e l'allegagione del clementine* (anno 1975).

Treatments	Flowers / m^2	Leafy inflor. / m^2	Leafless inflor. / m^2	Fruits / m^2	% Fruit-set
Shading	311	20	16	52	16.7
No-shading	1,240	103	126	211	17.0
Significance level	**	**	**	**	NS
GA	551 a	100 c	40 a	100 a	18.1 b
Alar	1,019 c	36 a	109 c	158 c	15.5 a
Control	757 b	49 b	65 b	136 b	18.0 b
Significance level	**	**	**	**	**
Interaction	NS	NS	NS	NS	NS

(1) See table 1, foot note (1), for meaning of statistical symbols and interpretation.

GA and Alar effect on flowering was about the same as in 1974. Low ligth intensity by shading also reduced the inflorescence number and the number of fruits per m^2, while no difference was observed as far as the fruit-set percentage is concerned.

The GA effect resulted in an increase of leafy inflorescences and in a decrease of leafless ones; the fruit number per m^2 was reduced and no difference with the control was recorded on fruit-set percentage. The Alar treatments produced a less leafy inflorescences, but more leafless inflorescences and fruits per m^2, while the fruit-set percentage was reduced.

c - *1976 Trials* - Residual effects of shading and chemicals sprays were observed during the spring of 1976. In that year shaded trees, contrary to the pre-

vious experiments, produced more flowers per m² of canopy (Table 4). Leafy inflorescences were reduced, while leafless ones were increased. No difference was found on fruit set per m², but fruit-set percentage was slightly decreased by shading. Meanwhile among shaded trees some differences were recorded. Trees shaded until 15 November 1975 produced the greatest number of flowers, of leafless inflorescences and of fruits per m² of canopy, but the leafy inflorescences number and the fruit-set percentage were reduced.

Table 4 - *Influence of artificial shading, and residual effects of gibberellic acid, and Alar sprays on flowering, and subsequent fruit-set of clementine mandarin* (1976 Trials) (1).

Tabella 4 - *Influenza dell'ombreggiamento, ed effetti residui dell'acido gibberellico e dell'Alar sulla fioritura e l'allegagione del clementine* (anno 1976).

Treatments	Flowers / m²	Leafy inflor. / m²	Leafless inflor. / m²	Fruits / m²	% Fruit-set
Shading	357	51	56	46	12.9
No-shading	273	101	22	42	15.4
Significance level	*	**	**	NS	*
Shading until Nov. 15	868 b	43 a	135 b	78 c	9.0 a
Shading until Dec. 30	106 a	49 a	21 a	39 b	36.8 c
Shading until Feb. 15	96 a	61 b	11 a	22 a	22.9 b
Significance level	**	**	**	**	**
Residual effects of					
GA	460 c	119 b	59 b	78 c	16.9 c
Alar	349 b	58 a	50 b	44 b	12.6 b
Control	135 a	51 a	8 a	10 a	7.4 a
	**	**	**	**	**

(1) See table 1, foot note (1), for meaning of statistical symbols and interpretation.

Trees shaded until 30 December 1975 or 15 February 1976 resulted in less flowers, less leafless inflorescences, and less fruits per m² of canopy, but the fruit-set percentage was strongly increased.

Observations on residual effects of growth substances showed that

trees sprayed with GA in the previous year produced more flowers, more leafy and leafless inflorescences, and more fruits per m^2 of canopy; the fruit-set percentage resulted also increased. Intermediate effects were found on trees with prior Alar sprays, while control trees produced still less flowers, less leafless inflorescences and less fruits, and the fruit-set percentage was drastically reduced.

Flower density effect

In all of the experiments the flower density was related to the number of fruits per m^2 of canopy and to the fruit-set percentage. Significant correlations were found in 1973, 1975 and 1976. Fig. 1 reports these correlations. Normally the fruit-set per m^2 of canopy increased as the number of flowers increased, while a negative correlation was found between the number of flowers per unit area of canopy and the fruit-set percentage.

Temperature effect

Mean temperatures during the 5 weeks before flowering were recorded every year and were related to the number of flowers produced per m^2 of canopy and to the fruit-set percentage. Results reported in Table 5 evidence that temperatures were normally positively correlated with the number of flowers produced per unit area of canopy, but negatively with the fruit-set percentage; however these correlations do not appear to be always true.

Table 5 - *Temperature effect on flower-number and fruit-set.*

Tabella 5 - *Relazione fra temperatura e entità della fioritura e dell'allegagione.*

Year	Mean temperature during 5 weeks before flowering °C	Flowers $\frac{}{m^2}$	Fruit-set %
1973	10.5	855	2.9
1974	12.2	3,100	1.0
1975	9.4	1,019	15.5
1976	10.0	615	8.0

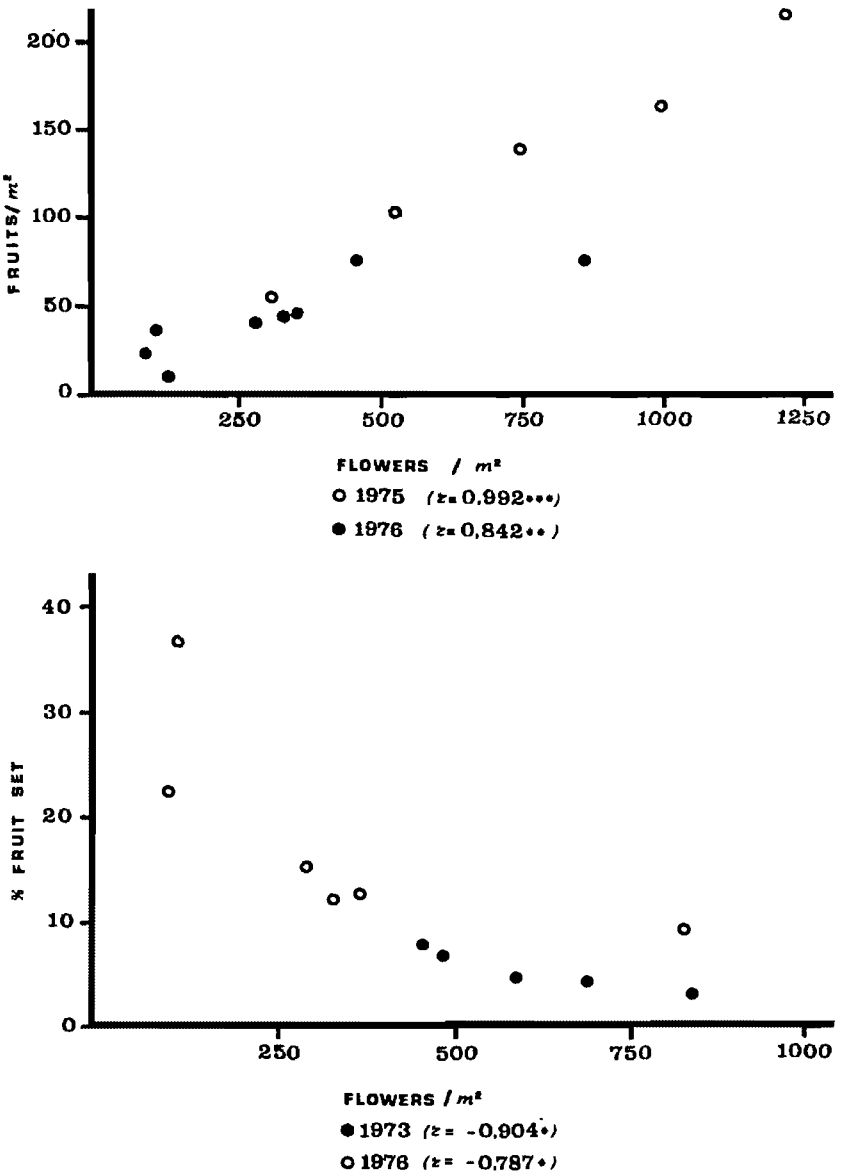

Fig. 1 - Relationship between the number of flowers and that of fruits per square meter of canopy (above), and between the number of flowers per square meter of canopy and the fruit-set percentage (below).

Fig. 1 - Relazione fra numero di fiori e numero di frutti per m² di chioma (sopra), e fra numero di fiori per m² di chioma e percentuale di allegagione (sotto).

DISCUSSION

GA effects - In these experiments we found that gibberellic acid when applied aroud the time of flower induction (11) reduces the flowering, so confirming our earlier experiences (4) and many others of various Authors, as reported by Moss (26, 27). Reducing density of flowers resulted in a higher fruit-set percentage. Undoubtedly, since GA induces more vegetative growth (7) and the formation of a greater number of leafy inflorescences with sufficient foliar surface and photosynthetic capacity to support early development of fruits in the same shoot, this resulted in a greater fruit-set percentage. Moreover, it has been found by Monselise and Hubermann that in GA-treated trees protein metabolism in also involved, since protein fractions present in buds producing flowers are different from those in which flower formation has been prevented by GA (17).

Alar effects - Previous results reported by Monselise et al. (13, 14, 15) indicated that growth retardants increased the flower formation in lemon trees and in normally yielding sweet orange trees, but failed to improve flower production in poor yielding trees. On the other hand Moss (22) stated that attempts to increase flowering of sweet orange trees in an off-crop year by Alar sprays were unsuccessful.

In our studies we found that Alar treatments improved flowering, but reduced the leafy-inflorescences per unit area of canopy; the number of fruits set per m^2 of canopy was increased, while the fruit-set percentage was in most cases decreased. This result, apparently contrasting with that reported by Moss (22), is probably due to the fact that in our experimental orchard no definite alternate bearing was established. In fact the average yield per tree was Kg 19.8 in 1973, Kg 18.3 in 1974, Kg 33.7 in 1975, and Kg 32.4 in 1976.

Shading effects - The main consistent effect of artificial shading resulted in a drastical reduction of flowering, of inflorescence, and of fruit number per m^2 of canopy, while no definite effects were found on the fruit-set percentage. These results were more evident in the second year of artificial shading. As reported by Reuther (33) a similar case is well-known in some other citrus areas, where citrus orchards are established in the shade of date palms or other plant species as windbreaks. Of course this kind of planting is done to give some protection from wind and frost damage, but, as Reuther

stated, « citrus production in the shade of date palms is only about one-half that obtained in comparable unshaded plantings ». On the other hand, an earlier work conduced by our Institute on grapefruit trees (1) confirmed that shading negatively affects flower differentiation and subsequent yield. If low light-intensity could increase gibberellin content in some tree organs, this would explain the negative effect of shading on flowering, but the experiences already known (2) do not confirm these assumptions, since the light-gibberellin interactions are often complex.

Temperature effects - From our experiment it would seem that warm temperatures before flowering increase flower formation, and relatively cold temperatures decrease it, but they increase the fruit-set percentage, so partially confirming earlier results reported by Milella (12).

Of course the reduction of the fruit-set percentage seems to be strictly related to the flower density (see also Fig. 1). Moreover, since the fruits produced per unit area of canopy are directly related to the number of flowers per m^2, it would be clear that warmer conditions before flowering would result in higher yields; but we have always found, as reported by Moss (26), that temperatures during the 5 weeks before flowering were negatively correlated with the subsequent yield (data not reported here). Thus, this fact could imply that a great number of fruitlets drops after fruit-set, so confirming previous data reported by Milella (12).

Unfortunately we have not recorded the fruit-drop percentage in our experiment, therefore explanation for this effect need further investigations.

SUMMARY

A four-year research study conducted in center Sardinia on clementine mandarin has evidenced that flowering and subsequent fruit-set can be affected by several factors, i.e., growth substances, light intensity and temperature before flowering. Particularly it has been shown that gibberellic acid sprayed during flower differentiation reduced the number of flowers/square meter of canopy,but increased the number of leafy inflorescences and the fruit-set percentage. Alar sprayed in the same conditions increased the number of flower/square meter and reduced the number of leafy inflorescences and the fruit-set percentage. Low light intensity obtained by shading trees with large cages covered with nets of black nylon decreased the number of flowers and leafy inflorescences, but no clear effects were found on the fruit-set percentage. Warm temperatures before flowering increased the number of flowers/square meter, but decreased the fruit-set percentage.

RIASSUNTO

Una ricerca quadriennale condotta nella Sardegna centrale (Oristano) ha messo in evidenza che la fioritura e la successiva allegagione del clementine possono essere influenzate da diversi fattori, fra cui sostanze di crescita, intensità luminosa e condizioni termiche prima della fioritura stessa. In particolare è stato messo in evidenza che trattamenti a base di acido gibberellico nel corso della differenziazione delle gemme a fiore riducono il numero dei fiori, ma aumentano il numero di infiorescenze provviste di foglie e la percentuale di allegagione. Trattamenti a base di Alar effettuati nello stesso periodo fanno aumentare il numero dei fiori, ma riducono quello delle infiorescenze con foglie e la percentuale di allegagione. E' stato osservato, inoltre, che la riduzione dell'intensità luminosa, ottenuta a mezzo di grosse gabbie ricoperte di rete di nylon nero e poste al di sopra e intorno alle piante in esperimento, fa diminuire il numero di fiori e il numero di infiorescenze provviste di foglie, mentre non si sono notati effetti probanti sulla percentuale di allegagione.

E' stato rilevato, infine, che il verificarsi di temperature relativamente miti prima della fioritura fa aumentare l'entità della fioritura stessa, ma riduce la percentuale di allegagione.

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