MODIFICATION OF THE FLORAL DIFFERENTIATION WITH GIBBERELLIC ACID IN NAVEL ORANGE

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SUMMARY

The application of gibberellic acid (GA3) over *Citrus* modifies the flowering. The different structures present variation in the sensibility to the hormone; the leafy inflorescences are less sensitive than the leafless inflorescences. The enhance in the percentage of leafy inflorescences allows to increase the fruit set, leading to a greater production, since in most cases the fruit set is the factor that determines yield. In this paper it is verified the effect of GA3 on floral differentiation, fruit set and quality fruit in three varieties of navel orange, under climatic conditions of the northeast of Buenos Aires. The experiment was performed with trees that belong to a fruit farming placed in Pilar. Three GA3 treatments were used (o p.p.m.; 20 p.p.m. and 40 p.p.m.). The results obtained are in agreement with those achieved in other places of the world: a redistribution of the sprouting that allows to obtain a greater quantity of leafy inflorescences and a greater quantity of fruits.

Key words: navel orange, gibberellic acid, differentiation, fruit set.

MODIFICACIÓN DE LA DIFERENCIACIÓN FLORAL MEDIANTE LA APLICACIÓN DE ÁCIDO GIBERÉLICO EN NARANJOS NAVEL

RESUMEN

La aplicación de ácido giberélico (GA3) modifica la floración en *Citrus*. Existe variación en la sensibilidad a esta hormona por parte de las distintas estructuras, siendo menos sensibles las inflorescencias con hojas que aquellas desprovistas de las mismas. El aumento en la proporción de inflorescencias con hojas permite un aumento en el cuajado de frutos dando lugar a una mayor producción, ya que el porcentaje de cuajado es en la mayoría de los casos el factor que determina el rendimiento. En el presente trabajo se verificó el efecto del GA3 sobre la diferenciación floral, cuajado y calidad de frutos obtenidos en tres variedades de naranjo del grupo navel para las condiciones climáticas de la zona noreste de la provincia de Buenos Aires. El ensayo se llevó a cabo sobre árboles de un monte frutal ubicado en la localidad de Pilar, realizándose tres tratamientos con GA3 (0 p.p.m.; 20 p.p.m. y 40 p.p.m.). Los resultados obtenidos concuerdan con aquellos logrados en otras partes del mundo, observándose una redistribución de la brotación que permite obtener mayor cantidad de inflorescencias con hojas y una mayor cantidad de fruto

Palabras clave: naranjo navel, acido giberélico, diferenciación, cuajado.

INTRODUCTION

Flowering in *Citrus* is inhibited by the application of exogenous gibberellic acid (GA3) (Guardiola *et al.*, 1982). Later applications of GA3, timed to bud sprouting when flower differentiation is detectable under the microscope (Nir *et al.*, 1972; Goldshmidt and Monselise 1972; Guardiola *et al.*, 1980) allows this effect to be produce.

Guardiola *et al.* (1982) observed that buds producing leafless inflorescences are far more sensitive than those developing into leafy inflorescence. Therefor when a tree is treated with GA3, a greater reduction in the apparition of the first structures is produced. Vegetative bud sprouting is insensitive to GA3 at this phase.

The fruit set period represents a critical stage (Martínez-Cortina and Sanz, 1991), in most cases fruit set and not flower number is the factor that determines yield (Goldschmidt and Monselise, 1977; Agustí *et al.*, 1982).

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When the number of flower buds is high, a significant proportion may abscise before anthesis (Erickson and Brannaman, 1960; Agustí *et al.*, 1982b). Competition for nutrients among the developing organs is one of the factors that determine abscission (Guardiola *et al.*, 1984).

Moss *et al.* (1972) suggested that inflorescence leaves in *Citrus* can enhance fruit set by supplying photosynthate. Exogenous application of gibberellic acid allows to increase the percentage of leafy inflorescences among the structures leading to an increase in the percentage of fruit set. Additionally, the application of exogenous gibberellins increases leaf size in the inflorescence to a value close to vegetative sprouts (Sanz *et al.*, 1987).

The increase in the number of leaves and in the average area of them allows to obtain a better leaf area-fruit relation; therefor it is possible to achieve a greater volume of fruits (Gil-Albert Velarde 1991).

With the exception of grapefruit (Jahn, 1973), lemons (Ermer, 1989), limes (Davenport, 1990), and Satsuma mandarins (García-Luis *et al.*, 1988; Guardiola, 1993), fruit set (Reece, 1945; Sauer, 1951; Lenz, 1996; Moss *et al.*, 1972; Jahn, 1973; Erner and Bravdo, 1983; Monselise, 1986) and fruit size (Lenz, 1966) were reportedly greater in fruits derived from leafy inflorescences.

The effects of gibberellic acid on orange trees under climatic conditions of the northeast (NE) of Buenos Aires are studied in this paper. First, the influence of GA3 on the types of floral structures developed after treatment was analyzed. Following, the impact that the latter effect produces on set fruit, inside fruit quality and final fruit volume was analyzed.

MATERIALS AND METHODS

The experiment took place in a plot that belongs to a fruit farm from Pilar, Buenos Aires, Argentina.

Adult trees about 18 years old of three varieties of navel orange grafted on Poncirus trifoliata were used for the experiment. Trees were spaced 5 m apart in 5-m rows and planted in an argiudol soil.

The varieties included in the essay were *Baianinha, Robertson navel* and *Buckeye*.

The chosen plot had no irrigation system, but a supplementation of water in a manual way in order to cover the periods with hydric deficit was planned.

In each variety were performed three treatments with three repetitions for each one. These treatments consisted in foliage sprays with GA3, over the whole tree. The hormone doses used were 0 p.p.m. (control: To), 20 p.p.m. and 40 p.p.m..

The applications of GA3 were realized during the swelled bud phase (August).

The evaluation was done over selected branches following the cardinal points, using four branches per tree located about 1,20-1,50 m above the ground.

Few days before the beginning of the anthesis, the recount of different types of structures (shoots: leafy inflorescences; leafless inflorescences; leafy single flowered, with a single flower on terminal position; leafless single flowered, consisting of a single flower; and vegetative, bearing only leaves) developed from the buds on the selected branch was performed. The results were expressed in percentage in order to offset the unequal number of buds that were present in the branches.

After fecundation, the number of fruit set in each treatment was evaluated (the results were expressed in the same way as the structures).

Four recounts were performed at the following moments: November; after December drop; in February and April (pre-harvest).

The experiment ended in May; the day of harvest was determined through the analysis of soluble solids (SS) (with a refractometer), and titratable acidity.

After the harvest, the fruit size was evaluated as well as the percentage of juice. This measurement along with SS was used in order to determine the effects of each treatment on the inside fruit quality.

The experimental design was a randomized complete block with three replications. Each replicate consisted of three trees. The values obtained were tested by analysis of variance followed by Tukey's test.

RESULTS

-The application of GA3 at the swelled bud stage (August) in *Baianinha* increased the percentage of leafy inflorescences and decrease the percentage of leafless inflorescences as well as leafless single flowered independently of the hormone concentration.

The values of leafy single flowered did not present significant differences among treatments. As for vegetative shoots, in the evaluated branches, this type of structure was not found (table 1, figure 1).

-In *Robertson navel*, the results were similar to the latter variety as to leafy inflorescences and

Table 1. Mean values of the different types of structures. Results expressed as percentage of the total of structures in each branch ± SE.

VARIETY	TREATMENT	V	LYSF	LYI	LSI	LSSF
BAIANINHA	To	0	3.745 ± 1.35 a	54.34 ± 5.25 b	39.16 ± 6.58 a	1.71 ± 0.18 a
	20 p.p.m.	0	2.96 ± 1.14 a	86.71 ± 3.25 a	9.94 ± 1.9 b	0.46 ± 0.23 b
	40 p.p.m.	0	5.12 ± 0.26 a	90.3 ± 0.05 a	4.75 ± 0.32 b	0 b
ROBERTSON NAVEL	To	0 b	0 b	46.09 ± 0.76 b	50.55 ± 1.84 a	3.34 ± 0.36 a
	20 p.p.m.	1.18 ± 0.11 a	0 b	61.96 ± 1.51 a	35.82 ± 1.33 b	0.4 ± 0.04 c
	40 p.p.m	0 b	0.42 ± 0.03 a	59.27 ± 0.30 a	39.58 ± 0.25 b	1.7 ± 0.08 b
BUCKEYE	To	1.01 ± 0.11 b	0.56 ± 0.08 c	57.33 ± 1.73 b	39.61 ± 1.05 b	1.46 ± 0.25 b
	20 p.p.m.	0.25 ± 0.05 c	1.26 ± 0.09 b	51.2 ± 1.38 b	45.75 ± 1.02 a	1.52 ± 0.24 b
	40 p.p.m.	2.82 ± 0.14 a	1.76 ± 0.07 a	65.9 ± 1.16 a	26.4 ± 0.75 c	3.09 ± 0.35 a

Values with the same letter inside each column do not present significant differences at the 5% of the Tukey's test.

References: V: Vegetative. LYSF: Leafy single flowered. LYI: Leafy inflorescences. LSI: Leafless inflorescences. LSSF: Leafless single flowered.

Fig. 1. Var. BAIANINHA. Mean values, percentages of the different types of structures.

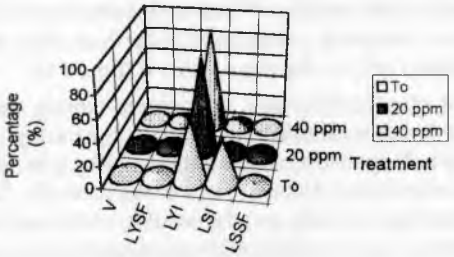


fig. 2. Var. ROBERTSON NAVEL. Mean values, percentages of the different types of structures.

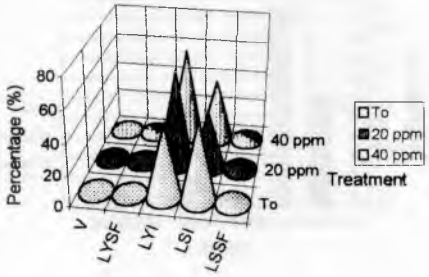
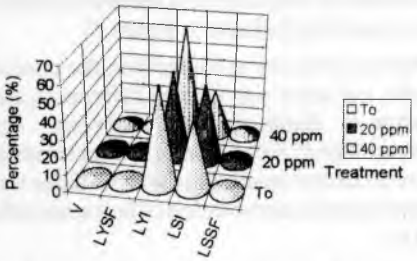


Fig. 3. Var. BUCKEYE. Mean values, percentages of the different types of structures.



leafless inflorescences. But it did not happen the same with the leafy single flowered; in this case was observed a significant increase in the trees treated with the highest hormone concentration. As for leafless single flowered there were differences among treatments. The highest and the lowest quantity were found in the trees that were used as control (0 p.p.m.) and in those that received 20 p.p.m. respectively (table 1, figure 2).

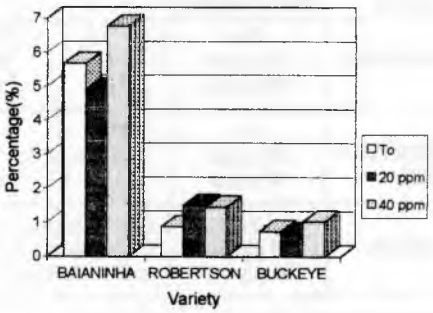
-Different results were found in *Buckeye* as for leafy inflorescences and leafless inflorescences. In the first case, there was a significant increase only with the highest concentration. In the second case, the lowest values were obtained as well with this concentration and the highest values with a concentration of 20 p.p.m. Differences with the other two varieties were also found as for leafless single flowered. In this variety, the highest percentage of

Table 2. Percentage of fruit set (Nov.). The results, expressed as percentage of the total of Flowers ± SE, represent the average of the mean values of each tree in each treatment.

	VARIETY		
	BAIANINHA	ROBERTSON	BUCKEYE
To	5.675±1.16 a	0.87 ± 0.096 b	0.74 ± 0.085 a
20 p.p.m.	4.900±0.12 a	1.50 ± 0.15 a	0.68 ± 0.066 a
40 p.p.m.	6.770±0.60 a	1.45 ± 0.14 ab	1.03 ± 0.107 a

Values with the same letter inside each column, do not present significant differences at the 5% of the Tukey's test.

Fig. 4. Percentage of fruit set.



this type of structure was obtained with a concentration of 40 p.p.m. In the cases of leafy single flowered and vegetative shoots, the highest percentages were obtained with the highest concentration, and the lowest percentages were associated with the control trees and with those treated with 20 p.p.m. respectively (table 1, figure 3).

After the fruit set in November, the number of fruits did not show significant differences among treatments in *Baianinha* and *Buckeye*. But in *Robertson Navel* there was a less percentage of fruit set in the tree controls as well as those treated with the highest concentration of hormone (table 2, figure 4).

As for the percentage of obtained fruit in relation to the number of flowers, there was a significant increase in the three varieties when a concentration of 40 p.p.m. was used. With the lowest concentration, the only significant differences obtained were respect to the controls in *Robertson navel* (table 3, figure 5).

The percentage of fruit drop was significantly minor in the trees treated with 40 p.p.m., independently of the variety. When a concentration of 20 p.p.m. was used, a reduction in the fruit drop was obtained only in *Buckeye* (table 4, figure 6).

As for the fruit size, differences among treatments were not found in any variety, but the highest sizes belonged to a concentration of 40 p.p.m., and the lowest sizes belonged to the tree controls. The percentage of juice and the soluble solids-acidity relation, were not affected by the treatments in any variety (table 5).

Table 3. Percentage of obtained fruits in relation to the number of flowers, (obtained fruits.100/number of flowers).

	VARIETY		
	BAIANINHA	ROBERTSON	BUCKEYE
To	2.34 ± 0.36 b	0 c	0.04 ± 0.001 b
20 p.p.m.	2.59 ± 0.12 b	0.04 ± 0.001 b	0.13 ± 0.02 b
40 p.p.m.	4.75 ± 0.66 a	0.4 ± 0.01 a	0.37 ± 0.03 a

Values with the same letter inside each column, do not present significant differences at the 5% of the Tukey's test.

Fig. 5. Percentage of obtained fruits in relation to the number of flowers.

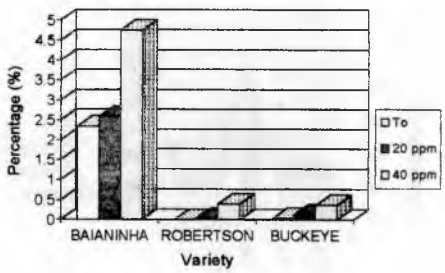


Table 4. Percentages of fruit drop, ((Fruits present in Nov - Fruits present in April).100 / Fruits present in Nov).

	VARIETY		
	BAIANINHA	ROBERTSON	BUCKEYE
To	58.88 ± 0.15 a	100 ± 0 a	93.54 ± 1.96 a
20 p.p.m.	57.01 ± 4.39 a	97.14 ± 1.65 a	80.76 ± 2.14 b
40 p.p.m.	34.36 ± 5.57 b	71.87 ± 1.42 b	64.0 ± 1.67 c

Values with the same letter inside each column, do not present significant differences at the 5% of the Tukey's test.

Fig. 6. Percentages of fruit drop.

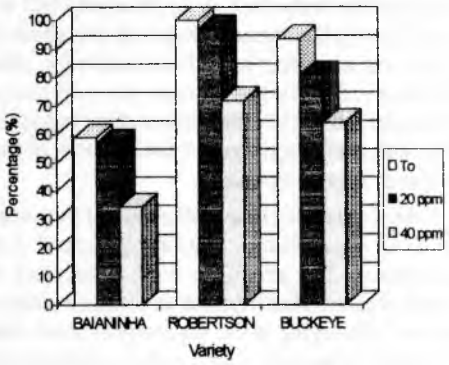


Table 5. Mean diameter; percentage of juice and soluble solids-acidity relation. The results represent mean values ±SE.

Variety	Treatment	Diameter (mm)	%Juice	SS/a
BAIANINHA	To	57.65 ± 0.20 a	51.41 ± 0.17 a	6.956:1 ± 0.2 a
	20 p.p.m.	58.63 ± 1.29 a	52.17 ± 0.73 a	7.706:1 ± 0.6 a
	40 p.p.m.	60.40 ± 0.51 a	51.26 ± 0.22 a	8.317:1 ± 1.2 a
ROBERTSON	20 p.p.m.	62.66 ± 5.34 a	42.22 ± 0.45 a	10.03:1 ± 1.6 a
	40 p.p.m.	64.88 ± 1.67 a	44.3 ± 1.27 a	11.33:1 ± 1.2 a
BUCKEYE	To	59.5 ± 3.77 a	48 ± 1.52 a	14.67:1 ± 1.8 a
	20 p.p.m.	62.5 ± 2.45 a	50 ± 1.44 a	13.33:1 ± 2.6 a
	40 p.p.m.	67.5 ± 4.95 a	51.66 ± 0.25 a	12.88:1 ± 2.1 a

Values with the same letter inside each column do not present significant differences at the 5% of the Tukey's test.

DISCUSSION

In the sweet orange (*Citrus sinensis* (L.) Osbeck) there are five types of shoots. The more abundant structures are those that present flowers and leaves together (leafy inflorescences). This type of structure represents about 50% of the total, followed by structures that only have flowers (leafless inflorescences). The leafless single flowered and vegetative shoots are present in fewer quantity, and the leafy single flowered are the fewest abundant (Guardiola *et al.*, 1977).

It must be considered that the shoots with flowers and leaves bring more than 75% of the fruits (Agustí *et al.*, 1985), therefore it is convenient to try to increase the abundance and predominance of this type of structure over the structures without leaves.

According to the results obtained in this essay, the application of GA3 in a concentration of 20 p.p.m. at the swelled bud stage, allow to achieve this objective in *Baianinha* and *Robertson navel;* as to *Buckeye*, 40 p.p.m. of GA3 was required in order to obtain a significant increment in the percentage of these types of structures.

The process of floral induction in the sweet orange begins in late autumn. During the induction period there is a time of maxim sensibility, at this moment the gibberellic acid: a) reduce the sprouting and flowering in an absolute way; b) increase the percentage of shoots with leaves and flowers, and reduce the percentage of shoots without leaves (Agustí *et al.*, 1991).

A second period of sensibility appears when the buds begin to sprout and when the floral rudiments are not visible yet.

The applications of gibberellic acid to the whole tree during these periods inhibit the flowering through the reduction of its intensity but without modifying the characteristics of the shoots. The GA3 has an effect of «all or nothing», since the formation of shoots occurs or not, and takes place through the selective inhibition of the bud sprouting, but without changing the development of the buds when those are sprouting.

Several essays have shown that the sensibility to GA3 is different among different types of structures. The structures without leaves are more sensitive to the hormone than those structures with leaves. Referring to the vegetative shoots, there are evidences that prove an increase in the production of those, while others report no variations in the formation of these structures when treated trees are compared with the controls (Krajewski*et al.*, 1995).

Most of the varieties of the navel group present an abundant flowering. But the flower drop previous to the anthesis or after anthesis, is so high that the number of fruits finally harvest, is lower than 10% of the flowers initially produced, and values lower than 0.5% were even observed (Agustí*et al.*, 1982b).

As it was mentioned before, the applications of GA3 over the whole tree allow to reduce the intensity of flowering, and therefore reduce the competition in the plant. Consequently: a) the flower size in the anthesis is bigger (Guardiola*et al.*, 1984) and there are a greater content of sugars and some mineral elements that contribute (partially) to enhance the initial efficiency of specific GA3 treatments in order to increase the set fruit (Agustí*et al.*, 1982a). b) The development of the ovaries is accelerated in the post-anthesis and this effect last until the harvest (Guardiola *et al.*, 1979).

Added to the effect that the applications of GA3, at the beginning of the sprouting, have on the reduction of the flowering intensity and on the increase of the percentage of leafy inflorescences, there is a stimulus that the hormone has on the development of the leaves and on the increase of their area.

The increase in the leaf area allows to obtain a greater production of carbohydrates and a reduction of the competition, leading to an enhancement of the fruit set, greater quantity of harvested fruits (in relation to the number of flowers), and a bigger fruit size compared with untreated trees.

Although in this essay the percentage of fruit set (November) was not affected, there was an important effect on the fruit drop (December drop; data not shown) and on the percentage of obtained fruits in relation to the number of flowers. It must be considered that in the period comprehended between the end of the December drop and the harvest, the fruit loss was not important, therefore the data shown in the table 4 allows to speculate the fruit loss magnitude that occurred during December.

In relation to the individual fruit size, it was mentioned previously a feasible increase. The reduction of the flowering and competition for nutrients among the developing organs, lead to a greater development of ovaries due to the increase of the number of cell files present in the crust (Guardiola *et al.*, 1982). Since the fruit growth, after December drop, occurs because of an increase of the cell size and not of its number, those fruits are in better conditions to obtain a bigger size. In spite of that, significant differences in the individual size were not found among treatments, due to the hydric deficit that the plants underwent during the fruit growth period, as consequence of technique problems that made impossible the irrigation.

The moisture of the soil is the principal environmental factor in the determination of the fruit size. Temporal problems in critic periods might cause irrecoverable delays in the development of the fruits (Erickson and Richards, 1955).

The application of GA3 had no effect on soluble solids-acidity relation, and this result agree with other reports (Manual para productores de naranja y mandarina de la región del Río Uruguay, 1996). The percentage of juice was not affected.

CONCLUSIONS

The applications of GA3 over orange trees at the beginning of the sprouting, under the climatic conditions of the NE of Buenos Aires, produce similar effects to those reports in other parts of the world:

Redistribution of the sprouting, that consist in an increase of the proportion of leafy inflorescences and a reduction of the leafless inflorescences.

A greater quantity of fruits in the moment of the harvest.

An increase of the individual fruit size (could not be proved).

In consequence, the gibberellic acid allow to enhance the relation between leaves and fruits, leading to a greater quantity and quality of fruits compared with untreated trees. This would allow to achieve a greater commercialization of the product in the domestic and foreign market, using a simple technique that could be employed by the farmer himself.

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