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Alternation of Heavy and Light Crops in the Valencia Late Orange.
The Alternation of Heavy and Light Crops in the Valencia Late Orange.

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Summary.

1. Valencia oranges on the irrigation areas are subject to the alternate-cropping habit that is found in many varieties of fruit trees. The oranges of the light crop year are excessively large, have a thick rind and low juice content, and are generally of a poor quality, while those of the heavy crop year are unduly small.

2. The differentiation of the terminal flower primordia of the orange occurs in early spring, when the young shoot is about to emerge from the protection of the scales, and that of the axillary flowers when the young shoots are about 1/4 inch in length.

3. Complete removal of the crop of the "on" or heavy year at any time up till August increases the subsequent blossoming and the subsequent crop. The earlier the removal of the fruit, the greater the effect.

4. Partial removal of the crop also increases the subsequent blossoming and the size of the following crop.

5. Thinning as late as March appears to have very little, if any, effect on the ultimate size of the fruit remaining on the tree. The effect of earlier (January) thinning in this connexion is being further investigated.

6. A January thinning of the fruit of the heavy crop year is recommended, to reduce the excessive swing of alternately heavy and light crops of Valencia oranges on the irrigation districts.

7. Other reactions of the tree to the partial removal of the crop are briefly discussed.

1. Introduction.

In a previous communication (1), the writers have made reference to the undesirable habit of the Valencia Late orange of bearing light and heavy crops in alternate years, and have indicated very briefly some aspects of the problem involved. The present article reports the progress which has been made in subsequent investigations designed to discover methods whereby the Valencia may be caused to produce moderate crops every season.

In many respects, the problem presented by the biennially bearing tendency of the Valencia is similar to that encountered in the case of alternately cropping deciduous trees, such as the apple. The majority of Valencia trees on the Murrumbidgee Irrigation Area produce their heavy crops of fruit in the one season—they are "in step" with one another. The production of Valencia oranges on the area therefore fluctuates from season to season, and causes marketing difficulties somewhat similar to those resulting from the fluctuation of the Australian apple crop (3).

Fig. 1 illustrates the alternation of heavy and light crops in the Valencia and its effect on the total production for the Murrumbidgee Irrigation Area. The average yield per tree, adjusted to eliminate the effect of young trees coming into bearing, gives the most accurate estimate of the extent of the biennial cropping habit. Similar data in respect to the Washington Navel are included in the charts to contrast the even cropping of this variety with the Valencia.

It would appear that the tendency of the Valencia to bear crops biennially is more marked in the inland and irrigation areas than in the coastal districts. Probably for this reason, the annual production...
of Valencias in Australia does not fluctuate to the same extent as the apple production, and as a consequence the marketing difficulties that arise are not so acute. On the other hand, the difference in the type of fruit produced by the Valencia in its "on" and "off" years is probably much greater than that produced by the biennially cropping apple. In the "off" year, the fruit is over-large, thick in the rind, of low juice content, and generally of inferior quality, whilst in the heavy crop year the fruit is under-sized and of poorer quality than that produced in a moderate crop.

![Chart](image)

FIG. 1.—Charts representing the total annual production and average yield per tree of Valencia Late and Washington Navel oranges in the Murrumbidgee Irrigation Area. Total production = white line, Yield per tree = heavy line. In estimating the yield per tree, trees in their first and second years of bearing have been omitted.

Very little information is available regarding the alternate cropping of oranges in other countries. In California, Parker (3) during 1932, states that "though small sizes of fruits constitute a troublesome marketing problem in some years, very little is known about the conditions which cause them"; and further that "in some years, particularly since the crop year 1926-27, the entire Californian production of oranges of both varieties (Valencias and Navels) has tended to alternate in magnitude."

In practically all orchard fruits, the production of an abnormally heavy crop is followed by an under-average yield the following season, and in this way all are subject to a certain degree of alternate cropping. In the majority of varieties, however, the tendency towards alternate cropping is masked by variations in yield due to seasonal environment. The grape is typical of such varieties, whilst the Navel orange is an extreme example of this group in which the yield seems to be almost independent of the influence of the previous season’s crop.

In some varieties, on the other hand, the regular alternation of "on" and "off" years results in a more or less constant biennial-cropping habit. Finally, other varieties, such as the Valencia orange, which are often regarded as annual bearers, show a marked tendency
towards the biennial-cropping habit. Observations made at the Com-
monwealth Research Station, Griffith, show that, in the Valencia,
alternate cropping is also related to the strain of the variety. Different
strains of the same variety may vary very considerably in their
tendency to adopt the biennial habit of cropping. So far, it has not
been possible to correlate these differences in physiological behaviour
with any particular morphological or phenological characteristics of
strain or variety.

It has also become apparent from observations made at Griffith
that the tendency to bear heavy and light crops in alternate years is
manifest in the Valencia as soon as the tree commences to bear fruit.
Another characteristic feature of the Valencia is the marked indivi-
duality exhibited by branches of all sizes in respect to cropping. Whilst
the tree as a whole is in its "off" year, frequently one or more branches
of various sizes may be in their "on" year, and vice versa.

Frequently, the entire tree may be out-of-step with its neighbours,
and occasionally almost an entire grove out-of-step with the other trees
of the district. This variation from tree to tree, and particularly the
variation within the tree itself, has rendered the task of obtaining
information from yield trials unexpectedly difficult.


The position in respect to alternate bearing in apples has lately
been summarized by Read (4), who points out that, whilst certain
methods of pruning and manuring may result in an amelioration of
the alternate-cropping habit, the most effective treatment has been found
to consist of defloration, or flower thinning, during the "on" year.
The amount of modification induced by pruning, manuring, and fruit
thinning methods is apparently dependent, inter alia, upon the
"degree" of alternate bearing exhibited by the variety. Defloration
during the "on" year, however, has been found effective in stimulating
fruit bud formation, and consequently the crop in the "light" year,
in the most extreme types of biennial-cropping varieties.

In the case of deciduous fruits, the formation or differentiation of
fruit buds, as is now well known, occurs during the year previous to
that in which the bud produces blossom. This bud differentiation
generally takes place shortly after extension growth of the shoots ceases,
and, in the apple, during late December in most varieties or early
January in late growing varieties. Obviously any treatment to be
effective in stimulating fruit bud formation must be applied some time
prior to the period of differentiation. The investigations referred to
above show that to be effective the treatment should operate from two to
three months prior to the time of differentiation.

The evergreen habit of the citrus, with its entirely different pheno-
logical characteristics, suggested that an investigation of the differen-
tiation and development of the flower bud of the orange, might, in
conjunction with thinning and manurial trials, contribute to our
knowledge of the physiology of alternately-cropping trees. The
investigations detailed in this article therefore contain an account of
the development of the bud of the Valencia and the results of thinning
trials which have been carried out during the past two years.*

*The effect of time of application of nitrogenous fertilizers is also being investigated, but
no conclusive data have so far been obtained in this respect.
3. The Development of the Bud.*

Buds of both Valencia and Washington Navel orange were collected at frequent intervals during the 1930-31 and 1931-32 seasons, fixed in formalin alcohol, and studied by means of microtome sections of material embedded in paraffin wax and by means of dissections under a binocular microscope. The organization of the bud prior to opening in early spring is illustrated in Fig. 1, Pl. 1. A bud consists of a short axis upon which a number of foliar appendages and scales are inserted in a close spiral sequence (phyllotaxy 3/5). The scales (Sc.) are triangular in shape and rather fleshy, the first outermost being invariably situated opposite the thorn. An accessory bud is formed in the axil of the 2nd scale, and is usually well developed at this stage. The structure which is normally regarded as a single bud is therefore really an eye consisting of two buds, viz.: the primordium and the accessory. Each bud usually possesses 4 to 6 scales, and above these, upon the axis, approximately 6 rudimentary leaves (L1-L6) are inserted.

No differentiation of flower primordia may be observed until the young shoot is about to emerge from the protection of the scales. The sepal primordia of the terminal flower arise in the same manner from the apex as the leaf anlagen, and are formed as a continuation of the same spiral sequence. The first sepal, which is usually the 6th or 7th appendage, cannot therefore be determined as such at the time of its initiation. There is no swelling or flattening of the apex preceding flower formation. The initiation of the 2nd, 3rd, and 4th sepals in a very close spiral sequence (simulating a cyclic arrangement) makes it possible to distinguish the rudimentary blossom at this stage (Fig. 2, Pl. 1). At the time when the young shoot is emerging from the scales, the differentiation of the sepals of the terminal flower has taken place.

The axillary flower buds differentiate a little later when the young shoots are about a quarter of an inch in length (Fig. 3, Pl. 1). First a small cushion of meristematic tissue, representing the axillary bud anlage, appears in the axil of each leaf. This meristematic tissue splits off one bud scale, and then grows forward rapidly as the flower primordium. A small leaf bud meanwhile arises in the axil of the scale leaf, and constitutes the vegetative axillary bud. The development of the axillary flower bud primordium is normal, sepals, petals, stamens, and carpels arising in their natural sequence. Until the flower bud were nearing maturity no difference was observed between the development of the Navel and that of the Valencia.‡

It is interesting to note that, in the case of a young sterile shoot, the axillary bud anlage splits off one scale and then grows forward to form the thorn, the small bud formed in the axil of the scale becoming the axillary bud. Sometimes, rudimentary leaves are developed at the apex of the thorn. The flower bud and the thorn are therefore homologous structures as regards position and origin on the shoot. The axillary flower bud is terminal on a short axillary branch represented by the flower stalk, whilst the thorn represents another modification of the axillary shoot.

*An article by C. K. Abbott dealing with fruit bud development in some citrus fruits has appeared (Ref. sug. Bu. of Fruit Inst., Rept. Abstracts, Vol. IV, No. 2, 253) in Citrus Industry, 1934, p. 15. The authors have not yet been able to obtain a copy of this article.

‡In the Washington Navel, flower bud development is normal until the stage of meiosis is reached by the sporogenous tissue of the anther. Instead of normal meiosis and pollen production, the spore mother cells divide erratically and subsequent degeneration results in the abortive anthers of the Washington Navel flower.
The elongation of the flowering shoots is checked by the presence of the terminal flower, whilst the first cycle of growth of the sterile shoots is completed by the apparent abscission of the terminal bud. As a matter of fact, it would seem that really the growth of the apex is arrested by the formation of a thorn-like structure by the apical meristem. A continuance of growth therefore necessitates the sprouting of one of the distal axillary buds. This habit gives rise to the cyclic nature of growth exhibited by citrus. It is only towards the end of the season that the terminal meristem persists for any length of time. It will be seen, therefore, that during the first cycle of growth in spring the twigs are limited in their extension, and that for the most part growth during this phase is merely a development of the parts previously formed in the dormant buds.

4. Thinning Experiments.

As the heavy crop of the "on" year leads to a very poor flowering the following spring, which is responsible for the poor crop following the heavy crop, experiments were carried out to determine the effect of thinning the fruit, after it had set, on the blooming and setting the following year.

References in the literature to thinning oranges are rather meager. Waynick (5) found that thinning the crop had no effect on the ultimate size of the remaining fruit, whereas Parker (3) found that thinning the crop of Washington Navel or Valencia Late oranges increased the size of the remaining fruit and also increased the following crop.

There is a voluminous literature concerning the effects of thinning various types of deciduous fruit. It is generally found that thinning carried out at the appropriate time largely modifies the size and quality of the remaining fruit (6). Much work has been done in the case of apples designed to determine the effect of thinning on the subsequent crop. In this respect, the results are generally negative, except when the thinning is carried out very early in the season. Only blossom thinning has definitely modified the formation of fruit buds to any considerable extent (7, 8).

In the following discussion, we will first consider the effects which we have found in our experiments of thinning on the subsequent crop, after which we will consider the effect of thinning the crop on the ultimate size of the remaining fruit.

Preliminary thinning trials were carried out during 1932, but owing to the great variation in the trees and the presence of out-of-step branches, the results were difficult to interpret.

During 1933, trees on Farm 471, Griffith, which were mainly out-of-step with the trees of the district, and thus were carrying their heavy crops, were used for further thinning experiments. When the trees were flowering in October, 1932, they were carefully examined, and trees that were out-of-step with the rest of the grove, or had large branches out-of-step, or were otherwise unsuitable, were eliminated.

Table I shows the treatments applied and summarizes the results.

The complete removal of the crop at three dates was made to determine what effect, if any, the time of removal of the fruit had, or in other words to determine if any critical time occurred after which the removal of the fruit would have no effect.

Removal of half the fruit in May was carried out in order to determine the effect of partial removal of the crop.
No fruit removed 17 ... 991 ... 246 0.25 741
Half fruit removed (May) 9 453 657 ... 148 0.23 1,047
All fruit removed (January) 8 1,288 ... ... ... 1,916
All fruit removed (May) 9 1,017 ... ... ... 1,204
All fruit removed (August) 9 1,008 ... ... ... 1,174

ANALYSIS OF VARIANCE—NUMBER OF FRUIT HARVESTED, 1934.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>4</td>
<td>3,750,410</td>
<td>937,603</td>
</tr>
<tr>
<td>Error</td>
<td>47</td>
<td>4,448,254</td>
<td>94,666</td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td>8,198,664</td>
<td></td>
</tr>
</tbody>
</table>

Each branchlet was taken as a unit, and half the number of fruit thereon removed. Where an odd number of fruit existed on a branchlet, the odd fruit was carried forward to the next branchlet and dealt with. The result of this was that, not only were the heavy bearing branches half thinned, but the out-of-step branches and branchlets, which already carried a small crop, were also half thinned. Table 1 shows that actually less than half the fruit were removed. This was due to overlooking some of the fruit during thinning, which seems inevitable in this type of work.

Table 1 shows that the variance for the number of fruit harvested in 1934 ascribable to the treatment is significant. There is no significant difference in the number of fruit harvested in 1934 between the treatments "half fruit removed in May," "all fruit removed in May," or "all fruit removed in August," though the values are in the expected directions.

The trees with no fruit removed yielded significantly less than all the rest, and the trees with "all removed in January" significantly more than all other treatments.

One is therefore justified in concluding that the removal or thinning of the fruit of the heavy crop at any time up until August will increase the fruit finally set the following year, and that the earlier the thinning is carried out the greater the effect. A critical time for thinning is not indicated.

That the August removal of fruit affects the number of fruit that set the following year, is important in so far as part of the crop is sometimes harvested at this time for export overseas.

*To be significant the means must differ by 300.
An inspection of the trees in October, 1933, showed that the thinning caused an increase in the blooming. Whether the increase in the following crop was also entirely due to this, or whether the thinning also affected the proportion of blossoms which set, cannot be determined from our data.

Thinning of the crop of the heavy year can therefore be carried out to increase the size of the following crop, and the earlier this thinning is carried out the better. The normal dropping of the fruit is completed by January, and the fruit is large enough then to make thinning practicable, so that January is the most suitable month in which to carry out the thinning.

5. Effects of Thinning on Size of Fruit.

It has been stated that during the “on” year the fruit is small, while the fruit in the “off” years tends to be excessively large and coarse. As a matter of fact, so striking is this that the fruit tends to fall into two distinct types, viz., large, coarse, poor quality fruit on trees, branches, and even branchlets bearing the “off” crop, and small, under-sized fruit on the trees, branches, and branchlets bearing the “on” crop. One would naturally expect, therefore, that thinning the heavy crop would increase the size of the remaining fruit. The data in Table 1 for the 1933 harvest do not show any significant differences in the size of the fruit due to thinning.

The thinning experiments were extended in 1934 on Farm 659, Griffith. These trees were uniform, in very good condition, and carrying their heavy crop. From seven trees the fruit was thinned in March, and four trees were unthinned.*

Table 2 summarizes the results of the 1934 harvest.

<table>
<thead>
<tr>
<th>Mean Number of Fruit removed</th>
<th>Thinned.</th>
<th>Not Thinned.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Number of Fruit harvested</td>
<td>1,434</td>
<td>2,219</td>
</tr>
<tr>
<td>Mean Number of Fruit removed and number harvested</td>
<td>2,829</td>
<td>2,219</td>
</tr>
<tr>
<td>Mean Weight of Fruit harvested (in lb.)</td>
<td>423</td>
<td>631</td>
</tr>
<tr>
<td>Average Weight of Oranges harvested (in lb.)</td>
<td>30</td>
<td>29</td>
</tr>
</tbody>
</table>

Again there are no significant differences in the sizes of the oranges due to thinning.

These thinnings, however, were carried out in May in the case of Farm 471, and in March in the case of Farm 659, by which time the fruit had already grown a considerable size. It is possible that a thinning during January, when the fruit is still the size of marbles, would cause the remaining fruit to grow to a larger size.

*Other treatments were carried out, results of which will be reported on at a later date, but these two treatments are the only ones relevant to the present discussion. The method of thinning this year was modified, instead of removing a definite proportion of the fruit from each branchlet, the fruit was thinned to a certain density, judged by the eye, over the whole tree. Heavy branchlets would thus receive a heavier thinning while no fruit would be removed from light branchlets.

† It was intended to carry out the Farm 456 thinning during January. The work was delayed until March, owing to the difficulty in selecting a grove suitable to the work.
6. Other Effects of Thinning.

During the course of this investigation it was noted that removal of the fruit had a marked effect upon the tree.

There was a very dry period during the 1933 winter, and, when removal of the fruit was carried out during May, the trees were in a state of great water stress. An immediate improvement took place as the trees which had the fruit removed. The day following removal they had regained the fresh green appearance of healthy trees, while control trees still had their leaves curled and drooping and showed all the signs of great water stress.

The soil on Farm 659 was kept in a good moisture condition; nevertheless, in September, 1934, the trees that were carrying the full crop (which was a very heavy one) showed signs of water stress when compared with the trees which had had the crop removed in August. These latter trees were bright green, and presented a fresh appearance. The trees which were carrying their full crop were paler green in colour, and the leaves were somewhat curled. The trees that had been thinned in March and were then carrying a lighter crop, presented an intermediate appearance. These are typical of the observations made during the whole course of the experiments.

It was further noted that removal of all or part of the crop of tree subsequently led to a greater vegetative growth.

It is a matter of general observation that trees in a state of water stress make less vegetative growth than trees not in this state. It often happens that, if the soil moisture is low, the citrus tree may miss or complete growth cycle. Again, if the tree is subject to water stress during the period of summer growth cycle, the leaves will harden or when they are quite small, whereas, if the soil is well supplied with moisture and there is no water stress, abundant vegetative growth with large leaves is found.

There may be many factors involved in the effect of removal of fruit both on the subsequent vegetative growth and the subsequent blossoming and setting, and, no doubt, the increased reserves of the products of carbon assimilation play an important role. However, it is possible to explain these effects of thinning either wholly or partly by a consideration of the water relationships.

7. Literature Cited.

Fig. 1.—Valencia bud partially dissected, showing the accessory bud in the axil of the second scale (Sc₂) and a second accessory (AB) is developing in the axil of the third scale. Six rudimentary leaves (L₁₋₆) have been formed in the primary bud. × approx. 20.

Fig. 2.—Valencia bud in which the shoot is about to emerge from the scales, dissected. The initiation of the second, third and fourth sepals of the terminal flower is apparent and the sixth appendage therefore designated as the first sepal (S₁) × approx. 20.

Fig. 3.—A young Valencia shoot from which the young leaves have been removed, showing a terminal flower with four sepals differentiated. The axillary meristems have divided to form the flower primordium and the scale. × approx. 25.