HORMONE-INDUCED PARTHENOCARPY IN THE CALIMYRNA FIG AND A COMPARISON OF PARTHENOCARPIC AND CAPRIFIED SYCONIA

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(WITH THREE FIGURES)

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Introduction

The problems associated with caprification (pollination) of Calimyrna figs and the desirability of standardizing or, still better, eliminating this cultural operation have been discussed (**5**). Because of its relatively low cost, low required concentration, and complete lack of injurious effects on fruit and foliage, para-chlorophenoxyacetic acid was found, during the season of 1948, to offer considerable promise as a material to induce parthenocarpy and, thereby, substitute for caprification of the Calimyrna fig (**4**). Commercial exploratory trials during the season of 1949 demonstrated the practicability of using this material as a substitute for cross-pollination by the fig wasp. The extent to which the industry adopts this practice depends mainly upon the demand by the consuming public for a fig that does not contain sclerified achenes ("seeds") and lacks the "nutty" flavor which characterizes caprified Calimyrna figs.

Although the largest percentage of figs set in the 1948 investigation was obtained with an aqueous spray containing 60 p.p.m. of para-chlorophenoxyacetic acid (**4**), further information was desired on the range in concentration of this compound effective in promoting parthenocarpy and the thoroughness with which the spray should be applied. Tests with Sure Set, a proprietary material containing para-chlorophenoxyacetic acid, para-fluorophenoxyacetic acid, and 2,4,5-trichlorophenoxyacetic acid were also made and will be discussed later.

The commercial trials mentioned above enabled the periodic collection of samples large enough to make certain physical and chemical comparisons between induced parthenocarpic and caprified figs.

Materials and methods

Parthenocarpic fig samples were obtained from a 20-acre orchard that was sprayed on June 21, 1949, with a water solution containing 60 p.p.m. of the ammonium salt of para-chlorophenoxyacetic acid (PCPA). The solution was applied with a Robinson Fan Sprayer at the rate of about 275 gallons per acre. Samples consisting of 100 figs, picked at random from the proximalmost nodes on as many shoots, were collected three times during the fruit-growth period. An equal number was also collected from an adjacent caprified orchard. The first samples were collected on June 21, the

day on which the spray was applied; on July 20; and on August 16, when the figs were mature. In addition to the notation of differences in color, the following measurements were made: volume, fresh weight, transverse and polar diameters, thickness of receptacular tissue, and diameter of floral cavity. Sugar determinations were made on both types of figs at maturity only.

To determine the range of concentration at which PCPA is effective in inducing parthenocarpy, as well as to carry on other incidental studies, an isolated Calimyrna orchard was chosen for test purposes. Because this particular orchard was four miles distant from the nearest caprified Calimyrna orchard, covering the test branches as was done previously (**4, 5**) with cloth bags to exclude the pollen-carrying fig wasp was unnecessary. The materials tested were applied on June 21, 1949, with a continuous-delivery type, hand-operated fly-spray gun. Both the leaves and the young syconia were sprayed unless otherwise specified. Ten branches were used per treatment, each bearing at least five syconia when the growth regulators were applied. As a basis for comparing the percentage of syconia set as a result of growth-regulator application, determinations of set were made in three orchards that had been caprified in the regular commercial manner.

In a previous paper (**3**), it was reported that 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) sprays at concentrations of 10 p.p.m. or greater not only induced parthenocarpy but greatly hastened fruit maturity, although they severely damaged or even killed the sprayed branches. Because accelerating the maturity of developing fruits is of both fundamental and practical significance, further studies were made with 2,4,5-T in an attempt to eliminate the undesirable reactions. This compound was used alone at various concentrations and in combination with PCPA.

Results and discussion

An examination of the data relating the concentration of PCPA to percentage of fruit set (fig. 1 and table I) clearly shows a progressive increase in set to a maximum at 80 p.p.m. of PCPA, beyond which the values decrease. However, even at a concentration of 100 p.p.m., over 10% more syconia set parthenocarpically than the average for the three caprified orchards. These results indicate that from a practical standpoint there is a fairly wide range of PCPA concentration that will produce a satisfactory set. The relationship shown in figure 1 apparently is typical for most hormone-induced responses (**7**), wherein there is an increase in response with increasing concentration to a maximum beyond which inhibition or toxicity occurs.

A spray containing 60 p.p.m. of PCPA applied to actively growing fig trees has been observed to cause considerable epinasty and chlorosis of the leaves and curling of the distal portions of the shoots. Fortunately, to induce parthenocarpy in the Calimyrna fig, the time at which the growth regulator sprays are applied is somewhat after the growth of the shoots has

ceased and the leaves have fully expanded. As a consequence, there were no observable symptoms of leaf, fruit, or shoot injury accompanying any of the concentrations of PCPA used. The rather wide range in concentration of PCPA effective in promoting parthenocarpy in the Calimyrna fig, together with the fact that no injury accompanies its use even at a concentration of 200 p.p.m., emphasizes the possibility of using this material commercially.

The comparative development of caprified and induced parthenocarpic syconia, as determined by certain physical measurements, is typified by the data in table II. Samples were collected and measured on June 21, the day the spray was applied, to determine the differences, if any, between syconia

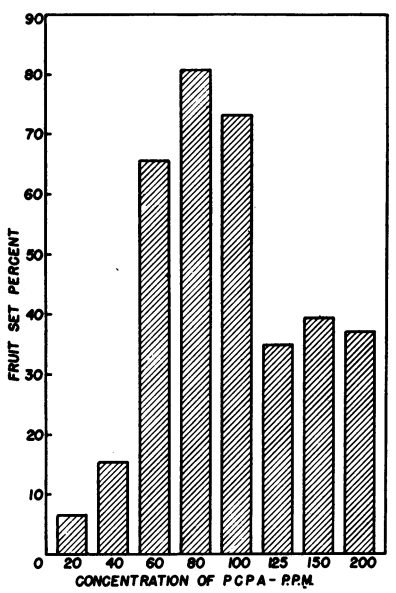

FIG. 1. Effect of concentration of para-chlorophenoxyacetic acid applied during the caprification period upon fruit set in the Calimyrna fig.

that were destined to develop parthenocarpically and those that were to develop as a result of caprification. The data in table II bear out the fact that syconia from the two orchards on this date were practically identical in all respects. However, by July 20, about a month before maturity, both external and internal differences were evident in the two types. Externally, the parthenocarpic syconia were considerably more ribbed than those caprified (fig. 2). The ribs were so prominent on some that the surface was corrugated. Although this condition persisted to a less degree at maturity, it was a distinguishing characteristic of the parthenocarpic fruits even after they were dried. In addition, the necks of these fruits were somewhat flattened. Upon maturity the parthenocarpic fruits were light lemon yellow in color while those caprified were typically golden yellow.

Internally, particularly upon maturity, the two types of figs were markedly different, the most pronounced differences being in the color of the pulp and in the development of the achenes (figs. 2 and 3). The pulp in caprified figs at maturity was of a light strawberry red color while that in the parthenocarpic fruits was a light amber yellow. Although the red pigmentation is confined to the outer ovary wall of the individual achenes, the latter are dispersed so thickly throughout the pulp in a thoroughly caprified

TABLE I

THE EFFECT OF CERTAIN GROWTH REGULATORS APPLIED AT VARIOUS CONCENTRATIONS UPON FRUIT SET IN THE CALIMYRNA FIG

Material or treatment	Concentration	Fruit set
	p.p.m.	%
Para-chlorophenoxyacetic acid	20	6.5
	40	15.4
	60	65.8
	80	81.0
	100	73.2
	125	35.0
	150	39.5
	200	37.2
Sure Set (Dow Chemical Co.)*	25	34.9
	50	31.0
	75	54.8
	100	57.8
Para-fluorophenoxyacetic acid	25	0.0
	50	33.3
	100	88.0
Para-chlorophenoxyacetic acid		
Applied to leaves only	60	71.7
Applied to fruits only	60	31.1
Caprified Controls		
Orchard 1		58.5
Orchard 2		65.8
Orchard 3		67.4
Average		63.9

*Sure Set contains para-chlorophenoxyacetic acid in a water-miscible solvent.

fig that the entire area appears light strawberry red in color. On the other hand, in syconia in which only a portion of the flowers are pollinated, the red pigmentation is confined to that area of the pulp containing the fertilized achenes (fig. 3).

Sclerification of the ovary walls of achenes had taken place by July 20 in caprified figs, whereas none had occurred in parthenocarpic fruits even at maturity, the latter being the so-called "seedless" figs. Apparently, the formation of red pigments is associated with the development of the ovary wall of the achene, since the pulp of parthenocarpic figs contains no red

color and since this coloration in the pulp of caprified figs is limited to areas in the syconium where the flowers are pollinated.

Caprified and parthenocarpic fruits were practically identical in average volume and diameter measurements (table II). Parthenocarpic figs at maturity, however, weighed about three grams (7%) less and were somewhat more oblate in form than caprified figs. Of particular interest is the differential development of the receptacular tissue in the two types of fruit. At the time the young syconia were either pollinated or sprayed with PCPA, the thickness of the receptacular tissue was approximately the same in both types. From that time on, this tissue in caprified syconia progressively decreased in thickness from 2.83 mm. to 2.11 mm. The receptacular tissue in parthenocarpic syconia, on the other hand, progressively increased in thickness from 2.74 mm. to 4.58 mm. at maturity. This tissue was more than

TABLE II

COMPARATIVE MEASUREMENTS OF CAPRIFIED AND PARTHENOCARPIC CALIMYRNA FIG SYCONIA PRODUCED WITH A SPRAY APPLICATION OF 60 P.P.M. OF PARA-CHLOROPHENOXYACETIC ACID

Type of syconia and date of sampling	Volume	Fresh weight	Transverse diameter	Polar diameter	Thickness of receptacle	Diameter of floral cavity
	cc.	*gm.*	*mm.*	*mm.*	*mm.*	*mm.*
June 21						
Caprified	11.71	6.76	25.36	21.61	2.83	19.70
Parthenocarpic	11.95	6.84	25.42	21.45	2.74	19.94
July 20						
Caprified	14.94	12.28	32.42	25.90	2.52	27.38
Parthenocarpic	15.13	10.59	33.07	24.03	3.71	25.66
August 16*						
Caprified	46.00	45.68	48.64	34.62	2.11	44.42
Parthenocarpic	46.30	42.48	49.48	33.10	4.58	40.30

*Syconia mature on this date.

twice as thick in parthenocarpic as in caprified figs, thus accounting for the smaller diameter of floral cavity in the former. A histological examination of caprified and parthenocarpic Calimyrna fig syconia made by BASKAYA and CRANE (1) revealed that the receptacular tissue in the latter contained somewhat larger cells and more cell layers than the former.

The receptacular tissue of the fig syconium is composed of parenchyma cells that function primarily for storage of elaborated food materials. Apparently, in caprified syconia these materials are gradually translocated from the parenchyma tissue of the receptacle into the developing achenes. Since the development of achenes in parthenocarpic syconia is incomplete (1), elaborated food materials that otherwise would be utilized by the achenes may accumulate in the parenchyma of the receptacle. This process may cause the receptacular tissue to thicken progressively with development of the syconia to maturity.

Parthenocarpic figs contained 4.5% more total sugars than did caprified fruits, substantiating previous investigations on the fig (**4**) and the tomato (**6**). On a dry weight basis, mature caprified and PCPA-induced parthenocarpic figs contained 74.5 and 79.0% total sugars, respectively.

The differential development of the receptacular tissue in caprified and parthenocarpic figs offers a partial explanation for the fact that the latter contain a higher percentage of sugar than the former. As mentioned above, the parenchyma in the receptacle is primarily storage tissue; since the ratio of this tissue to the remainder of the syconium is larger in parthenocarpic

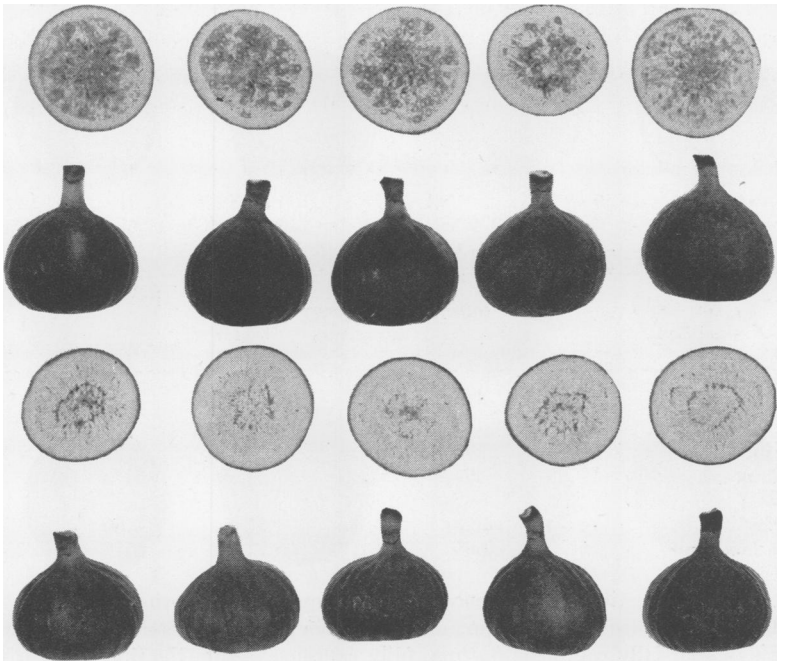

FIG. 2. *Top,* Calimyrna figs produced by the normal process of caprification; *bottom,* parthenocarpic Calimyrna figs produced with 60 p.p.m. of the ammonium salt of para-chlorophenoxyacetic acid. Samples collected on July 20, 1949, one month after caprification and spraying.

than in caprified syconia, the difference in sugar content may be explained on this basis.

A spray of PCPA applied only to the leaves induced more than twice as many syconia to set parthenocarpically as when it was applied to the young syconia only (table I). The "transmission of effect" of naphthaleneacetic acid on apple drop, as reported by BATJER and THOMPSON (**2**), is demonstrated clearly here in the use of PCPA to induce parthenocarpy in the fig. This response is in direct contrast to that obtained in 1948 with gamma-(indole-3)-*n*-butyric acid (**4**).

The difference in response when PCPA and IBA were applied to either the leaves or young syconia is of interest. Factors such as differential rate

and degree of absorption of the growth regulators by the leaves and syconia, translocation of the materials within the plant to regions where utilized, and inherent differences in the potency of the chemicals themselves are undoubtedly of much importance in this respect.

The application of Sure Set at various concentrations gave a trend in parthenocarpic fruit set similar to that obtained with PCPA (table I). Sure Set, however, appears to be somewhat less effective in promoting parthenocarpy in the Calimyrna fig than PCPA when used at identical concentrations. This discrepancy is not understood but may be the result of a difference in degree of absorption of the two materials by the leaves.

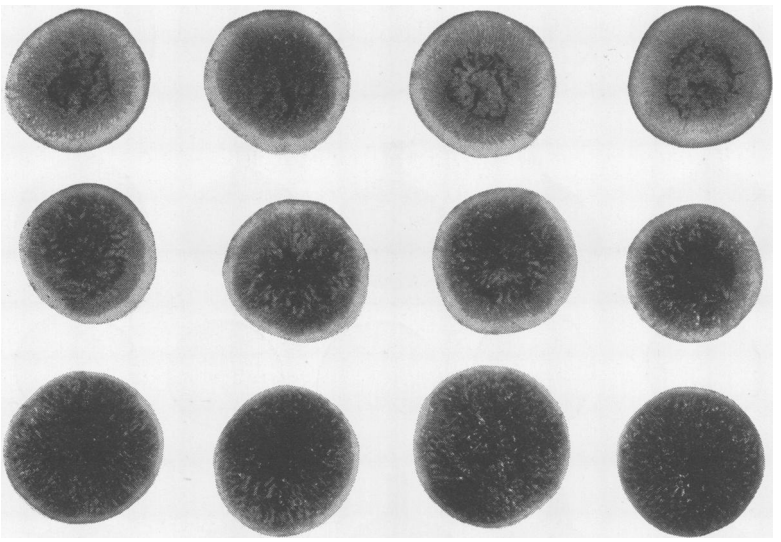

FIG. 3. Cross sections of parthenocarpic and caprified Calimyrna fig syconia. *Top,* parthenocarpic induced by 60 p.p.m. of ammonium salt of para-chlorophenoxyacetic acid; *middle,* partially caprified; *bottom,* fully caprified. Note the difference in thickness of the receptacular tissue in the three samples of syconia, as well as differences in red pigmentation indicated by the darkness of the pulp. Samples collected on August 16, 1949, at maturity.

Para-fluorophenoxyacetic acid appears to be equally as effective in promoting parthenocarpy as PCPA, an 88% fruit set being obtained with a concentration of 100 p.p.m. of this material (table I). Here, likewise, there were no deleterious effects of foliage, fruits, or shoots from the use of this material.

Concentrations of 2,4,5-T less than 10 p.p.m. did not induce parthenocarpy, but at or above this concentration, parthenocarpic fruit maturation occurred about two weeks after application. When 2,4,5-T was combined with PCPA at 60 p.p.m., the syconia were invariably set, but acceleration of maturation did not occur unless the concentration of 2,4,5-T was 10 p.p.m. or greater. Hastening of maturity, however, was always accompanied by

leaf chlorosis and injury to the shoots in varying degree, depending upon the concentration of 2,4,5-T, and was not significantly modified by the presence of the other hormone.

The toxic effect of 2,4,5-T apparently is not separable from the property of inducing parthenocarpy by any means so far tried, at least with the Calimyrna fig. The difference in concentration between a spray that will set fruit and one that will result in injury is small or non-existent. This is not an uncommon phenomenon; *e.g.*, the well known deleterious effects often occurring when 2,4-D or PCPA is sprayed on tomato plants in sufficient quantities to induce fruit set.

The data presented in table III serve to emphasize how relatively small differences in molecular structure may modify physiological response. Three closely related compounds—2,4-D, 2,4,5-T and PCPA—all will set syconia parthenocarpically in the Calimyrna fig, all will cause an acceleration in maturation, and all will cause injury. Yet the concentration required for each chemical to bring about each of these reactions is very different.

TABLE III

THE RELATIONSHIP BETWEEN CONCENTRATION OF CHLORINATED PHENOXY ACIDS AND INDUCED RESPONSE

Acid	Minimum concentration in p.p.m. required for:		
	Inducing parthenocarpy	Accelerated maturation	Injury
2,4-D*	250	250	250
2,4,5-T	10	10	10
PCPA	20–40	250	250

*See literature cited (8).

Although the reason for these differences is not known, certain conclusions are evident. With 2,4-D or 2,4,5-T, there is no difference in concentration between that which will cause the syconia to set and that which will bring about injury, whereas with PCPA this difference is of considerable magnitude. It is also apparent that when acceleration of maturity occurs, injury also results.

Summary

With a progressive increase in concentration of para-chlorophenoxyacetic acid to 80 p.p.m., there was a progressive increase in the percentage of syconia induced to set parthenocarpically, 17% more being set at the 80 p.p.m. concentration than on the caprified controls. Concentrations above 80 p.p.m. resulted in a depressing effect upon the percentage of syconia that were set. The rather wide range in concentration of para-chlorophenoxyacetic acid found to be effective in promoting parthenocarpy without injury to syconia, leaves, or shoots emphasizes the commercial possibility of this material for use by the fig industry.

A comparison of caprified and parthenocarpic Calimyrna figs produced with 60 p.p.m. of para-chlorophenoxyacetic acid revealed that the two types were not markedly different with respect to volume and diameter. Upon maturity, parthenocarpic fruits were somewhat more ribbed and lighter in color than caprified fruits. Parthenocarpic fruits weighed about 7% less than caprified fruits, and were somewhat more oblate in form. The pulp in caprified figs was of a light strawberry red color, while that in parthenocarpic fruits was a light amber yellow. In contrast to caprified figs, where sclerification of the inner ovary wall or endocarp of the achenes took place a month or more before maturity, no sclerification of this tissue was evident at maturity in parthenocarpic figs. The width of the receptacular tissue progressively decreased with development of caprified syconia to maturity, whereas in parthenocarpic syconia this tissue progressively increased in thickness, when at maturity it was twice as thick as in caprified fruits.

As a consequence of rate and degree of absorption or translocation within the plant, para-chlorophenoxyacetic acid was much more effective in promoting parthenocarpy when applied to the leaves than when applied to the young syconia.

Para-fluorophenoxyacetic acid was found to be as effective in promoting parthenocarpy as para-chlorophenoxyacetic acid. The application of this material likewise resulted in no deleterious effects on foliage, syconia or shoots.

With 2,4,5-T alone or in combination with PCPA, it was not possible to obtain accelerated fruit maturation without accompanying toxicity to the foliage.

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