CITRUS-GROWING IN AUSTRALIA

BY

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ANGUS AND ROBERTSON
SYDNEY LONDON MELBOURNE WELLINGTON
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To my Mother

EDITH JANE BOWMAN (née BROMLEY)
PREFACE

This work arose from the lack of a general reference book on Australian citrus-growing, and was written for the use of orchardists, students, small-scale growers, and others who may need a manual that gives the foundations of the subject. The editor of the series in which this book appears laid down as guiding principles that the text should be concise, Australian in treatment, and, while incorporating the findings of the latest research, practical in outlook.

The arrangement of the subject matter is practical. Starting with a brief history of the adaption of citrus fruits in Australia, the general plan is to traverse the subject from the propagation of trees through planting and development to bearing, care of the bearing tree, and preparation of the fruit. I have adopted in this work a suggestion first made by Professor J. R. A. McMillan with regard to my university lectures, namely, to endeavour to integrate knowledge from related agricultural sciences—climatology, soil science, botanical science, and so forth—into the culture of the crop. These passages are short, but they may suffice to suggest that broad fields of scientific knowledge bear upon an important matter to producers and consumers—the culture of the crop.

References to further reading are listed by chapters at the back of the volume.

During visits to other citrus-growing States I have had the pleasure of discussions and inspections in company with local fruit officers, and I gratefully acknowledge the assistance they have given, as well as that given me by colleagues in my own State. I wish to express appreciation of the facilities afforded by the Mitchell Library, by the late Mr K. Burrow and staff of the Fisher Library, and by Mr Woodward Smith of the Medical Department, University of Sydney. My thanks are also extended to Mrs C. Vincent, of the University of Sydney, for much typing assistance, to my daughter, Elizabeth, for clerical assistance with the manuscript, and to Mr E. C. Levitt, Citrus Specialist, and Mr P. C. Hely, Senior Entomologist, both of the New South Wales Department of Agriculture, for a critical reading of the manuscript.

Acknowledgments for the climatic data in Figs 18, 21, 22, and 23 are made to Commonwealth Meteorological Bureau publications and acknowledgments for illustrations used from other sources are made in the text.

F. T. B.
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<tr>
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</tr>
</tbody>
</table>
CHAPTER 1

THE INTRODUCTION AND SPREAD OF CITRUS

HISTORICAL BACKGROUND

Seeds of the orange, lime, and lemon, as well as some young plants, were brought in the First Fleet from Rio de Janeiro by Governor Phillip and the chaplain, the Reverend Richard Johnson. Phillip’s trees were planted alongside the first Government House, but not long after were removed to Parramatta. The chaplain’s orange-trees were planted on the site of the present Lands Department, in Bridge Street, Sydney, and were the first orange-trees to bear fruit in the colony.

Lieutenant-Governor King took orange-trees with him to Norfolk Island, where they thrived until cut down in 1827 by Lieutenant-Colonel Morisset, who believed that their fruit provided runaway convicts with food.

Horticultural plantings started to increase appreciably in the period of the land grants, 1792-1831. Citrus-trees were planted extensively in gardens and commercial areas in localities along the Parramatta River. Suttor was the first to plant orange-trees at Baulkham Hills, his trees having been brought by Lieutenant-Governor Paterson from San Salvador in 1800.

By 1803 the lemon and China and Seville oranges were generally cultivated. A few limes, citrons, sweet lemons, and shaddocks were also grown. Lemons did particularly well.

In 1804 at Seven Hills a Mr Joyce began an orange-grove which became famous in the hands of the Pye family. Many of the orange-trees planted thus near Parramatta lived for close on a hundred years, reached a height of fifty feet, and bore as many as forty bushels of oranges each. In 1808, when 546 acres were under orchards, oranges were being grown along the line of settlement to Penrith. By 1821 the acreage had doubled.

Seedlings from the early South American, mainly Brazilian, introductions were the principal type of orange grown. Numerous varieties were introduced by the settlers and officially, as is shown by a list of varieties in the Sydney Botanic Gardens in 1828 (Table I). All the common species of citrus fruits except grapefruit are represented, an interesting item being that the Bahia Navel had been recorded in bearing thus early. The Lisbon lemon and some other varieties not included in the table were reported to have been in cultivation four years earlier.*

* Sydney Gazette, 22nd April 1824.
<table>
<thead>
<tr>
<th>Common name</th>
<th>Varieties</th>
<th>Bearing state</th>
</tr>
</thead>
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<tr>
<td>Sweet orange</td>
<td>Common</td>
<td>Abundant</td>
</tr>
<tr>
<td></td>
<td>Chinese</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Malta red</td>
<td>Not yet borne</td>
</tr>
<tr>
<td></td>
<td>Seedling, Brazil</td>
<td>Shy bearer</td>
</tr>
<tr>
<td></td>
<td>Siletta</td>
<td>Not yet borne</td>
</tr>
<tr>
<td></td>
<td>Navel, Bahia</td>
<td>Shy bearer</td>
</tr>
<tr>
<td></td>
<td>Pernambuco</td>
<td>Not yet borne</td>
</tr>
<tr>
<td></td>
<td>Maranhão</td>
<td></td>
</tr>
<tr>
<td></td>
<td>St Jago's</td>
<td>Shy bearer</td>
</tr>
<tr>
<td></td>
<td>Tangerine, Brazil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small-leaved China</td>
<td>Not yet borne</td>
</tr>
<tr>
<td></td>
<td>Nankin oval</td>
<td>Now in bearing</td>
</tr>
<tr>
<td></td>
<td>Chinese downy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long-leaved China</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long-leaved dwarf</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chinese seedling</td>
<td>Not yet borne</td>
</tr>
<tr>
<td>Seville orange</td>
<td>Common</td>
<td>Bears freely</td>
</tr>
<tr>
<td>Mandarin</td>
<td>Common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fang-Kau, Liaoan</td>
<td>Not yet borne</td>
</tr>
<tr>
<td></td>
<td>Tuan-Kat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chu-Cha-Kud</td>
<td></td>
</tr>
<tr>
<td>Common lime</td>
<td></td>
<td>Bears freely</td>
</tr>
<tr>
<td>Sweet lemon</td>
<td>Persian</td>
<td></td>
</tr>
<tr>
<td>Common lemon</td>
<td>Whaley’s seedling</td>
<td>Not yet borne</td>
</tr>
<tr>
<td>Shaddock</td>
<td>Puniclo of Java</td>
<td></td>
</tr>
<tr>
<td></td>
<td>of Brazil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green-fruited Samabaya</td>
<td>Bears freely</td>
</tr>
<tr>
<td>Citron</td>
<td>Brazilian oval</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dwarf large-fruited Brazil</td>
<td></td>
</tr>
</tbody>
</table>

The Parramatta district supplied the rest of the colony and new colonies, holding a virtual monopoly of the industry, until about 1880. The first available record of export is in 1828, when oranges and lemons worth £224 were sent to Van Diemen’s Land.

In South Australia George Stevenson, private secretary to Governor Hindmarsh, introduced orange-trees in 1836, some of which were still bearing in 1921. The Port Phillip district was slow to take up the orange and preferred to import citrus fruits from the mother settlement. Although Captain Bligh had introduced citrus to Van Diemen’s Land in 1788, it never thrived, and attempts made since to grow citrus fruits there have been unsuccessful.

The two earliest books show that citrus-trees around Sydney were prolific and profitable. A good assortment of varieties was available, but rootstocks in the main were very susceptible to root-rot. Growers were perturbed by soil-moisture conditions but were not troubled by the pest and disease problems of later days.

In 1835 Shepherd in his Lectures on Horticulture stressed the need for
irrigation in dry areas and dry seasons. Shepherd wrote of a “fine free rich black or yellow loam” as the best soil “in a situation sheltered from cold wind”. He said, “... the ground should be well trenched three spades deep, and mixed with rotten dung at the time of trenching.... In dry seasons hundreds of bearing orange trees die for want of water.... If insects attack orange trees, strong lime-water is as good a remedy as any I know of to destroy them.” He advocated the bitter orange as a rootstock, also the citron for early bearing. The kinds of fruits he thought desirable for the colony were sweet orange, Seville orange, Lisbon lemon (especially for export), citron and shaddock.

In 1843 Sutter in his *Culture of the Grape Vine and the Orange in Australia and New Zealand* recorded that he had found the Spanish lemon the best rootstock for the common orange. Like Shepherd he enumerated five species of the citrus family, and recognized some varieties as hybrids or mules. He warned growers against wet or swampy ground and rocky sandy soil. He said that the orange, lemon, and citron were very prolific in Australia, but found the lime was too tender to frost at Parramatta.

**Decline in 1860s**

During the decade 1860-70 hundreds of acres of orange-trees died in the Parramatta district because of root- and collar-rot, which occurred through excessive wet weather and defective drainage. Such devastation of an industry that was the pride of Parramatta brought about an official inquiry. A Select Committee found that certain measures had been successfully evolved to meet the trouble. These measures have been incorporated in all latter-day sound citrus-growing. They are: choice of a well-drained and protected site; working the variety high on the rootstock—grafting was commonly employed then, but budding was advocated because it enabled higher working; planting the union above ground-level; not burying the union by resoiling; surface drainage in the centre of the rows; tile drainage if practicable; treatment of the collar-rot by excision.

The Government Botanist, Charles Moore, was sent abroad to study the disease. On Mediterranean experience, he recommended the resistant rootstock, bitter orange. He also arranged for the introduction of new varieties from the Azores, including a navel “which is a regular and heavy bearer, the fruit thin-skinned, and superior in flavour to any orange grown in this Colony”. These varieties were propagated by Pye at Parramatta and widely distributed.

Evidently the advice on bitter orange was taken, since in 1874 Mackay in the *Australian Agriculturist* was able to advocate this stock from Australian experience.

He stressed suitability of the soil, pointing out that “in the Parramatta district enormous crops of oranges are grown on open sandy soil manured on the surface with guano or other rich ammonia compost. .... The lemon is much more difficult to suit with soil than the orange. It suffers badly, should the roots reach clay.”

About this time orchards on the Lane Cove and Parramatta deteriorated
badly from infestations of scale insects, and it was not until late in the 1880s that the introduction of kerosene emulsion and resin sprays as control measures called a halt to the parasites.

An Important Growers' Conference

At a conference of delegates from the fruit-growing industry held in Sydney in 1890* a remarkable pooling of experience took place. The most detailed information was put forward by Thomas Pye, the son of a veteran orange-grower. Other growers contributed substantially to the fund of information.

Pye was a practising nurseryman and emphasized the need for great care and judgment in the selection of plants and varieties. He condemned Seville orange stock as a complete failure and advocated Common or Rough lemon, which he considered better under local conditions than sweet orange. He had fifty-six different varieties of citrus, of which he listed the most suitable varieties for commercial purposes as: true common orange, Siletta, Navel orange imported by Moore, Seville orange, Emperor mandarin, Thorny mandarin, Lisbon lemon, and citron. He stated confidently,

The best time to plant the citrus tribe is the second week in August for spring planting, and the first or second week in February for autumn planting. I have very frequently refused to supply trees during winter months. . . . After the trees are planted the cheapest and best system to work the land is to plough and harrow between the trees, and work the strips not ploughed with forked hoes. In a few years, as the trees become large, the best plan is to break up the whole of the land with forked hoes once a year, as deep as possible, without injuring the fibrous roots, and harrow as soon as the land is dry enough, after every rain, for by so doing you leave the land loose on top, thereby preventing the growth of weeds until the next fall of rain.

It is evident that the extreme form of clean cultivation which was recommended a few years later was not yet in vogue. Animal manures and certain mixtures of artificial manures, but no green manure crops, were used. Resoiling was common. Pye mentioned one family's orange-grove on the Parramatta which was one thousand acres in extent.

In 1893 Crichton in the *Australasian Fruit Culturist* emphasized eight cardinal points, namely, "suitable climate and soil; perfect preparation of the soil; selection of healthy young trees; full and regular supply of congenial food for the trees; supply of water during periods of drought; disturbance of the roots as little as possible; keeping the ground free from weeds and other undergrowth; shelter from strong winds". He appears to have been the first to mention trifoliata rootstock, at the same time intimating that it was little affected by disease.

Increase in Interstate Production

Towards 1890 citrus was grown to a limited extent around Melbourne and was sparsely dotted from Wangaratta westward in the interior of

* Reported as Bulletin No. 1, Department of Agriculture, New South Wales, October 1890.
Victoria. Production on the Adelaide plains had reached a point allowing of export to Melbourne. Plantings in Queensland and Western Australia were limited to local requirements.

The introduction in 1887 of irrigation at Renmark in South Australia and Mildura in Victoria by the Chaffey brothers paved the way for the development of the Murray Valley as an important region. Citrus plantings occupied 1260 acres at Mildura by 1896. Mildura and Renmark were the forerunners of a number of irrigation settlements now reaching from Shepparton to Mypolonga. The Murrumbidgee irrigation area, now the third main producing region, was first planted with citrus in 1912. Small irrigated areas have been established at Dubbo and Narromine, New South Wales. In other States fruit is grown under irrigation on the Harvey River in Western Australia, and at Gayndah in Queensland. Figure 1 shows the progress of planting in the Australian States and the Commonwealth from 1879 to 1953.

![Figure 1](image_url)

**Fig. 1.** Areas planted to citrus-trees (bearing and non-bearing) in Australia. **NOTE:** Australia, areas available for 1905, 1908, 1914, and annually after 1920. Victoria, 1904-20, area estimated from number of trees recorded triennially, using a factor of 80 trees per acre. Queensland, 1899-1920, oranges only. South Australia, 1896-1920, area estimated from number of trees, using a factor of 90 trees per acre.

(Source: Government Statistician, N.S.W.; Commonwealth Statistician.)

**Commonwealth Survey, 1930**

Possibly the most interesting feature of the Commonwealth survey made in 1930, at the present date, is the account of the problems raised by irrigation and of the vicissitudes of the Victorian Murray settlements:
Certain soils have proved less suitable to citrus than others, but in the majority of cases unsuitable conditions have been further: aggravated by seepage, salt trouble, injudicious use of irrigation water, insufficient attention to drainage, saline irrigation water, and general neglect.

Soils which to our present knowledge seem to be less suited to the growth of citrus are of the grey Mallee type as compared with those of the red Mallee (as at Tresco and Nyah), and the stiff clay soils (as at Murrabit and in the Goulburn Valley).

The main areas where citrus acreages declined were listed as follows:

**Merbein:**
Peak, 968 acres; present, 408 acres.
Causes: Seepage, faulty irrigation, saline water.

**Mildura:**
Peak, 888 acres; present, 629 acres.
Causes: Seepage, water table, saline water.

**Tresco:**
Peak, 801 acres; present, 379 acres.
Causes: Seepage, misuse of irrigation water, saline water. Trouble more pronounced on grey Mallee soils underlain by a stiff clay containing a high percentage of limestone than on red sandy Mallee soils extending to a fair depth without a highly impermeable clay subsoil.

**Nyah:**
Peak, 530 acres; present, 263 acres.
Causes: Similar to Tresco.

**Swan Hill:**
Peak, 328 acres; present, 254 acres.
Causes: Overwatering, unsuitable soil.

**Murrabit:**
Peak, 653 acres; present, 575 acres.
Causes: Unsuitable soil, neglect, drainage, frost.

The total acreage that has gone out from any of the above causes or others, such as commercial considerations, is in the vicinity of 1700 acres.

Large areas had not reached bearing age and much bearing area had not reached full production in 1930. A considerable increase in production was forecast in the report. A total of one and a half million boxes of citrus in excess of the previous twelve-year average was predicted for 1936.

The report concluded by recommending a conservative policy with regard to future plantings, a high standard of productive efficiency, the development of export trade with Canada, the United Kingdom, and the East, together with an improved organization to do so, and assistance to the industry by marketing and production research.

In point of fact, the predicted increases in production never materialized, owing largely to the onset of economic depression in the 1930s, and the necessary adjustment of production to the limited purchasing power in the hands of consumers.

**World War II and After**

World War II found citrus acreages at a comparatively low level. After the Japanese attack on Pearl Harbour in 1941 the arrival in Australia of over a million Americans with a taste for citrus fruits greatly increased the demand on the already low production.
Citrus Control Orders were gazetted during 1943. Prices were fixed for the various classes of citrus fruit. Later 25 per cent of the total orange crop, 50 per cent of the lemon crop, and 100 per cent of the grapefruit and Seville and Poorman orange crops were diverted to defence.

The conclusion of the war also saw several attempts to survey the reconstruction necessary in the rural industries, namely the reports of the Rural Reconstruction Commission and surveys of horticultural requirements for the post-war period.

A comprehensive and detailed survey of the citrus industry was carried out by the Commonwealth Department of Commerce and Agriculture.

Fig. 2. Area of citrus in Australia and Australian States, relative to other fruits and vines, 1939-43.

(Rural Bank of N.S.W.)
on information collected by State Departments of Agriculture, which was published in 1946 as the *Report on the Citrus Industry Survey 1945.*

In the post-war period thousands of acres of young trees were planted in the main regions. Unlike the plantings that followed World War I, which were largely contributed to by repatriation schemes, much planting after World War II was done by private growers. Large War Service Land Schemes, in which citrus is included, are at Loxton in South Australia, Robinvale in Victoria, and Coomealla in New South Wales. New citrus plantings totalled 7499 acres for the period 1946-9 and 2008 for 1950. Wet seasons at the start of the present decade have caused reverses in the east coast districts, and much replacement and replanting have taken place.

**THE PRESENT POSITION**

**The Place of Citrus in Australian Fruit-growing**

Citrus fruits rank foremost among the evergreen or tropical and subtropical fruits grown in Australia, far exceeding the area or production of the others combined. The same applies in the different citrus-growing States except Queensland, where citrus production is overshadowed by the area of both bananas and pineapples.

Midway through this century, citrus-trees occupied 57,000 acres or one-seventh of the total area devoted to fruit and vines in the Commonwealth. They represent 27 per cent of the total area under fruit and vines in New South Wales, 16 per cent in Queensland, 15 per cent in Western Australia, 7 per cent in South Australia, and 6 per cent in Victoria. They are not grown in Tasmania. The relative proportion planted with citrus is shown diagrammatically in Fig. 2.

**TABLE II**

*Average Area Under Citrus-Trees (Bearing and Non-Bearing), 1950-1 to 1954-5*

<table>
<thead>
<tr>
<th>Type</th>
<th>Qld</th>
<th>N.S.W.</th>
<th>Vic.</th>
<th>S.A.</th>
<th>W.A.</th>
<th>Aust.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>acres</td>
<td>acres</td>
<td>acres</td>
<td>acres</td>
<td>acres</td>
<td></td>
</tr>
<tr>
<td>Sweet orange:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valencia</td>
<td>1,557</td>
<td>15,956</td>
<td>2,522</td>
<td>2,711</td>
<td>2,126</td>
<td>24,872</td>
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<tr>
<td>Navel</td>
<td>983</td>
<td>9,274</td>
<td>2,421</td>
<td>3,513</td>
<td>1,593</td>
<td>17,784</td>
</tr>
<tr>
<td>Other</td>
<td>1,215</td>
<td>810</td>
<td>178 (c)</td>
<td>199</td>
<td>47</td>
<td>2,449</td>
</tr>
<tr>
<td>Seville and Poorman</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oranges</td>
<td>(b)</td>
<td>350</td>
<td>84 (d)</td>
<td>39</td>
<td>19</td>
<td>492 (e)</td>
</tr>
<tr>
<td>Lemon and lime</td>
<td>442</td>
<td>3,313</td>
<td>1,783</td>
<td>334</td>
<td>553</td>
<td>6,425</td>
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<tr>
<td>Mandarin</td>
<td>1,534</td>
<td>2,059</td>
<td>96</td>
<td>118</td>
<td>217</td>
<td>4,024</td>
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<tr>
<td>Grapefruit</td>
<td>112</td>
<td>744</td>
<td>338</td>
<td>233</td>
<td>164</td>
<td>1,591</td>
</tr>
<tr>
<td>Other citrus</td>
<td>12</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5,843</td>
<td>32,518</td>
<td>7,422</td>
<td>7,185</td>
<td>4,719</td>
<td>57,687</td>
</tr>
<tr>
<td>Percentage</td>
<td>10</td>
<td>56</td>
<td>13</td>
<td>13</td>
<td>8</td>
<td>100</td>
</tr>
</tbody>
</table>

* Source: Commonwealth Statistician.
  (a) Includes Seville and Poorman.
  (b) Included with "Sweet oranges, other".
  (c) Includes Poorman.
  (d) Excludes Poorman.
  (e) Incomplete.
INTRODUCTION AND SPREAD OF CITRUS

TABLE III

AVERAGE PRODUCTION OF CITRUS FRUITS, 1950-1 to 1954-5*

<table>
<thead>
<tr>
<th>Type</th>
<th>Qld</th>
<th>N.S.W.</th>
<th>Vic.</th>
<th>S.A.</th>
<th>W.A.</th>
<th>Aust.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bush.</td>
<td>bush.</td>
<td>bush.</td>
<td>bush.</td>
<td>bush.</td>
<td>bush.</td>
</tr>
<tr>
<td>Sweet orange:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valencia</td>
<td>122,751</td>
<td>1,732,141</td>
<td>279,917</td>
<td>345,028</td>
<td>209,593</td>
<td>2,689,430</td>
</tr>
<tr>
<td>Navel</td>
<td>85,781</td>
<td>1,128,564</td>
<td>312,090</td>
<td>758,122</td>
<td>174,165</td>
<td>2,458,722</td>
</tr>
<tr>
<td>Other</td>
<td>104,148(a)</td>
<td>91,348</td>
<td>24,678</td>
<td>39,530</td>
<td>6,497</td>
<td>266,201</td>
</tr>
<tr>
<td>Seville and Poorman oranges</td>
<td>(b)</td>
<td>46,589</td>
<td>10,751</td>
<td>7,176</td>
<td>1,616</td>
<td>66,132</td>
</tr>
<tr>
<td>Lemon and lime</td>
<td>63,468</td>
<td>380,472</td>
<td>162,236</td>
<td>53,821</td>
<td>88,705</td>
<td>748,702</td>
</tr>
<tr>
<td>Mandarin</td>
<td>127,751</td>
<td>196,165</td>
<td>16,059</td>
<td>29,196</td>
<td>16,920</td>
<td>386,091</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>17,840</td>
<td>130,384</td>
<td>49,394</td>
<td>40,548</td>
<td>22,275</td>
<td>260,441</td>
</tr>
<tr>
<td>Other citrus</td>
<td>2</td>
<td>1,725</td>
<td></td>
<td>3,645</td>
<td>11</td>
<td>5,383</td>
</tr>
<tr>
<td>Total</td>
<td>521,741</td>
<td>3,707,388</td>
<td>855,125</td>
<td>1,277,066</td>
<td>519,782</td>
<td>6,881,102</td>
</tr>
<tr>
<td>Percentage:</td>
<td>8</td>
<td>54</td>
<td>12</td>
<td>18</td>
<td>8</td>
<td>100</td>
</tr>
</tbody>
</table>

* Source: Commonwealth Statistician.
(a) Includes Seville and Poorman.
(b) Included with "Sweet oranges, other".

Area and Production

Area and production of citrus as distributed amongst the Australian States are shown in Tables II and III, which also show the percentage in the different States.

The average yield of trees in bearing for the period 1950-1 to 1954-5, in bushels per acre was:

Queensland 115·9 bushels, New South Wales 142·9 bushels, Victoria 147·8 bushels, South Australia 265·9 bushels, Western Australia 132·7 bushels, and the Commonwealth as a whole 153·1 bushels.

Relation to World Production

Production figures are known for the main citrus centres of the world except for a large area of Asia—China, Malaya, Indonesia and India—where production must be considerable.

The figures set out in Table IV have been taken from the Fruit Annual 1949-50, in which it is stated:

The following figures have been prepared by the office of the foreign agricultural relations of the United States Government or estimated on the basis of statistics and reports by officials of the United States Foreign Service. The production figures relate to the crop from the bloom of the year shown. Production in the various countries as listed in the table has been converted to boxes of the following weights: oranges, 70 lb.; grapefruit and limes, 80 lb.; lemons, 70 lb.

The weights of packed bushel cases are: oranges and lemons 45 to 50 pounds, grapefruit 40 to 43 pounds.

b
<table>
<thead>
<tr>
<th>Continent and country</th>
<th>Average 1935-9</th>
<th>1947</th>
<th>1948(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,000 boxes</td>
<td>1,000 boxes</td>
<td>1,000 boxes</td>
</tr>
<tr>
<td><strong>NORTH AMERICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Mexico</td>
<td>4,761</td>
<td>10,866</td>
<td>11,653</td>
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<tr>
<td>United States</td>
<td>67,034</td>
<td>114,510</td>
<td>102,170</td>
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<td>Cuba</td>
<td>1,050</td>
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<td>1,500</td>
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<tr>
<td>Dominican Republic</td>
<td>500</td>
<td>409</td>
<td>425</td>
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<tr>
<td>Jamaica</td>
<td>595</td>
<td>700</td>
<td>763</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>800</td>
<td>900</td>
<td>1,000</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>55</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td><strong>EUROPE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aegean Islands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>43</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Greece</td>
<td>37</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Italy</td>
<td>1,470</td>
<td>1,714</td>
<td>2,302</td>
</tr>
<tr>
<td>Spain</td>
<td>11,701</td>
<td>12,123</td>
<td>12,926</td>
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<td><strong>ASIA</strong></td>
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<tr>
<td>Cyprus</td>
<td>24,167</td>
<td>27,589</td>
<td>25,627</td>
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<td>Lebanon</td>
<td></td>
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<tr>
<td>Lebanon (e)</td>
<td>1,093</td>
<td>1,650</td>
<td>1,020</td>
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<td>Palestine</td>
<td>8,652</td>
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<td>Japan</td>
<td>15,895</td>
<td>6,496</td>
<td>15,590</td>
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<td>Philippine Islands</td>
<td>195</td>
<td>313</td>
<td>300</td>
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<td><strong>SOUTH AMERICA</strong></td>
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<tr>
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<td>9,212</td>
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<td>800</td>
<td>900</td>
</tr>
<tr>
<td>Ecuador</td>
<td>580</td>
<td>227</td>
<td>400</td>
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<tr>
<td>Paraguay</td>
<td>5,000</td>
<td>6,500</td>
<td>5,500</td>
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<tr>
<td>Peru</td>
<td>1,000</td>
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<td>1,250</td>
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<td>Surinam</td>
<td>20</td>
<td>55</td>
<td>100</td>
</tr>
<tr>
<td>Uruguay</td>
<td>1,300</td>
<td>1,016</td>
<td>1,200</td>
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<td></td>
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</tr>
<tr>
<td>Algeria</td>
<td>3,168</td>
<td>3,716</td>
<td>7,023</td>
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<td>British East Africa</td>
<td>100</td>
<td>150</td>
<td>150</td>
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<tr>
<td>Egypt</td>
<td>6,455</td>
<td>7,427</td>
<td>6,370</td>
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<tr>
<td>French Morocco</td>
<td>1,203</td>
<td>2,747</td>
<td>3,889</td>
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<tr>
<td>Northern Rhodesia</td>
<td>9</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Southern Rhodesia</td>
<td>194</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Tunisia</td>
<td>245</td>
<td>705</td>
<td>661</td>
</tr>
<tr>
<td>Union of South Africa</td>
<td>4,000</td>
<td>5,464</td>
<td>6,000</td>
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<tr>
<td><strong>OCEANIA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>2,683</td>
<td>2,820</td>
<td>3,240</td>
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<tr>
<td><strong>World total</strong></td>
<td>212,897</td>
<td>274,016</td>
<td>266,581</td>
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### TABLE IV—continued

#### GRAPEFRUIT

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<th>Continent and country</th>
<th>Average 1935-9</th>
<th>1947</th>
<th>1948(a)</th>
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<td><strong>NORTH AMERICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>1,000 boxes</td>
<td>1,000 boxes</td>
<td>1,000 boxes</td>
</tr>
<tr>
<td>Cuba</td>
<td>31,787</td>
<td>61,630</td>
<td>46,220</td>
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<tr>
<td>Jamaica</td>
<td>375</td>
<td>130</td>
<td>150</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>213</td>
<td>250</td>
<td>321</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>448</td>
<td>525</td>
<td>525</td>
</tr>
<tr>
<td><strong>ASIA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>44</td>
<td>159</td>
<td>200</td>
</tr>
<tr>
<td>Palestine</td>
<td>1,445</td>
<td>1,500</td>
<td>1,000</td>
</tr>
<tr>
<td>Philippine Islands</td>
<td>170</td>
<td>345</td>
<td>350</td>
</tr>
<tr>
<td><strong>SOUTH AMERICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>(b) 49</td>
<td>129</td>
<td>125</td>
</tr>
<tr>
<td>Surinam</td>
<td>10</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td><strong>AFRICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td>(b) 9</td>
<td>26</td>
<td>38</td>
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<tr>
<td>French Morocco</td>
<td>25</td>
<td>31</td>
<td>85</td>
</tr>
<tr>
<td>Union of South Africa</td>
<td>495</td>
<td>771</td>
<td>849</td>
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<td><strong>OCEANIA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Zealand</td>
<td>15</td>
<td>59</td>
<td>60</td>
</tr>
<tr>
<td><strong>World total</strong></td>
<td>35,259</td>
<td>65,871</td>
<td>50,268</td>
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</table>

#### LEMONS

<table>
<thead>
<tr>
<th>Continent and country</th>
<th>Average 1935-9</th>
<th>1947</th>
<th>1948(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NORTH AMERICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>9,552</td>
<td>12,870</td>
<td>9,100</td>
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<tr>
<td><strong>EUROPE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aegean Islands</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Greece</td>
<td>422</td>
<td>635</td>
<td>769</td>
</tr>
<tr>
<td>Italy</td>
<td>9,637</td>
<td>8,137</td>
<td>7,386</td>
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<tr>
<td>Spain</td>
<td>1,444</td>
<td>2,756</td>
<td>1,886</td>
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<td><strong>ASIA</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>66</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Lebanon</td>
<td>(c) 464</td>
<td>580</td>
<td>348</td>
</tr>
<tr>
<td>Palestine</td>
<td>88</td>
<td>500</td>
<td>250</td>
</tr>
<tr>
<td>Syria</td>
<td>(e) 74</td>
<td>317</td>
<td>242</td>
</tr>
<tr>
<td>Turkey</td>
<td>371</td>
<td>1,343</td>
<td>1,044</td>
</tr>
<tr>
<td><strong>SOUTH AMERICA</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>250</td>
<td>625</td>
<td>850</td>
</tr>
<tr>
<td>Surinam</td>
<td>2</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td><strong>AFRICA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td>102</td>
<td>92</td>
<td>125</td>
</tr>
<tr>
<td>Egypt</td>
<td>83</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>French Morocco</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Tunisia</td>
<td>35</td>
<td>174</td>
<td>174</td>
</tr>
<tr>
<td>Union of South Africa</td>
<td>142</td>
<td>193</td>
<td>212</td>
</tr>
<tr>
<td><strong>OCEANIA</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>308</td>
<td>348</td>
<td>398</td>
</tr>
<tr>
<td>New Zealand</td>
<td>65</td>
<td>89</td>
<td>72</td>
</tr>
<tr>
<td><strong>World total</strong></td>
<td>23,124</td>
<td>28,938</td>
<td>23,160</td>
</tr>
</tbody>
</table>

(a) Preliminary. (b) Less than 5 years. (c) Includes Syria. (d) Orange production in Israel only; representing 90 percent of total Palestine acreage. (e) Included in Lebanon.
TABLE IV—continued

<table>
<thead>
<tr>
<th>Fruits</th>
<th>1,000 boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oranges</td>
<td>212,897</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>35,259</td>
</tr>
<tr>
<td>Lemons</td>
<td>23,124</td>
</tr>
<tr>
<td>Limes</td>
<td>2,268</td>
</tr>
<tr>
<td>Total</td>
<td>273,548</td>
</tr>
</tbody>
</table>

It appears that, with the omission of the Asiatic countries referred to, the world production of citrus is in the range of three to four hundred million boxes. Since Australian production is in the range of three to four million boxes, our production is about one per cent of world production.

Export

Long-distance export, first attempted in 1887, was abandoned within a few years, after heavy losses of fruit. Resumed in 1921, it was again
virtually abandoned for the same reason. All exports were low in the early 1930s. By the late 1930s exports had reached a peak, and they had already started to fall away immediately prior to World War II. The effects of the war on shipping, coupled with the Citrus Control Orders that came into operation in 1943, brought about a decline in export that lasted till 1945-6. In subsequent years exports rose almost to the peak of the late 1930s.

The data assembled in Fig. 3 show that New Zealand has always received the bulk of our export. Especially since World War II, some increase to Eastern markets has taken place; Western Australia has figured most prominently in the supply of fruit to these markets, owing to the shorter shipping distance.

Consumption

The consumption of citrus fruits in Australia per head of population has been at a fairly high level for decades. Comparison with some other countries is shown in Table V, in which it appears that consumption in Australia is well ahead of that in citrus-importing countries (Europe, Canada, and New Zealand), but below that of heavy citrus-producing countries shown (United States of America and Brazil).

According to the Government Statistician, Australian consumption per head of citrus fruits in recent years has been as follows: average 1936-7 to 1938-9, 31·9 pounds; 1948-9, 39·3 pounds; 1949-50, 33·9 pounds; 1950-1, 37·4 pounds. Oranges are the main fruit consumed, the next most important kind of citrus, the lemon, averaging about 12 per cent of the total consumption.

<table>
<thead>
<tr>
<th>TABLE V</th>
</tr>
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<tbody>
<tr>
<td><strong>Estimated Annual Per Head Consumption of Fresh Citrus Fruit</strong></td>
</tr>
<tr>
<td>(In kilograms. One kilogram = 2·2 lb. avoirdupois.)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Pre-war average</th>
<th>1948</th>
<th>1949</th>
<th>Post-war average (2-year)</th>
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<td>European countries:</td>
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<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>13·4</td>
<td>11·7</td>
<td>7·8</td>
<td>9·8</td>
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<tr>
<td>France</td>
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<td>6·7</td>
<td>10·4</td>
<td>8·6</td>
</tr>
<tr>
<td>Belgium-Luxembourg</td>
<td>8·7</td>
<td>13·1</td>
<td>11·3</td>
<td>12·2</td>
</tr>
<tr>
<td>Netherlands</td>
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<td>Switzerland</td>
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<td>Germany</td>
<td>3·7</td>
<td>0·2</td>
<td>2·7</td>
<td>1·4</td>
</tr>
<tr>
<td>Italy</td>
<td>8·5</td>
<td>11·2</td>
<td>7·9</td>
<td>9·6</td>
</tr>
<tr>
<td>Sweden</td>
<td>6·9</td>
<td>7·4</td>
<td>10·0</td>
<td>8·7</td>
</tr>
<tr>
<td>Norway</td>
<td>7·7</td>
<td>2·6</td>
<td>3·0</td>
<td>2·8</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>2·7</td>
<td>2·0</td>
<td></td>
<td>2·0</td>
</tr>
<tr>
<td>Other countries:</td>
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<td></td>
</tr>
<tr>
<td>United States</td>
<td>22·2</td>
<td>24·4</td>
<td>21·5</td>
<td>23·0</td>
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<td>Brazil</td>
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<td>19·2</td>
<td>21·1</td>
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<td>19·1</td>
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</tr>
<tr>
<td>New Zealand</td>
<td>6·9</td>
<td>5·2</td>
<td>5·6</td>
<td>5·4</td>
</tr>
</tbody>
</table>

CHAPTER 2

VARIETIES, SPECIES, AND HYBRIDS

Two varieties of sweet orange, Washington Navel and Valeria, in approximately equal quantities, make up 70 per cent of the total citrus production of the Commonwealth. All varieties of sweet oranges add up to 75 per cent. Lemons account for about 13 per cent (limes included in this figure being negligible), mandarins for 8 per cent, and grapefruit for 3 per cent. Seville and Poorman oranges (which are mainly diverted to marmalade production) amount to only 0.5 per cent. Data are shown diagrammatically in Fig. 4.

The proportion within the individual States differs from the Commonwealth ratio, as shown in Fig. 4. Notable differences from the Commonwealth proportion are, among oranges the comparatively high percentage of common oranges and low percentage of Washington Navel in Queensland and the high percentage of Washington Navel in South Australia; among mandarins the high percentage in Queensland; among lemons the high percentage in Victoria.

With the main varieties so prominently established, sudden or marked changes in varietal production cannot be expected. The main changes in Commonwealth production predicted by 1936 in the Report of the Citrus Industry Survey 1945 are a marked swing to Valencia plantings mainly at the expense of Washington Navel, a decrease in common oranges and mandarins, and an increase in grapefruit. The predicted percentages are Washington Navel 32 per cent, Valencia 39 per cent, common oranges 4 per cent (a total for sweet oranges of 75 per cent), lemons 13 per cent, mandarins 6.8 per cent, grapefruit 4.7 per cent, Seville and Poorman oranges 0.5 per cent.

Whilst the swing from Washington Navel to Valencia oranges is taking place, it is unlikely that the increase in grapefruit will occur, owing to the incursions of the stem-pit virus.

The genera and species of cultivated citrus fruits are set out below in the order in which varieties of them will be discussed in this chapter.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
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<tbody>
<tr>
<td>Citrus sinensis</td>
<td>Sweet orange</td>
</tr>
<tr>
<td>C. aurantium</td>
<td>Seville or sour orange</td>
</tr>
<tr>
<td>C. reticulata</td>
<td>Mandarin</td>
</tr>
<tr>
<td>C. limon</td>
<td>Lemon</td>
</tr>
<tr>
<td>C. aurantifolia</td>
<td>Lime</td>
</tr>
<tr>
<td>C. medica</td>
<td>Citron</td>
</tr>
<tr>
<td>C. grandis</td>
<td>Pummelo or shaddock</td>
</tr>
<tr>
<td>C. paradisi</td>
<td>Grapefruit</td>
</tr>
<tr>
<td>Fortunella margarita</td>
<td>Oval cumquat</td>
</tr>
<tr>
<td>F. japonica</td>
<td>Round cumquat</td>
</tr>
<tr>
<td>Poniellus trifoliata</td>
<td>Trifoliate orange</td>
</tr>
</tbody>
</table>

14
Complete tables of the species and keys for the identification of sub-tribes, genera, and species are given in the Appendix.

A feature observed among varieties is that a number are clearly intermediate in characteristics between the different species, and this feature has occasioned considerable difficulty in arriving at a satisfactory classification. The difficulties have been resolved very largely by three important discoveries which were made about the turn of the century, namely hybridity, apogamy, and chromosome numbers.

Hybridity. Of the vast majority of plants, it is generally held that crossing between species is difficult and between genera very exceptional or impossible. Hence the faculty in citrus of producing hybrids of an inter-specific and intergeneric nature is highly exceptional and in fact constitutes a unique characteristic for such a numerous group of plants. Successful hand pollinations between genera and species were first effected by Swingle at the end of last century, leading him to conceive that natural hybridization had occurred during the millenniums in which species were growing wild or in cultivation in the ancient cultures of the Orient, and that natural hybrids would be found that were intergrades between species and genera. The problem then became to establish the valid species and to ascertain which varieties were hybrids.

Apogamy. By the process of apogamous reproduction, also called nucellar embryony, which will be found described on p. 46, the natural hybrids could be perpetuated. Thanks to this characteristic, some natural hybrids, which are culturally important today, have been propagated since ancient times. Of them Rough lemon, the rootstock for millions of trees, is perhaps the best example.

Chromosome numbers. By the examination of chromosome numbers the validity of true species has been strengthened and the indications of hybrid origin have been confirmed in different instances. The basic chromosome number in citrus is eight. Chromosomes are the characteristic and constant number of fragments into which the nucleus of a cell divides during the process of cell division.

These discoveries and the subsequent studies of systematic botanists have led to the modern view that there is a limited number of definite genera of citrus, and in each genus there is a number of species, capable of being distinguished from one another by certain well-defined characters. It is then considered that forms with intermediate characters, or combining some characters of one species and some of another, are hybrids.

Hybrids, whose parentage is known or is clearly apparent in their characteristics, are designated by synthetic names. The names are derived from a combination of syllables from the parental names, such as

- Citrange: Citrus trifoliata x Orange
- Tangor: Tangerine x Orange
- Tangelo: Tangerine x Pomelo

In the case of natural hybrids, the parentage is unknown and it may not be clearly discernible in the characteristics of the plant. For these reasons, and on the grounds of long-established usage, the customary common name is adhered to. An example is Rough lemon.

One other characteristic of varieties that has become prominent
commercially should be mentioned here which is the result of selection over the centuries, namely, reduced seed content or ultimate seedlessness. The reasons for this characteristic are discussed on p. 46.

In the following account of varieties emphasis is placed on their cultural value and qualities. Technical descriptions are omitted.

SWEET ORANGES (Citrus sinensis)

Sweet oranges are in two distinct groups: Navel oranges and common sweet oranges. In Australia the Navel, Valencia, and common oranges

![Diagram of citrus production in Australia and its states](image)

*Fig. 4. Varietal production of citrus, Australian States. (Citrus Industry Survey.*)*
Washington Navel orange

Valencia orange

Thomson Navel orange

Joppa orange
Marsh grapefruit

Lisbon lemon

*Colour photographs by courtesy of the Commonwealth Department of Primary Production.*
are distinguished, varieties such as Jaffa, Joppa, Siletta, and Parramatta being grouped as common. This was the classification used in the Report on the Citrus Industry Survey 1945 and in the Citrus Orders during World War II. A subdivision of the common oranges comprises a group of blood oranges such as Maltese Blood, Ruby Blood, and St Michael’s Blood. These are of no value on the east coast, because the development of the red-coloured flesh is quite unreliable. Patchy development of colour in the flesh is objectionable. Inland the red colour is much more dependable, but the retail demand for blood oranges depending as it does on novelty, is limited, and they have no special sales value as a type.

It is of more practical convenience to classify oranges as early, mid-season, or late. In the early group Washington Navel has so far outstripped all other varieties whether navel or non-navel that they are of quite negligible economic importance. Norris Early or Hamlin and Parson Brown are other early varieties and are non-navel in type.

Mid-season varieties include the old seedling types such as Parramatta and Paterson River, and other seeded varieties such as Joppa, Mediterranean Sweet, Jaffa, Siletta, and Homosassa, of which the latter is the latest ripening in the group. Parramatta is the variety used as the sweet orange rootstock in Australia unless otherwise specified. Joppa is considered the best commercial variety of this group. Varieties of common orange are more extensively grown in Queensland than in any other State. Some seedling types are undoubtedly of high eating quality.

The late-ripening group consists for all practical purposes of one variety, Valencia.

Washington Navel

The Washington Navel is the standard early or winter orange, and as we have seen in Fig. 4 it yields half of the orange crop of the Commonwealth. Table I shows that the Bahia Navel—the original name of the Washington Navel—was growing in the Sydney Botanic Gardens in 1828.

Other introductions of this variety were made in the early days. In Shepherd’s catalogue (1851) it is stated: “The Bahia ... is now cultivated in every orangery. ... In extensive orangeries, especially if far distant from a market, it should not be the leading one.” High-quality strains were commanding high prices by the 1860s. Later there were at least two major importations of the Bahia Navel, one by Moore in 1870 from the Azores, and another by the Chaffey brothers in 1890 from California for the establishment of their Renmark and Mildura irrigation areas. This latter introduction is often referred to as the “Old Mildura” strain of Washington Navel.

The change of name from Bahia to Washington occurred when it was introduced from Brazil in 1870 by the United States Department of Agriculture to Washington, D.C., whence it was distributed in the United States and took the name of Washington.

Coit’s statement that the true and false forms existed here as early
as 1860 accounts for the fact that the then “false” form introduced to California in the 1870s, along with the true Bahia, was christened the Australian Navel. This variation, which is here often referred to as Dud, is characterized by greater vigour of growth, extremely shy bearing, and coarseness of skin. It possibly originated as a seedling.

Perhaps the Washington Navel introduced for the Mildura and Renmark settlements was an improved strain, for the popularity of the Washington Navel definitely increased after 1890. The boost given to Navel plantings by the irrigation settlements alone would probably have been sufficient to increase this variety in popular esteem.

The variety is fairly widely adapted in the Commonwealth. It predominates in the South Australian Murray plantings and is grown extensively in most districts except some coastal districts of Queensland, where it is somewhat shy bearing and is replaced by mandarin varieties and Joppa oranges.

A number of strains have originated as bud mutations. Of these the most recent and promising is the Leng Navel,1 which was selected on the property of the Leng brothers, Irymple, Victoria. It is about ten to fourteen days earlier than Washington and yet has a good full Navel orange flavour. The tree is vigorous. This strain is being planted fairly widely.

Strains of Navel that have been extensively tested and passed into discard include Thomson (owing to lack of juice in the fruit), Golden Nugget (skin too thin round the navel of the fruit and the tree lacks vigour), Robertson (fruit usually small, lacking in flavour, and somewhat fibrous, and tree lacks vigour), and many others.

A number of seedlings of Washington Navel have been propagated at times, but nothing transcending the Washington Navel in all-round character has so far evolved from them.

Bud selection is very important in this variety to maintain the standard type.

Valencia

Valencia is the standard late variety, and the plantings slightly exceed those of Navel. It is an old variety of the Mediterranean region and was introduced into the United States of America in 1873 from England as Excelsior, but was growing there before then. It became known as Hart’s Tardiff in Florida and as Valencia in California. It must have been soon introduced into Australia, for it was listed and described by Crichton in the Australasian Fruit Culturist in 1893. Trees of this variety were also introduced from the United States for the early Mildura and Renmark plantings, among which occurred the Lord Howe or Berri strain, noted in those districts for the late-hanging quality of the fruit. Valencia not only ripens late (twelve to thirteen months after blossoming), but can be held on the tree for another four to five months and even longer in the late districts, before appreciable deterioration of quality sets in. Control of black spot on the coast and septoria spot in the inland districts is necessary to securing the advantages of late hanging. If held too long re-greening and other defects may develop (see p. 269).
Sweet Orange Hybrids

Hybrids with sweet orange parentage are referred to under the other species; see citranges, Meyer lemon, Poorman orange, and tangors.

SEVILLE OR SOUR ORANGES (Citrus aurantium)

Rough Seville

Also called bitter or Bigarade orange, Rough Seville is the true Seville orange. The Rough Seville is the type that is meant when reference is made to Seville or sour rootstock, although Bittersweet may have been used unintentionally for Rough Seville in some instances. The fruit is used primarily for making the typical or standard marmalade; grapefruit, lemon, and orange marmalades being variations from the product accepted as commercial marmalade. No varieties of Seville comparable with the numerous varieties of the sweet orange are recognized commercially in this country. It takes its name Seville from the fact that when the sour orange was widely grown in Mediterranean Europe and Africa, the province of Seville in Spain attained the greatest prominence and fame for its sour-orange groves.

Bergamot

Many early writers on citrus in this country pointed out the value of the oil of bergamot that may be distilled from the flowers of the Bergamot strain of Seville orange. Only specimen trees of this variety are known.

Myrtle-leaved Orange or Mandarin

Although the fruit is a sour orange, it is popularly called mandarin in New South Wales owing to its tangerine colour and small size (about one-quarter to one-third the size of Rough Seville, which it otherwise resembles externally). The skin on bruising has a mandarin aroma and it peels from the quarters showing more or less reticulated pith reminiscent of a mandarin. This form is grown occasionally as an ornamental tree for its tiny clustered leaves and highly decorative fruit. It has been shown to arise as suckers from sour orange. An oversea name for this variety is Chinoti.

Seville Orange Hybrids

Smooth Flat Seville

Smooth Flat Seville is distinguished from the true Seville by longer and narrower leaves, lacking or almost lacking a petiolar wing. The fruit is as highly coloured, but is flatter in shape and has a smooth skin. The texture and colour of the flesh and the seeds (when present) resemble Rough Seville. The origin of Smooth Flat Seville is unknown, but it is probably local since it does not seem to be referred to in oversea publications. It was first mentioned in Shepherd's catalogue (1851). It is never used as a rootstock. This variety is sometimes referred to erroneously as Poorman.
Poorman

Poorman is characterized by leaves rather like Smooth Flat Seville, but better described as intermediate between Rough and Smooth Sevilles. The fruit is large, not as flat and as smooth as Flat Seville. The flesh is free of bitterness but with a high juice content and a texture resembling Rough Seville. The skin of the fruit is typically straw-coloured and the flesh is light-orange coloured, whereas in the Smooth Seville the colours of skin and flesh are the reverse. The centre is solid in Poorman, hollow in Smooth Flat Seville. Differences in the seed shape further distinguish Poorman from Smooth Flat Seville. Both have few seeds.

Poorman orange was taken to New Zealand by Sir George Grey, who grew it on Kauai Island near Auckland in the Hauraki Gulf, whence it came to be known as Kauai grapefruit, later as New Zealand grapefruit, and a variant as Morrison’s Seedless grapefruit. It is grown fairly extensively in the vicinity of Kerikeri and Gisborne.

Mr R. J. Benton, formerly citrus specialist of the New South Wales Department of Agriculture, has recently had the opportunity to compare New Zealand-grown Poorman oranges with Ugli grapefruit from Jamaica and considers them identical. Poorman was mentioned in Shepherd’s catalogue (1851) as having been recently introduced from Shanghai by a Captain Simpson.

It is obviously not a true grapefruit and its resemblance to true Seville in some characters and to sweet orange in other suggests that it is possibly a natural hybrid between these species.

Bittersweet

Bittersweet resembles the ordinary Seville orange, but since the flesh is sweet-flavoured it is thought to be a natural hybrid, possibly of sour and sweet orange parentage.

MANDARINS (*Citrus reticulata*)

Mandarins, also known less commonly as tangerines, have preserved a place in the markets owing to their distinctive flavour and appeal. They were grown extensively in the Sydney region, but they have declined very considerably in the past few decades owing to severe sales competition during the orange season, commencing with Washington Navel. The main varieties, Emperor, Ellendale, and Glen Retreat, however, are still those that are marketed during the orange season. Varieties harvested at this time must have inherent size and quality. Further, they should be grown commercially only when these qualities develop. They attain these qualities notably in Queensland, where a substantial proportion of the citrus area is devoted to them (Fig. 4). Early varieties have the advantage of being marketed in advance of the Navel orange, and there is a distinct place for a good early variety, for all grown at present are defective in some commercial character.

Varieties, which to the trade come in the category of mandarins, may be classified on their season as follows:
Early: Imperial, Unshiu, Fewtrell, Clementine.

Mid-season: Beauty of Glen Retreat, Emperor, Scarlet, Dancy, Parker, Silverhill Satsuma, Thorny or Willow Leaf.

Late: Burgess or Solid Scarlet, Ellendale, Wallent, Umatilla, Kara.

Some of these are true mandarins and some are tangors. Rough-skinned varieties like King, Poncan and Tanakan are not grown commercially.

The typical mandarin is a fine-leafed bushy tree. It produces tangerine-coloured flatish fruits, in which the peel readily comes away from the flesh, disclosing a noticeable reticulum of fibre, whence the specific name, and the flesh readily divides into the carpels or quarters. They are seedy, and the embryos, distinctively, are green in colour. Typical varieties are Imperial, Thorny, Emperor, Scarlet, and Glen Retreat.

Imperial

The earliest variety, six weeks earlier than Emperor, Imperial attains only a fair size, often tending to run small and to fall into irregular cropping. It does not colour well when it is of a size suitable for picking, and is only a golden yellow, or at best, a pale orange, when mature; flesh qualities are mediocre, for the juice content is only fair and tinged with some acidity. Apparently resistant to brown spot.

Emperor

Emperor of Canton succeeds in maintaining its position as the leading commercial variety of mandarin, in competition with Washington Navel orange, owing to its attractive external and internal qualities, and the fact that it ripens slightly in advance of Washington Navel orange, it being usual under comparable conditions to obtain a picking from the Emperor mandarin in advance of the Washington Navel orange. There is, therefore, a readier place in the citrus market for Emperor mandarins from early localities than from late districts. They cannot be held on the tree too long or they become puffy. Late strains have been selected. In Queensland Emperor does well in the coastal districts.6

Beauty of Glen Retreat

Beauty of Glen Retreat which is slightly earlier than Emperor, forms a bushier tree and is prone to alternate heavy and light cropping. It does well inland. In the heavy year, severe scalding is common, and the fruit runs to small size and tart flavour; pruning to prevent heavy cropping is essential to control the scalding and to assure sizeable and well flavoured fruit. The fruit is very solid and thin-skinned, and is distinctive with its pronounced nipple at the stalk end and deep tangerine colour. The variety originated as a seedling in an orchard owned by Mr W. H. Parker, of Glen Retreat, Enoggera, now a suburb of Brisbane.3

Mandarin Hybrids

Tangors

In addition to the mandarins that conform to the species characteristics there are those which in this country are classified with the mandarins,
but which technically seem to be tangors, that is, tangerine × orange hybrids. Varieties that give evidence of this hybridity are Unshiu, Fewtrell, Clementine, Satsuma (Silverhill), Ellendale, Waffent, Umatilla, and Kara.

Ellendale. This originated about 1878, as a seedling which was raised on Mr E. A. Burgess’s property of that name in the Burrum district, Queensland. Competent observers consider it very similar to the Temple orange of America. The fruit is late and large—about 50 per cent showing a slight navel—with tangerine-coloured skin and high-quality juicy flesh. Flesh qualities coupled with the fact that it does not peel readily suggest hybridity with the orange. It is very prolific and the tree shows a tendency to split at the crotches when carrying heavy crops. The skin of the fruit is also apt to crack at the base at all stages of development. The Queensland fruit is well and favourably known on southern markets during July and August. In Queensland the faults mentioned are more accentuated in coastal than in inland districts, where Ellendale does particularly well.

Tangelos

Tangelos are hybrids between mandarin and grapefruit, the name being derived from the synonyms tangerine and pomelo respectively. Minneola is the best variety. Its distinctive necked shape and smooth, highly tangerine-coloured skin, coupled with its agreeable flesh qualities, may give it a market opportunity. Other varieties are Orlando, Thornton, Sampson, San Jacinta, and Seminole. Coming in competition with well-known citrus varieties, and having novel flavours, these varieties can scarcely be expected to find a ready place in the industry.

Other Mandarin Hybrids

Other mandarin-like fruits are referred to under other categories of citrus, namely Myrtle-leaved mandarin (under sour orange), Rangpur and Kusaie limes (under lime hybrids). The mandarin evidently hybridizes freely and widely with other citrus species.

Calamondin. This is evidently a natural hybrid, with unpalatable flesh. Owing to its vigour, it has been tried as a rootstock.

LEMONS (Citrus limon)

Eureka

Eureka or Sweet Rind is well adapted to the milder regions such as the coast of New South Wales. Of the ever-bearing habit, it produces a main winter crop with peak production about August, and a summer crop, but the winter crop must be carefully regulated to ensure the production of the more profitable summer crop. The thornless tree, almost seedless fruit, and suitability for curing make Eureka a very desirable variety.

Lisbon

Lisbon is generally recognized as being hardier and better adapted to cooler growing conditions as in the south or where the conditions of winter
and summer are more extreme than by the east coast. It is thus the recommended variety in Victoria, South Australia, and Western Australia. The thorny nature of the tree is something of a disadvantage. The earliest record of this variety is in the *Sydney Gazette* of 22nd April 1824. The name indicates that it was introduced from Portugal, although it has not been identified with any Mediterranean variety. The Doncaster Improved strain of Lisbon, selected for its reduced thorniness, is recommended for the vicinity of Melbourne. In southern areas the fruits of Lisbon and its strains do not grow as large and as coarse as those of Eureka in the spring.

*Villa Franca*

Villa Franca is sometimes written as one word; it is the chief variety in Queensland, where it is favoured because of its summer cropping. It does particularly well in the inland districts of that State. It is susceptible to a rind breakdown known in Queensland as "March disease", which causes considerable loss when the wet season is prolonged. This variety and Genoa are of Eureka type. It is thornier than Eureka, but less thorny than Lisbon. Genoa is found on a commercial scale mainly in Queensland.

*Lemon Hybrids*

*Rough Lemon*

Although Rough lemon never appears in the retail fruit trade it must be regarded as one of the important varieties of citrus in Australia. It is also called Bush, Common or Norfolk Island lemon and Citronelle. It is the rootstock for probably ninety-odd per cent of the five million citrus-trees in Australia. Besides this, the backyard trees, in cities and towns at least along the east coast, which have developed as chance seedlings or from the over-growth of a budded tree by a sucker from the rootstock, provide countless households with an acceptable lemon type of fruit for drink or flavouring purposes. Groves of Rough lemon that became established on Norfolk Island have provided the main source of Citronelle seed for New South Wales nurserymen for some decades past. The distinctive roughness of the skin and the flavour of the fruit, and the green shoots (instead of purple shoots typical of the lemon), suggest a hybrid origin of this variety, and the characteristics indicate a cross between lemon and citron. Almost complete nucellar embryony likewise suggests a hybrid origin and has provided the means of propagation true to type of the variety, which appears to be sterile from the point of view of producing sexual embryos. In any case, its origin is lost in antiquity and its extreme adaptability has enabled it to become feral in many parts of the world.

*Perrine*

Perrine, a cross between lemon and Mexican lime made by Swingle, shows the possibilities in citrus-breeding. Although not a typical lemon, and not grown in Australia, this variety has the merit of resistance to
scab disease, which it inherits from its lime parent. It is also resistant to lime wither-tip, which it inherits from its lemon parent.

**Meyer**

Meyer, a natural hybrid, was introduced to the Western world by the plant explorer of that name in 1908 from China. The lemon was clearly one parent of this variety, and the growth habit and the pale-orange skin colour of the fruit suggest that the orange was the other. At present the variety is a useful backyard tree, although it does not have the ever-bearing habit to the same extent as the true lemon. The fruit ripens early—in advance of the main crop of other lemon varieties—when lemons are often dear. The smooth attractive skin of the Meyer whilst green, shortly before the skin changes colour, may give the variety some place in commercial production. Meyer is less susceptible to frost than the lemon.

**LIMES (Citrus aurantifolia)**

Limes of various kinds are used in most warm and tropical countries as the thirst-quenching drink *par excellence*. Very few trees, either of true lime or hybrid limes, are grown, and they are negligible commercially in Australia.

**West Indian or Mexican Lime**

West Indian or Mexican lime is the true lime. It is a small lemon-like fruit that is gathered for use after it attains a yellowish colour and drops from the tree. The tree is comparatively small and is the most frost-tender of the citrus species.

**Lime Hybrids**

**Persian Lime**

The large-fruited variety, Persian, Tahiti, or Pacific lime, is characterized by a larger type of tree, a large fruit, of less pronounced but nevertheless distinct lime aroma and flavour, and is practically seedless. This variety is susceptible to lemon scab although resistant to wither-tip. It is therefore thought to be a natural hybrid. A few specimen trees are grown.

**Mandarin Limes**

Of the mandarin limes, Rangpur resembles the mandarin in the appearance of the fruit and to a less extent in that of the tree. The flesh of the fruit has a distinct lime taste. Specimen trees only exist. Kusaie does not have the tangerine skin colour of the mandarin, but the carpels or quarters separate readily.

**Palestine Sweet Lime**

The Palestine sweet lime is extensively used as a rootstock in Palestine; it is not grown commercially in Australia.
VARIE TIES, SPECIES AND HYBRIDS

CITRONS (Citrus *medica*)

Citrons are scarcely to be found nowadays in commercial planting, for their only use is in the production of candied peel, the demand for which is supplied by lemon peel. Varieties grown in earlier times were Bengal, Oval, and Knights or Citron of Commerce. The last-named is preferred for processing, although the tree is of weak growing habit and extremely susceptible to frost.

PUMMELOS OR SHADDOCKS (Citrus *grandis*)

Commercially the shaddock is on a par with the citron, only occasional trees now being seen. The large thick-skinned fruit is used for making a sort of marmalade by those who prefer it. Pummelos are extremely popular in the East Indies and the tropical Pacific islands, where they grow to perfection.

There are many variations of the spelling of pummelo, which need cause no confusion in Australia, for there has been no concerted attempt to give one of them, pomelo, to grapefruit as was done in the United States.

GRAPEFRUITS (Citrus *paradisi*)

The commercial rise of grapefruits is one of the spectacular developments of modern citrus-growing, particularly in the United States of America, where it has been developed to a stage now rivalling the lemon in popularity, and this during a period of general increase in citrus-growing. Grapefruit has made considerable progress also in Australia, relative to other citrus fruits, until recently. Although the grapefruit species was brought to the attention of growers as early as 1871, present-day grapefruit varieties were much later in reaching Australia. Many varieties are of quite recent origin.

The grapefruit is undoubtedly very similar to the pummelo or shaddock and has often been grouped with it. Swingle prefers to consider the grapefruit a different species from the pummelo. He says, “It seems best to retain the grapefruit, for the present at least, as an independent but satellite species immediately following *C. grandis*, with which it is so closely allied that many citrus taxonomists consider it a variety of that species.”

Most varieties of grapefruit are very seedy; Marsh was the first seedless variety.

There are a number of red-fleshed varieties: Foster, a seedy variety, which is a bud-sport of Walters grapefruit; Thompson, a sport of Marsh Seedless; Ruby, a bud-sport of Thompson in which the red colour extends to a blush tingeing the rind. Like the blood oranges, the colour of coloured grapefruit is poorly developed, if at all, on the east coast. On the Murray, where the fruit can hang longer the colour is more dependable. In intermediate districts, such as Narromine and the Murrumbidgee, Thompson usually attains an amber-coloured pulp. American experience is that the pink-fleshed varieties are objectionable for canning because colour is
imported to the syrup, and that seedy varieties can better than the seedless, since the flesh holds together better.

Grapefruit may be grouped as the seedy varieties (pallid or pink-fleshed), and seedless (pallid or pink-fleshed) as follows:

**Seedy:**

(a) pallid-fleshed, Duncan, McCarthy, and many others;
(b) pink-fleshed, Foster.

**Seedless or nearly so:**

(a) pallid-fleshed, Marsh;
(b) pink-fleshed, Thompson, Ruby.

The virus disease stem-pit constitutes the greatest threat to continued expansion of grapefruit-growing. Unless resistant or tolerant strains are found, stem-pit bids fair to wipe true grapefruit varieties from the east coast or any other area where the insect vector black citrus aphid is prevalent. Grapefruit can still be grown with some asssurance in inland districts.

Marsh seedless and the hybrid Wheeny are the main varieties in Australia. The popularity of Marsh is due to its seedlessness and the fact that it grows well in all the inland districts. Both are highly attractive to fruit-fly.

**Grapefruit Hybrids**

**Wheeny**

Wheeny is tolerant to stem-pit and for this reason assumes first place in coastal districts. It is susceptible to lemon scab disease. It originated as a chance seedling at Wheeny Creek, Kurrajong, New South Wales, and was named by Mr R. J. Benton. The fruit is to all external appearance a grapefruit, but the texture of the flesh, free juice, the flavour, with its peculiar tartness and bitterness, and seed characteristics suggest either the lemon or sour orange in the parentage. It is very seedy. The leaves are long, pointed, and with small narrow petiolar wings.

The name is also spelt Wheeney on official maps; the shorter spelling is adopted herein.

**Other Grapefruit Hybrids**

Other hybrids of grapefruit are the tangelos, previously mentioned under mandarin hybrids.

**CUMQUATS (Fortunella spp.)**

The two common varieties of cumquat are different species: Oval or Nagami, and round or Marumi. The variety Meiwa is thought to be a hybrid between the two. Although not grown commercially and of negligible horticultural importance, cumquats are seen as occasional ornamental or yard trees or as potted plants, when they are utilized either for decorative purposes, or for their small fruits, which are used for making a preserve. Cumquats are highly susceptible to fruit-fly.
There are a few hybrids of the cumquat with other genera such as the citrangequat and the limequat which at present carry no practical interest.

**TRIFOLIATE ORANGE (Poncirus trifoliata)**

The trifoliolate orange is the only deciduous species of the cultivated citrus-trees. The fruit, which ripens in autumn, before leaf-fall, is inedible; the seeds are used for producing a rootstock that is in demand for two reasons: (a) its immunity from Phytophthora root-rot, and (b) its beneficial effects on many qualities of the fruit of the scion. Trifoliola forms an impenetrable hedge owing to its extremely thorny stems, although its use in this direction is limited by the necessity to control the pests of commercial citrus which attack it.

No varieties are available in this country. Trifoliola shows little variation compared with that which occurs in Citrus species. Recent investigations into variation for the purpose of making selections for rootstock trials have established small but distinctive variations in habit of growth, precocity of blossoming, type of flower, and other characteristics.

**Trifoliata Hybrids**

*Citrange*

Citranges are hybrids of trifoliata and sweet orange parentage. They take their name from the first syllable of Citrus—an old generic name for Poncirus—and the last syllable of Orange. There are several varieties of citranges. They are unpalatable as dessert fruits. Morton, Carrizo or Texan, and Troyer are of experimental interest in this country for rootstocks, owing to their resistance to Phytophthora root-rot and the degree of promise they have shown as rootstocks in the United States.

*Citremon*

Citremon is a hybrid between trifoliata and lemon. The fruit is unpalatable. It was of some interest as a possible rootstock on account of its resistance to Phytophthora root-rot, but it has been found to be susceptible to quick-decline virus.

There are other hybrids of trifoliata such as citrangequats and citrangeclins, which are of no interest in this country beyond their novelty or possible experimental use.
CHAPTER 3

THE SELECTION OF VARIETY AND ROOTSTOCK

In the purchase or propagation of young trees the first matters to be decided are the choice of variety and the rootstock. Both of these are much larger questions than might appear at first sight.

VARIETY

It is recognized in all fruits that the choice of variety should be limited to those few that supply the market during the season, are well known to the buying public, and return remunerative prices. This generalization applies no less to citrus than to other fruits, and consequently there is no room in the industry for inferior or obsolete varieties.

The policy of limitation of varieties has been well carried out in citrus fruits as evidenced by the predominance of the few varieties grown for commercial production (Fig. 4), in contrast with a long list of varieties that has been recorded in Australia.17

The main varieties of the different kinds recommended, are as follows:

**Oranges.** Leng Navel, as the earliest navel orange; Washington Navel, all States except in coastal districts of Queensland; Joppa, Queensland and New South Wales; Valencia, all States.

**Lemons.** Eureka, all States; Lisbon, Victoria, South and Western Australia and Interior districts; Villa Franca, Queensland mainly.

**Mandarins.** Emperor and Ellendale, the latter particularly for inland districts; Beauty of Glen Retreat is also recommended for inland parts of Queensland; Daney is favoured in South Australian Murray districts.

**Grapefruit.** Marsh, Interior districts; Wheeny, coast of New South Wales.

Although the limitation of varieties has reached a satisfactory stage while the markets remain as at present—that is, production mainly for a fresh-fruit market—it should not be overlooked that a marked shift in the outlet could materially alter the varietal demand. The development of the orange-juice market in Australia, for instance, would almost certainly create a demand for a juicier variety than Washington Navel.

There is some room for specialized production of certain uncommon lines, such as Smooth and Rough Sevilles for marmalade, near factories. There is also room for limited plantings of some selected varieties, for example, of early mandarin, mid-season orange, or even some novelty such as the best tangelo, for which, after careful consideration, it is concluded that there will be definite market possibilities. These should only
be planted in a small trial area. If they turn out unremunerative the loss of profitable area will not be great and the replanting of it or the topworking of the trees to a profitable variety will not be a large operation.

On the whole, growers will be guided by the main varieties in the district in which they propose to operate. It will usually be found that there are reasons connected with the seasonal supply to the markets, the suitability to the district of the varieties grown there, and the qualities of the fruit from that district which are known to the markets.

**BUD SELECTION**

The next step is to locate trees that will provide the buds. Careful selection of the budwood trees is necessary. On the evidence of records or by reliable reputation, these trees should be known to be highly productive; they should produce fruit true to type for the variety, and of high standard in external and internal qualities; the trees should be free of abnormal variations.

As well as having known performance in these directions over a number of years, the trees should be examined whilst they are carrying a crop. The trees should be in a vigorous condition, since any variations are more likely to show then than if they lack vigour. Trees carrying any limb variants should be discarded. Any off-type trees should be rejected as budwood sources. It is to be preferred if the trees have been used for budwood previously and have shown that they reproduce their characteristics.

It is also desirable that the trees should be on the same rootstock as that which it is intended to use; in fact, this is essential in certain cases, as explained in a later section on virus diseases.

If the budwood-trees are also selected in a district where it is intended the future trees shall be planted, the possibility that the type is especially suitable to the district is also taken care of; it is possible that outstanding strains in a given district may be particularly suited to that district but not necessarily superior to the best local strain in another.

In most States some form of budwood selection scheme is in operation, under which buds are available from trees that have been selected over a long period for their desirable characteristics. If individuals wish to propagate trees from budwood external to these schemes, they must make close inquiry along the lines indicated into the characteristics of the proposed budwood-trees.

**Bud Sports or Mutations**

The need for careful budwood selection in citrus varieties is due to the occurrence of bud sports or bud mutations.

Examination of any number of fruit-trees of most citrus varieties, even of a bud-selected line, will show that there is a certain amount of variation in the vegetative growth and the fruit characters, which is to be ascribed to natural variation, is not due to fundamental changes in the tissue in the trees, and is not reproducible by budding.

Some variants, however, are capable of reproduction from buds on
the wood directly bearing the variant. It is considered that the variant has originated in some change in the tissue of the bud that produced the variant shoot. For this reason they are called bud sports or bud mutations. Mutations may affect almost any character of the tree—leaves, shoots, flowers, and fruit—and give rise to differences from the normal type. Mutations modifying fruit characters are usually the most important commercially, for they may affect productivity, size, shape, season of maturity, skin qualities, and flesh qualities. Common mutations are sectorial fruit, corrugated or banded fruit, thick-skinned and coarse-skinned fruit, and variegated leaf patterns. Mutations are usually a variation from type clearly beyond the range of natural variation, although not necessarily so.

Buds taken from mutations may give rise to an entire tree of the variant, a tree that starts off as the variant but then produces branches with normal characteristics, or a tree that from the start is a mixture of the variant type and the normal. Some strains of a given variety are more prone to sporting or mutation than others, and such strains will reproduce the sporting tendency continually in trees propagated from them by budding. Fig. 5 shows a range of fruit produced by a sporting strain of Valencia investigated by Levitt.13

Mutation may occur in a fruit bud, giving rise, for example, to a typical banded or sectorial fruit. If this mutation originated in the fruit bud, and not in the vegetative bud that gave rise to the fruiting shoot, the mutant will not be reproducible by buds taken from the wood back of the fruit. Occasional fruit of this nature—non-reproducible mutations—can be found in many a commercial crop.

The occurrence of bud mutation is greater in citrus than in any of the other commonly grown fruits, and it is the object of bud selection to select positively towards good-type fruit and thus select away from all apparent off-type variation.

The process of selection for improved type has been going on for centuries in the case of an old variety like the Navel, which has been vegetatively propagated of necessity, and the best modern type probably represents an accumulation of selected favourable variations.

Useful bud mutations or sports have been selected in the past. Many distinct strains of standard varieties have originated through the discovery, selection, and propagation of economically useful mutations. If they are sufficiently distinct from the parent they are given the status of a new variety. Examples are mentioned under Washington Navel and Grapefruit in Chapter 2.

 Cause of Mutations

Mutations are thought to be due to a distinct and sharp change in the genetic make-up of one or more cells at the growing point of a bud. Presumably the change can occur in any one of the three primary layers of cells or histogens in a growing point. The mutation may occur by a change in the units—the genes—of which the chromosomes of the nucleus are composed, or during the division of the nucleus when a loss of one or some of the units, or an abnormal recombination of them, may take
place. The mutating cells and the normal cells, as they multiply during the phases of cell division, enlargement, and differentiation, give rise to genetically dissimilar tissue. Fruit buds are formed sooner or later from this mixture, for they, too, are formed at a growing point. The fruits, therefore, consist of a mixture of mutated and normal tissue. The relation of the one to the other gives rise to certain possible patterns. Hence we get sectorial chimeras, corrugated or banded patterns, and variegation.

![Image of Valencia orange-tree mutations](image)

**Fig. 5.** Mutations produced by a Valencia orange-tree of inferior strain. (Agricultural Gazette of N.S.W.)

Very occasionally a different sort of variation may occur, namely the graft hybrid or bizzarria. It arises, presumably where a bud is formed at the point of union of two varieties (say, stock and scion) and the bud is a mixture of two varieties instead of being wholly one or the other. On growing it would give rise to a shoot composed of mixed tissue of the two varieties.

**Selection against Pests and Diseases**

It is obvious that the budwood should be free of pests and diseases. Some, however, may be so concealed, for example citrus-bud mite or some virus diseases, that unless close investigation is made the budwood may be used without knowledge of its disease or pest content.

**Virus Diseases in Relation to Propagation**

A new chapter has been opened in budwood selection by the discovery that certain diseases, some of them appearing only in certain stock-scion combinations, are the manifestations of virus infection.

Some of the viruses cause death of trees, some bring about large reductions in tree size and productivity, and even the least noxious of them may be responsible for some decline in yield. Some of the diseases are spread in the field by an insect—this particular carrier of the virus infection being called the vector. For others no vector is known as yet.
All of them will be disseminated by the use of infected budwood. Consequently the choice of budwood should always be made from unaffected trees of sufficient age on the hypothesis that such trees are free or may be resistant or are protected by a mild strain infection. Considerable inquiry is required in this direction with some of the viruses because they do not exhibit their symptoms till the trees are many years of age, for example, scaly-butt, psorosis, shell-bark and mandarin decline. Therefore budwood should be selected only from trees which, being old enough to have exhibited the symptoms, are nevertheless unaffected. Considerable work is in progress with methods for the rapid and early detection of viruses in citrus, which it is hoped will afford a guide for budwood selection in the future. As regards the stock, seedling stocks can be considered to be free of virus infection for reasons which will be explained later in this chapter.

Although information is as yet incomplete and is being accumulated rapidly, it is necessary to take a bird's-eye view of the virus diseases because of their importance to the selection of stock and scion. The following virus diseases are recognized: bud-union decline;\textsuperscript{15} scaly-butt;\textsuperscript{1,2,3,4,5} stem-pitting;\textsuperscript{18} mandarin decline;\textsuperscript{10,19} psorosis;\textsuperscript{10} shell-bark;\textsuperscript{10} lemon crinkle-leaf. In the present state of knowledge it is not known if there is any exact relationship between some apparently different diseases, and there may be others at present in Australia. Other citrus virus diseases are known abroad, and a close watch is being kept for any outbreak of them in this country.

\textbf{Fig. 6.} Psorosis.  
\textit{(Photo: A. E. Vincent.)}

\textbf{Fig. 7.} Scaly-butt.  
\textit{(Agricultural Gazette of N.S.W.)}
**Selection of Variety and Rootstock**

*Psorosis* (Fig. 6). This does not appear till the trees are fourteen or so years of age. In young infected trees an oak-leaf pattern occurs in the young leaves for a short time. The symptom is ephemeral, but should be watched for, since it affords an early indication of the presence of the disease. The virus affects sweet orange, mandarins, grapefruit, and trifoliata; lemon and Seville carry the virus without showing symptoms.

A vector is not known. The virus is spread by propagational methods. This disease may therefore be excluded during propagation by selecting budwood from trees fourteen or more years of age that have not developed symptoms. Except in Queensland the disease has been of limited importance in Australia, and appears to be increasing.

*Scaly-butt*. This is a scaling of the bark of trifoliata rootstock (Fig. 7), which does not occur till infected trees are from three to eight years of age. The virus is carried without showing symptoms in other citrus varieties. A vector is not known, and spread is effected by propagating from infected budwood. Varieties growing on any other stock than trifoliata can give no indication that they may be infected. The virus may be excluded by the use of virus-free budwood, obtained from trees growing on trifoliata stock, eight or more years of age. Scaly-butt is associated with stunted growth; stunting on trifoliata may occur without scaling of the stock.

*Tristesa, quick decline or bud-union decline*. Variable symptoms are shown according to the species and the stock and scion combination. Infected sweet orange and mandarin on Seville stock show a rapid decline of the tree, giving the name quick decline. Gumming of the phloem (or inner bark) occurs, resulting in the starvation of the roots, hence the name bud-union decline.

Lemon on Seville is symptomless, and infected sweet orange on Seville in the early stages of infection can be top-worked to lemon. Sweet orange or Seville on their own roots and Seville on sweet orange root do not show the disease.

*Stem-pit, dimpling, or stunt-bush*. Infected grapefruit trees show stunted and clustered growth, deep pitting or shallow dimpling of the stems and trunk, and reduced size, malformation and marked thickening of the skin of the fruit (Fig. 8). This disease occurs in grapefruit on any stock; Wheeny is symptomless. The vectors are *Aphis citricid*is and *A. gossypii*, and thus trees are constantly exposed to infection on the coast, but somewhat less so inland, owing to the less frequent occurrence of these two aphids. Budwood should be obtained from symptomless trees in case they have mild-strain protection or are tolerant strains.

*Yellows*. This causes severe leaf-yellowing and stunting in seedlings of Eureka lemon, Seville orange, grapefruit, and citrons, and less severe yellowing of Ellendale mandarin and some other varieties. The virus may be responsible for decline disease of Ellendale mandarins on Rough lemon stock. It is transmitted by the black citrus aphid, *Aphis citricid*is.10

*Shell-bark*. Symptoms usually occur in lemons and Seville oranges at some eighteen or more years of age, and periodically thereafter. Affected
trees develop yellow foliage, leaf-fall, and die-back of the twigs; the bark around the butt gums and splits (Fig. 9). New bark forms below the affected tissue, which flakes off, and the tree recovers after about a season. Shell-bark is widespread in Australia, but is not known in metropolitan Victoria. The cause of the disease and the method of transmission have not been ascertained. Buds should always be taken from trees that show no active bark symptoms. Grapefruit has a high degree of resistance, and may be successfully top-worked to lemons and Seville oranges.

Fig. 8. Stem-pitting, extreme symptoms.  
Fig. 9. Shell-bark.

*Mandarin decline.* A general unthriftness of the Ellendale, Imperial and Glen Retreat mandarin varieties develops after about eight years of age if they are on Rough lemon stock, in contrast to the continuation of satisfactory growth if they are on trifoliata or sweet orange stock. Emperor mandarin may also show a decline on Rough lemon.

**ROOTSTOCKS**

A range of stocks is available from which to make a choice. The principal rootstocks in use in Australia in order of popularity are Rough lemon, sweet orange (variety Parramatta), trifoliata, Seville orange, and mandarin (variety Emperor).

In addition, quite a number of other varieties are under investigation. Overseas, extensive use is made of varieties such as the Palestine sweet lime in Palestine and the Hog shaddock in Jamaica. Of these we have
little or no experience, and, together with other species and hybrids, they have yet to be tested under Australian conditions.

On the other hand some rootstocks have been discarded on past experience. The citron and cultivated lemon mentioned by early workers proved too susceptible to root-rot during the 1860s. The Seville, sour or bitter orange was condemned in the Sydney area in 1890. Its recent failure in inland districts has spelt the ultimate eclipse of this variety as a rootstock for oranges and mandarins. The cause in this case is tristesa or bud-union decline. Some reference to this stock is made in the following section, although it does not deserve practical consideration for oranges and mandarins until its susceptibility to that virus can be overcome. Grapefruit seedlings have been a failure in the nursery.

Among mandarins, seedlings of Emperor and Scarlett have been used fairly extensively for mandarins and oranges in Queensland with evident satisfaction. The variety Cleopatra, however, has not shown favourably for various varieties in New South Wales.

Requirements of a Rootstock

As the rootstock is the part of the cultivated tree that will occupy the soil and support the scion variety, it should be chosen with five aspects well in mind. The main considerations are those of the trees in the orchard. Nursery characteristics are of secondary importance in the selection of a stock, and, insofar as they affect nursery practice, are discussed in Chapter 4. The five requirements in orchard trees are: (i) resistance to Phytophthora root-rot; (ii) resistance to decline from virus infection; (iii) suitability to the soil conditions of the intended orchard; (iv) desired effects on the tree and fruit of the scion variety; and (v) suitability to the selected variety or varieties.

These requirements will now be discussed in turn, and in the light of the discussion stocks for the different scion varieties will be tabulated.

Resistance to Root-rot and Other Root Troubles

A rootstock should be selected with a full knowledge of its susceptibility to the root-rot caused by Phytophthora citrophthora, which destroys the root fibre and even invades the larger root, causing death of bark (Fig. 10). Deep roots are first affected, and if wet conditions prevail eventually only the surface roots survive.

The root condition affects the top. Leaves turn yellow and fall, twigs die, and the tops of the trees become very thinly foliaged and open. Trees existing only on shallow roots are very subject to dry spells, as well as to cold in winter. Fruit-fall and irregular bearing results. Promising young trees after a few early crops may decline rapidly. Depending upon the extent of the root infection, trees on susceptible stocks may be found that vary in condition from excellent through various stages of unthriftiness to advanced decline, or death.

The organism also causes a highly destructive collar-rot and gummosis, a fruit-rot called brown rot, and a leaf-spotting and -blight.

Conflicting reports are to be found on the relative susceptibility of
rootstocks, when they are based on field evidence. Investigations by Fraser⁸ carried out under controlled conditions gave the following definite order of susceptibility.

**Highly resistant**
- Trifoliat
- Citrange, var. Carrizo

**Resistant**
- Citremont
- Citrange, var. Morton
- Tangelo, var. Sampson
- Tangelo, var. Thornton
- Sour orange
- Mandarin, var. Cleopatra
- *Microcitrus*, Sydney Hybrid

**Susceptible**
- Eureka and Lisbon lemon
- Rough lemon
- Sweet orange
- Sweet lime
- Grapefruit, var. Duncan
- Grapefruit, var. Wheeny
- Citron, var. Bengal
- Citron, var. Knight
- *Citrus excelsa*
- Yuzu

Since the eclipse of sour orange, trifoliat is the main root-rot-resistant stock, and its hybrids a source of potential new ones. Mandarin has a degree of resistance, and some of its hybrids inherit this resistance.

---

As the most widespread disease of citrus in Australia, Phytophthora root-rot should be given first consideration in the selection of a rootstock. On this score, planting policy may be summed up as follows:

(a) For planting in affected soil, resistant varieties must be used. For replanting old citrus land a resistant stock is essential. For soils and situations favourable to the disease, a resistant stock is required.

(b) For ideal situations—for virgin soils of light texture, good depth and excellent drainage—susceptible varieties such as Rough lemon or sweet orange may be used, if the trees themselves are free of root-rot, and subsequent management is directed at the prevention of excessive soil moisture.

Other important parasites of the root are *Armillaria mellea*, nematode, and fruit-tree-root weevil. Stocks are not available for resistance to these troubles.
Another root disease, known as sudden death is presumably due to a fungal organism. *Trifoliate* is susceptible, but the other common stocks seem to be little affected.

**Resistance to Decline from Virus Infection**

Sour orange is the classical example of a citrus rootstock showing collapse of sweet orange and mandarin scions on infection by a virus (in this case quick decline or tristeza), owing to the rapidity and completeness with which the collapse often occurs. With lemon scions quick decline does not occur on this stock.

*Trifoliate* is subject to scaly-butt and stunting from virus infection, but this trouble can be obviated by budwood selection, as already mentioned, except for lemon scions in which there are no virus-free sources at present. This stock apparently does not deteriorate from other common viruses.

Rough lemon appears to be tolerant of all the common viruses except mandarin decline. Certain varieties of mandarin, such as Ellendale, Imperial and Glen Retreat show a decline from about the eighth year, the trees losing vigour of growth and size of fruit and failing to rejuvenate.

Sweet orange seems to be tolerant or resistant to all the main viruses causing decline.

There seems to be no rootstock giving resistance to deterioration of citrus-trees when they are affected by scaly-bark psorosis, when grapefruit are affected by stem-pit, or lemon-trees are affected by shell-bark.

Having separated out from rootstock effects in general, those due to Phytophthora effects and those due to virus infection, there remain several other effects to be noted.

**Suitability to Different Soils**

*Rough lemon*. This shows the best response in deep sandy soil; many instances can be quoted of this rootstock growing satisfactorily on much heavier soil when drainage is good, but not when it has been defective over a period of time. Heavy soils carry an element of risk because Phytophthora will develop rapidly if the conditions for its growth are favourable. When heavier soils are used, special attention must be given to surface and underground drainage. Even so, they carry too narrow a margin of safety for *Rough lemon* or other susceptible stocks. Rough lemon is well suited to the acid soils of humid districts, where it maintains its early advantage in growth and yield much longer than in inland districts. Possibly it is better suited to benefit by the variable rainfall.

*Sweet orange* (and *Seville*) rootstocks. These are more tolerant of the neutral to alkaline soil conditions of inland districts than Rough lemon. They are both less tolerant of droughty conditions than Rough lemon.

The sweet orange stock is somewhat shallow-rooted and does not thrive when the locality is subject to drought conditions. Under irrigation, frequency of irrigation must be more carefully watched than with *Rough lemon* stock in order that trees will not suffer in the irrigation interval.
In humid districts orange-trees on sweet orange are apt to show greater water-stress than trees on Rough lemon during dry spells.

*Trifoliata.* This is undoubtedly more tolerant of heavier and wetter soils by virtue of its immunity from Phytophthora, but does not thrive in soils more acid than pH 5.0. Soil pH is described in Chapter 9.

On fairly lengthy experience this stock has proved very satisfactory for soils in the humid districts of New South Wales, where it is recommended provided that proper attention is given to the selection of budwood. In inland districts experience is less extensive, but the evidence is that the more suitable the soil is for Rough lemon, the more suitable it will be for trifoliata.

In Chapter 9 is given the reaction of stocks to special conditions such as excess boron in the soil, and on p. 75 the reaction of different stocks to salt. Resistance to toxic soil conditions on the part of any rootstock applies only to low concentrations, for resistance disappears at higher concentrations and the soil becomes quite unsuitable for any rootstock.

**Effect of Rootstock on Tree Characters and Productivity**

*Rough lemon* generally gives trees of the orange (except Maltese Blood), grapefruit, and lemon that are vigorous, upright-growing, and finally large and heavy-bearing. They crop well in the early years along with vigorous growth. Rough lemon is one of the deeper-rooted species under good citrus soil conditions, although this characteristic cannot assert itself where variable soil moisture and the soil reaction (pH range of 5.5 to 7.5) are favourable to the impairment of the root system by Phytophthora. Hence, depending upon the extent of root-rot infection, trees on Rough lemon may vary in condition from excellent to unthrifty. Ellendale, Imperial and Glen Retreat mandarins become unthrifty on Rough lemon stocks after about eight years of age, due to the mandarin decline virus.

*Sweet orange* gives citrus-trees that are somewhat slow-growing during their early years after planting. At first they are light-cropping also, but in the inland districts with their neutral to alkaline soils orange-trees on sweet orange stock by about eight years of age usually become larger than those on Rough lemon stock, and thereafter surpass them in growth and yield. They finally make large shapely trees. On the east coast the early, slow-growing period lasts much longer. In a trial at Narara, in New South Wales, Washington Navel and Valencia orange-trees on sweet orange are still smaller at fourteen years of age than those on Rough lemon. Mandarins on sweet orange surpass those on Rough lemon after about eight years of age. As sweet orange is susceptible to Phytophthora the same remarks as recorded above for Rough lemon apply to sweet orange stock.

The productivity of Washington Navel and Valencia oranges on sweet orange, sour orange, and Rough lemon stocks, in a trial at Irymple, Victoria, is shown in Table VI. The trees were planted in 1934 and were first allowed to bear in 1938. Yield of recent years and total yield are shown in the table.
TABLE VI

YIELD OF ORANGES FROM VARIOUS ROOTSTOCKS, IRYMPE, VICTORIA

<table>
<thead>
<tr>
<th>Type</th>
<th>Yield per tree</th>
<th>Total per tree 1938-9 to 1951-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navel:</td>
<td>lb.</td>
<td>lb.</td>
</tr>
<tr>
<td>Sweet orange</td>
<td>131</td>
<td>391</td>
</tr>
<tr>
<td>Sour orange</td>
<td>106</td>
<td>298</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>117</td>
<td>261</td>
</tr>
<tr>
<td>Valencia:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet orange</td>
<td>242</td>
<td>324</td>
</tr>
<tr>
<td>Sour orange</td>
<td>245</td>
<td>252</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>231</td>
<td>235</td>
</tr>
</tbody>
</table>

Certain peculiarities of sour orange on Victorian experience may be noted.

Trees on this stock typically show overgrowth of the stock by the scion at the bud union and normally grow rather slowly, although they finally are not much smaller than trees on Rough lemon and sweet orange. Like sweet orange it cannot stand relatively dry soil conditions. The reason for this is not a shallow rooting system, for it is in fact deep rooting, but rather in the very low osmotic pressure of its roots. This low osmotic pressure makes it impossible for the roots to withdraw moisture from soil even moderately dry.

*Trifoliata* has often been referred to as a dwarfing stock. This effect can be discounted now that it is known to be caused by a virus that can be excluded during propagation.

Varieties of orange, mandarin, and grapefruit on trifoliata stock are rather slow-growing in their non-bearing and early-bearing period, although there have been as yet no controlled experiments where scaly-butt-free wood was used, to show the exact difference. Experience is that on trifoliata, trees free of scaly-butt and stunting virus attain adequate size in later life, and where root-rot occurs they outgrow trees on susceptible stocks and survive after they have failed.\(^4\) The leading lemon varieties cannot be used on trifoliata owing to the lack of scaly-butt-free budwood.

During the winter orange-trees on trifoliata show a characteristic leaf-roll, a condition that is quite independent of the soil-moisture situation and may be connected with the deciduous nature of this stock.

The health of the root has many beneficial effects. Varieties worked on this stock have often been noted to have somewhat greater frost resistance and drought resistance than when on other stocks.
In coastal New South Wales trees on trifoliata stock often show denser foliage and darker green, larger leaves and better shoot-growth at the top than trees on Rough lemon. Maintenance of vigour in the mature tree tends to reduce black spot, which is well known to be less prevalent on vigorous trees.

There have been numerous observations that bearing is more regular on trifoliata than on Rough lemon stock. The fruit is held more firmly on the trees, particularly at maturity—an effect that is especially noticeable in periods of heavy rain or in locations subject to flooding. The holding of the fruit on the tree and the retention of quality shows up noticeably following the incidence of light frosts and moderate drought. These are commercially valuable characteristics, particularly for certain varieties such as Valencia oranges and Marsh grapefruit.

Mandarins on trifoliata, as on sweet orange, do not show the decline that they do on Rough lemon.

In bearing propensities, trees on trifoliata stock are definitely precocious, often to the extent that early crops should be removed in order that the young tree may make more structural growth. Cropping is usually heavy in relation to the size of the tree.

Effect of Rootstock on Fruit Characters

Rough lemon gives a fruit with a somewhat thicker skin and often with a noticeably pebbly texture, owing to the protuberance of the oil-cells. The shoulder at the stalk end may be more pronounced.

In the Irymple rootstock trial some clear effects on Washington Navel and Valencia oranges were recorded.\(^{16}\)

The fruit from trees on Rough lemon stock is the least attractive, has most rind and consequently least juice, but generally attains market maturity on the average three weeks earlier than fruit from trees on the other two stocks. Lower acidity of fruit on Rough lemon stock is associated with lower soluble solids.

It is noticeable that this fruit has not the full flavour of fruit from sweet orange and sour orange stocks, which is higher both in acidity and soluble solids.

Late in the season, owing to the drying out of the fruit at the stem end, that is granulation, the rag of fruit on Rough lemon increases rather seriously. The fruits from trees on sweet orange and sour orange stocks are comparable and retain their quality late in the season, compared with the loss of flavour and granulation, and the re-greening in particular of Valencia oranges on Rough lemon stock.

Storage tests of the oranges at 45°F. showed that those from sweet orange and Seville stocks kept a few weeks longer than those from Rough lemon. Reduced storage life of fruit from trees on Rough lemon is probably due to their three-weeks earlier maturity.

Rough lemon produces the poorest-quality fruit with mandarin and grapefruit scions. Mandarins become puffy and dry out earlier than when on trifoliata or sweet orange.
Oranges from sweet orange and sour orange stocks compared with Rough lemon stock are thinner and smoother-skinned and the flesh is usually deeper in colour. As pointed out in the Irymple trial they are higher in acidity and soluble solids, with the result that they are of improved flavour. These stocks are conspicuous for causing the retention of quality late in the season. Granulation and re-greening of the fruit of Valencia oranges are delayed most by sweet orange stock.

Typical analyses of fruit qualities show the differences presented in the following table.

**TABLE VII**

**ANALYSIS OF ORANGES FROM VARIOUS ROOTSTOCKS, IRYMPE, VICTORIA**

<table>
<thead>
<tr>
<th>Type</th>
<th>Juice</th>
<th>Rind</th>
<th>Rag</th>
<th>N/10 Sodt</th>
<th>Brix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>degrees</td>
<td></td>
</tr>
<tr>
<td>Washington Navel:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet orange</td>
<td>53</td>
<td>34</td>
<td>13</td>
<td>18.6</td>
<td>11.2</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>50</td>
<td>37</td>
<td>13</td>
<td>16.8</td>
<td>10.3</td>
</tr>
<tr>
<td>Sour orange</td>
<td>50</td>
<td>37</td>
<td>13</td>
<td>20.1</td>
<td>11.5</td>
</tr>
<tr>
<td>Valencia Late:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet orange</td>
<td>60</td>
<td>31</td>
<td>9</td>
<td>17.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>57</td>
<td>32</td>
<td>11</td>
<td>12.9</td>
<td>11.5</td>
</tr>
<tr>
<td>Sour orange</td>
<td>59</td>
<td>31</td>
<td>10</td>
<td>16.7</td>
<td>12.4</td>
</tr>
</tbody>
</table>

* Equivalent to per cent total soluble solids in juice.

**Trifoliata** decidedly affects the internal qualities of fruit, compared with other rootstocks, but particularly so when compared with Rough lemon. Such fruit is a little later in ripening, according to the acidity test, but even so is better flavoured. The difference in flavour is supported by a three-year chemical examination of Valencia and Washington Navel orange and Marsh grapefruit from three rootstocks—trifoliata, Rough lemon, and sweet orange.¹¹ The best-quality fruit of the three varieties was produced on trifoliata rootstock, the fruit being usually highest in specific gravity, acidity, soluble solids, and flavour. Grapefruit was markedly sweeter and less bitter on trifoliata stock than on other stocks. Oranges held their palatability longer on the trees on trifoliata and sweet orange stocks than on trees on Rough lemon. The flavour of mandarins is improved most noticeably by trifoliata rootstock. Trifoliata takes second place to sweet orange rootstock for delaying granulation and re-greening of late-held Valencia oranges.

Bitterness in orange juice is also affected by rootstocks.¹² Bitterness is due to the presence of the limonin group of compounds that occur in the albedo and carpel walls of the fruit. Immature fruits always give bitter juices, but with advancing maturity the bitterness decreases and may eventually cease to be detectable.

Early varieties are an exception. In them the process of removal of the
bitter principles does not keep pace with the process of normal ripening. Thus Navel oranges may yield bitter juice even when they are apparently mature. On the other hand the juice of late varieties such as Valencia is generally free from bitterness at normal eating ripeness.

Rootstock effects on bitterness of the canned juice of Washington Navel oranges, picked on the same day, were as follows: trifoliata was least bitter, with tangelo and Cleopatra mandarin not very different; Parramatta sweet orange and East Indian and sweet limes were inter-

### TABLE VIII

**ROOTSTOCKS FOR CITRUS VARIETIES**

<table>
<thead>
<tr>
<th>Scion</th>
<th>Rootstock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Orange:</td>
<td></td>
</tr>
<tr>
<td>Washington Navel and</td>
<td>Trifoliata for conditions liable to root-rot if scion</td>
</tr>
<tr>
<td>Valencia</td>
<td>wood is free of scaly-butt. Sweet orange for inland</td>
</tr>
<tr>
<td></td>
<td>well-drained districts. Rough lemon for safe locations,</td>
</tr>
<tr>
<td></td>
<td>if the young trees are free of root-rot. Sour orange</td>
</tr>
<tr>
<td></td>
<td>is not recommended.</td>
</tr>
<tr>
<td>Joppa and other common</td>
<td>As above. Special care is necessary to ascertain that the</td>
</tr>
<tr>
<td>oranges</td>
<td>budwood is free of scaly-butt for use on trifoliata, and</td>
</tr>
<tr>
<td></td>
<td>is free of psorosis.</td>
</tr>
<tr>
<td>Maltese Blood</td>
<td>As above, except that Rough lemon is not recommended.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Lemon:</td>
<td></td>
</tr>
<tr>
<td>Lisbon</td>
<td>Rough lemon. Sour orange is recommended in Victoria.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Eureka and other varieties</td>
<td>Rough lemon. Sour orange may be used. Trifoliata cannot be</td>
</tr>
<tr>
<td></td>
<td>used, owing to lack of scaly-butt-free wood.</td>
</tr>
<tr>
<td>Mandarin:</td>
<td></td>
</tr>
<tr>
<td>Emperor, Imperial, Glen</td>
<td>Sweet orange. Trifoliata for improved quality, if the</td>
</tr>
<tr>
<td>Retreat, Ellendale</td>
<td>scion is free of scaly-butt virus. Rough lemon should not</td>
</tr>
<tr>
<td></td>
<td>be used owing to mandarin decline virus; fruit quality is</td>
</tr>
<tr>
<td></td>
<td>inferior. Emperor mandarin had been used satisfactorily in</td>
</tr>
<tr>
<td></td>
<td>Queensland.</td>
</tr>
<tr>
<td>Other varieties</td>
<td>Sweet orange, or trifoliata if scaly-butt-free wood is</td>
</tr>
<tr>
<td></td>
<td>available. Rough lemon will give inferior fruit quality and</td>
</tr>
<tr>
<td></td>
<td>may show mandarin decline.</td>
</tr>
<tr>
<td>Grapefruit:</td>
<td>Rough lemon. Trifoliata for improved quality if scion is</td>
</tr>
<tr>
<td>Marsh, Wheeny and other</td>
<td>free of stunting and scaly-butt.</td>
</tr>
<tr>
<td>varieties</td>
<td></td>
</tr>
</tbody>
</table>
mediate in bitterness. Rough lemon and Kusaie lime were most bitter. Navel oranges on trifoliata lost bitterness early in the season, but on Rough lemon never lost it. The bitter principle content of the peels ran approximately parallel with the bitterness of the juices. Vitamin C content of the canned juice was not affected by rootstocks.

The effect of rootstocks on the quality of canned juice from Valencia oranges was also investigated. Whereas juices of Valencia oranges from trifoliata and sweet orange stocks were virtually free from bitterness at normal maturity, that from Rough lemon was appreciably bitter up to an advanced stage of maturity.

In general quality Valencia juice from trifoliata rootstock was rated best and from Rough lemon worst, with sweet orange in between. This preference for trifoliata was due not only to its lack of bitterness but also to a distinctive aromatic flavour that greatly increased its attractiveness.

Stocks for Different Varieties

Following upon the detailed information given in the preceding sections, suitable stocks for different varieties may be summarized as in Table VIII.

CITRUS SEED AND SEEDLINGS

Rootstocks are seedlings of the varieties referred to. Some knowledge of the nature of seed reproduction is desirable to explain the occurrence of multiple embryos, why they are free of virus, and why it is that some varieties breed true to type from seed, whilst others do not. It is convenient to consider also the question of seediness, since seedlessness is a character much sought after in commercial varieties.

Formation of Sexual Embryos

Citrus seeds often produce more than one seedling (Fig. 11). They may contain both sexual and asexual embryos that are capable of developing into seedlings. The occurrence of several embryos is polyembryony (poly, many). The extent of polyembryony varies with the species, and may vary even with the size of seed and the nutrition that has been given to that seed.

Seed development is an integral part of fruit formation. The development of the flower and its parts from a vegetative growing point are described in Chapter 14.

In Fig. 12 is seen the minute female ovule in the pistil of the flower; the male pollen grains in the anthers are not included in the illustration. The bursting of the anthers at their proper stage of maturity releases the pollen, which is carried to the stigma, usually by bees or other insects, for the attractive fragrant flowers with their sticky stigmas are obviously adapted to the insect type of pollination. Here it germinates, producing a germ tube, which grows down the style, carrying two male nuclei to the entrance or micropyle of the ovule.
The mature ovule consists externally of covering walls or integuments and internally of tissue, the nucellus, in which is located, towards the micropylar end, the embryo sac. The embryo sac is a large cell containing eight nuclei—the egg nucleus, two guide nuclei or synergids, two polar nuclei in a central situation, and three antipodal nuclei at the base of the embryo sac.

Fertilization consists of (a) the union of one of the male nuclei with the egg nucleus (this is the start of the embryo), and (b) the union of the second male nucleus with the two polar nuclei. The tissue produced from this triple fusion is the endosperm, which, however, is short-lived.

Fig. 11. Germinating trifoliata seeds showing polyembryony (above) and crooked root development (below).
The sexual embryo, being the combination of male and female nuclei, is different from the maternal tissue in which it lies, and is the beginning of a new plant that may be unlike any plant produced before. The male nucleus may have come from pollen of the same plant or from a different plant of the same variety (self-pollination). However, the embryo formed as the result of self-pollination does not necessarily give rise to a plant exactly like the parent.

*Fig. 12.* Longitudinal section of flower of Navel orange, showing vascular connections of the organs of the flower and navel carpels (p. = petal; s. = sepal; st. = stamen; v.b. = vascular bundles).

If the male nucleus came from pollen of a different variety, the embryo is the result of cross-pollination; if it came from a different species or genus it is called a hybrid. In citrus wide crosses have resulted in some important hybrids, a fact already dealt with at greater length in Chapter 2.

The embryo can be seen to consist of two cotyledons or seed leaves enfolding the axis of the embryo plant—the growing point of the future stem, the plumule, and the embryonic root, the radicle.
Formation of Asexual or Nucellar Embryos

The fusion of a male and female nucleus to form the sexual embryo, or even the mere occurrence of pollination and the growth of the pollen tubes down the style, provides a considerable stimulus to nucellar tissue, and certain cells in the nucellus are prone to multiply and become organized into an embryo. Several may form. As such embryos are formed without fusion with a male nucleus, they are said to be apogamous or apomictic (without marriage), and since they are formed from nucellar tissue they are appropriately called nucellar embryos.

The important difference between such nucellar embryos and the sexual embryo is that the former are derived entirely from mother tissue, and they can be expected to reproduce exactly the maternal or fruit parent. In fact, it has been found, in the case of nucellar seedlings of Valencia orange, for example, that they resemble the mother Valencia in type, but they usually possess long thorns and are more vigorous. Nucellar seedlings of Washington Navel do not resemble the parent as nearly.

Some varieties have a better developed faculty of nucellar embryony than others, and produce more nucellar embryos or seedlings. In a few instances (for example, shaddock) the variety habitually fails to produce nucellar embryos, and consequently all the embryos and the subsequent seedlings are sexual. In other cases, for example, Rough lemon, the variety seldom produces sexual embryos, and practically all of the seedlings are nucellar and thus of the mother type.

Exclusion of Virus

Virus infection is usually concentrated in tissue external to the cambium, namely the bark and the foliage. The virus particles, to gain entrance to an embryo, have to pass through several dense, specialized types of tissue—the chalaza at the base of the ovule, and the nucellus. These appear to act as barriers, since the embryos succeed in remaining free of virus infection. It is of the greatest practical importance that virus infections are naturally excluded from sexual and nucellar embryos despite the fact that they lie in such close contact with the maternal tissue in which the viruses develop. Seedlings start off free of virus, and if virus-free buds are employed the young tree is not handicapped by infection.

Failure of the Sexual Process

Sexual seedlings usually fail to develop in some varieties owing to defectiveness at some stage connected with the egg apparatus, or during fertilization or embryo growth.

To take an extreme case of one sort, Washington Navel usually produces no viable egg-cells. Hence no sexual embryos can be produced, and since the variety appears to have a poor faculty of apogamy it produces no nucellar embryos, and hence is usually seedless. Sometimes, however, an occasional seed is found in fruits of the Navel orange, which, owing to the sterility of the egg-cell, is considered to be of apogamous origin. Failure of the sexual and the apomictic methods of reproduction results in seedlessness.
An extreme case of another sort is Rough lemon, a hybrid. In hybrids the sexual process is apt to fail, and in the case of Rough lemon it usually fails, so sexual embryos are usually not formed. But this variety has a well-developed faculty of producing nucellar embryos. Hence it seeds freely and, moreover, since practically all the embryos are nucellar the resulting seedlings exactly reproduce the Rough lemon parent. Hence Rough lemon as reproduced all over the world from seed comes remarkably true to type. Failure of the sexual process but persistence of the apomictic faculty gives seeds that on germination come true to type.

Proportion of Nucellar Seedlings

Apart from the instances just mentioned, citrus seeds usually produce on germination a mixture of sexual and nucellar seedlings. It is not possible by inspection to differentiate between the nucellar embryos and the sexual embryos in the seed, but there is a method that has been used to ascertain the proportion of each. It consists of the ingenious technique of utilizing the morphological differences between species.

When a sweet orange flower is pollinated with another sweet orange the sexual seedlings arising resemble sweet orange in growth characters. The nucellar seedlings are also, of course, sweet orange, and it is impossible to tell the difference between the two.

If, however, a sweet orange flower is pollinated with sour orange or grapefruit, at least some of the hybrids arising inherit the typical winged petiole of their pollen parents and may be distinguished, on this character, from the wingless-petioled sweet orange nucellar seedlings. Some of the hybrids may also have the wingless petiole.

If now the sweet orange is crossed with trifoliata pollen, the dominance of the three-leaved character of the pollen parent gives the hybrids the divided leaf character, and they are distinguishable from the sweet-orange-leaved nucellar seedlings.

By the use of controlled crosses to produce morphologically distinguishable seedlings along such lines, the proportion of nucellar seedlings has been arrived at for many citrus species and varieties. Cytological examination of the ovules and pollen and the principles of heredity have been enlisted also to unravel the intricacies of seed reproduction in citrus.

Nucellar seedling production in citrus approximates to the following order: 96 to 100 per cent in Rough lemon; somewhat less (80 to 90 per cent) in sweet orange, mandarin, trifoliata, sour orange, and grapefruit; still less (about 50 per cent) in cultivated lemons; nil in shaddock.
CHAPTER 4

THE PROPAGATION OF YOUNG TREES

The propagation of citrus-trees in the nursery for transplanting to the orchard is a project that extends over two and a half or three years. The procedure consists of deciding on the stocks and buds to be used, as described in Chapter 3, and then carrying out the process of raising seedling rootstocks, transferring them to the nursery row, budding them to the scion variety, and developing the young tree from the bud.

The type of tree required is one that is well grown at one year old from the bud, with a well-developed root system and free of diseases and pests of the root and top, especially Phytophthora root-rot and avoidable virus diseases.

It is probably because of the lapse of time rather than any difficulty with the methods that growers generally prefer to buy their trees than to propagate them. Many growers rely unreservedly on nursermen to supply suitable trees, and it speaks volumes for nursermen generally that such confidence in them has not been misplaced. If the nurserman has the required rootstock, orders need only be placed eighteen months or even one year in advance of planting; but if the rootstock required is not available, the full period of two and a half to three years must be allowed when placing the order.

SOIL AND SITE FOR NURSERY

The site for a citrus nursery should be frost-free, have a warm aspect, and be sheltered from prevailing winds, especially those bringing cooling or scorching influences. A water-supply convenient and ample enough for dry spells is also a primary consideration. The temperature and water-supply of the location should be such that the propagator can produce rapid and free growth of the plants, lengthen the period during which stock can be budded and thus allow a better regulation of his working arrangements.

The soil should be friable and deep to permit good root development and ready working by hand tools, a good deal of this type of work being necessary in nurseries. The soil should also be free of Phytophthora as well as eelworm and other root parasites. It is commonly stated that, owing to the disease factor, citrus should be raised on virgin ground. This is not always practicable, but it is desirable that the citrus nursery should be rotated, so that each lot of citrus is grown on ground that has not been under these plants for four or five years. If ground is suspect
the soil can be made less favourable to Phytophthora by particular attention to drainage and by avoiding excessive watering. A sunny situation, the control of weeds to allow the free passage of air among the seedlings, and the roguing and burning of infected plants will help to control Phytophthora. Any spraying for the leaf-blight phase of Phytophthora with Bordeaux mixture must be completed before March to enable safe fumigation with hydrocyanic acid gas to be carried out during the next spring.

The nursery must include provision for seed beds, compost beds, and nursery rows, and provide facilities for the packing, dispatch, and fumigation of the trees. These points will be dealt with at length later in this chapter.

The equipment required varies with the size of the undertaking. A small nursery may be operated by hand tools alone. Good spades, hoes, and other tillage tools, as well as the tools of a more horticultural character such as secateurs and budding knives, together with an ample supply of stakes, pegs, and labels, should be provided. For pest and disease control a knapsack spray or power pump equipped with a long length (120 feet) of quarter-inch spray hose is essential.

**Accessioning and Labelling**

Book records of all material entering the nursery as well as that dispatched from it, and field labelling are an important and integral part of nursery work. The entry or accession book should show the receipt date of all seeds, stocks, budwood, and other propagating material, together with a brief description of the material and, as exactly as possible, its source. This material is numbered serially as received, irrespective of whether it is stock or scion, or the budwood may be accessioned separately from the seeds and stocks.

Reference may need to be made to entries in the event of inquiry years later. Proper accessioning offers the opportunity to prove over a period of years the superiority of some stocks, seeds, or budwood compared with others.

The accession numbers can be carried into the field on labels. A useful type of label is made from pine or white softwood, each label being about ten inches long, one inch wide, and a quarter to three-eighths of an inch thick, planed smooth on one side. The pieces are pointed at one end, and the planed surface towards the other end is wiped over with white paint on which the required information is written before the paint dries. This type of label will remain legible for three years. The required number of labels should be prepared, inscribed, and left for the paint to dry thoroughly in advance of requirements.

**NURSERY CHARACTERISTICS OF VARIOUS STOCKS**

In subsequent sections the general order of nursery work for the production of young trees is discussed, and to avoid digression to special details connected with any particular stock, reference will first be made to nursery characteristics of the various stocks. They cannot all be treated
in the same way as the most common stock, Rough lemon, with the expectation of similar results.

**Rough Lemon**

Ample seed of Rough lemon is available from July to August. It germinates readily and produces a high proportion of tall-growing uniform seedlings for budding. The bark slips for budding till late in the season. When budded early, buds are apt to break out into growth; later buds remain dormant. A high proportion of vigorous trees results from the buds in one growing season. The seedlings are very susceptible to scab and may require spraying with Bordeaux mixture.

**Seville Orange**

Seville orange stock is almost as vigorous as Rough lemon, but is in eclipse owing to bud-union decline.

**Sweet Orange**

Sweet orange stock is definitely not as rapid in growth as Rough lemon, and even with careful attention is usually not large enough for budding as soon as Rough lemon. It may require two seasons in the nursery row before budding. Only the most vigorous seedlings should be selected for carrying to the nursery row, and in the nursery row only the most vigorous should be budded. Germinating seedlings require shade to prevent burning off.

**Trifoliata**

Seed of trifoliata is available in the autumn, and if sown then will germinate, producing small seedlings. In frosty situations they will require the provision of screens during the winter. Alternatively, the seed may be stored and sown in late winter, which is preferable, for there is less trouble with weeds. In the seed bed and nursery row this stock is not as rapid in growth as Rough lemon, and when transplanted to the nursery row seedlings are usually shorter (eight to twelve inches). To produce taller seedlings with less low branching the seed is sown thickly to give crowded conditions and the seedlings transplanted when they are some fifteen inches high. This will save excessive trimming up of the stems of the stocks prior to budding.

In the autumn the budding season is shorter than with evergreen varieties—Rough lemon and sweet orange. It is advisable to start autumn budding early in order that any patching required can be done early, remembering that spring patching can only be done late on this stock because the bark will not lift until the spring flush of growth is approaching maturity. Compensating for the need to start autumn budding early is the fact that the buds usually remain dormant, not starting into a short growth in the autumn as do early buds on Rough lemon. Autumn transplanting of worked trees is not recommended.

Seedlings of trifoliata, as well as sweet orange, should be given every attention in order for them to approximate to the nursery programme of Rough lemon seedlings. Further, these stocks should be planted in
well-prepared ground and receive good moisture-supply, fertilizer, and weeding in the nursery rows.

Mandarins

By keeping watch on the growth of mandarin stock it can be made to approximate to the Rough lemon programme more readily than sweet orange or trifoliata. Shading of the seed beds is necessary to prevent burning off.

SEED FOR ROOTSTOCK

Seed for rootstock should always be obtained from a reliable source. In the case of out-of-State sources, reliability is often a question of confidence in the seller. Whenever possible the actual tree or trees that are to provide the seed should be known to the propagator. Variants from the type that is known to be satisfactory should be avoided.

Collecting the Seed

A few fruits should be examined to ascertain the seed content and plumpness. A test of their viability can be made by conducting a germination test of a sample on damp cotton-wool or blotting-paper at a temperature above 50°F. to 60°F. In the course of two to three weeks the germinative quality will be known with certainty. In estimating the number of seeds to be obtained, allowance must then be made for a lower germination in the seed beds, losses by culling at transplanting time, misses at budding and culling of the year-old trees. It will therefore be on the safe side to obtain three or four times as many seeds as the number of year-old trees required.

As a guide to ordering or collecting seeds, the following figures give the approximate number of seeds per ounce and per bushel of fruit respectively: trifoliata, 150, 12,000; Rough lemon, 240, 1000 to 4000; mandarin and sweet orange, 250, 4000.

Treating the Seed

The fruits of the various rootstock species ripen conveniently for immediate sowing of the seed, trifoliata ripening in the autumn and the remainder ripening towards the spring. Citrus seeds should not dry out before sowing. They may be kept in the fruits practically till sowing time. The dampness of the seeds as extracted may be preserved by placing them between wet bags. When all the seeds have been obtained they should be washed well in water to remove flesh and juice and to discard any that float; they should then be spread out in the shade to dry superficially, for surface-dry seeds are more readily handled during the sowing.

In some instances storage of the seed is necessary. In this case the extracted seeds should be dipped or dusted with a surface sterilizer and, after stratifying, placed in a cool, damp spot. Stratifying consists of placing alternate layers of seed and damp sand or sawdust in a container. They should be held at a temperature slightly below 50°F. in order that
they will not germinate, and examination should be made from time to
time to see that the sand and seeds are damp, but not wet, for excessive
moisture conduces to mouldiness. If mould starts to develop, the seeds
should be sown as soon as possible, because it seriously reduces the
germination.

Seed Beds

Seed beds are used to raise large numbers in a small space, to facilitate
care of the tender plants and, at lifting time, to cut the tap-root, thereby
causing it to branch, and to enable a rigid selection of the seedlings to be
made.

In design, seed beds should be narrow, three to four feet being ample,
in order that they can be conveniently tended from the paths on either
side. They should be raised a few inches above the level of the paths thus
providing surface drainage as well as making for easier working. The
level of the beds above the path may be maintained by timber supports,
in order that the edges of the bed will not dry out more than the
centres. However raised seed beds are not essential in very well-drained
locations.

Provision for some form of overhead protection against the possibility
of frosts in winter or excessive heat in summer is desirable. When seed
beds are not in a lath house, protection may be afforded by erecting
timber supports to a height of some three feet on which tea-tree or other
fine-foliaged brush may be laid. Hessian may be used on supports of this
nature; it has the advantage of being easily rolled and unrolled as required.

The seed beds should be prepared well in advance of sowing. To re-use
seed beds, the old soil is dug out to dispose of any ungerminated seed
and infections prejudicial to the new lot of seedlings, and is replaced by
good fertile virgin soil or composted soil. Compost is prepared by building
up alternate layers of the selected sandy soil and partly decomposed
leaf-mould or other fairly fine organic matter until the heap is about
three feet high, three or four feet wide, and as long as necessary. Super-
phosphate sprinkled on each layer of organic matter will aid decom-
position. The heap is kept damp. Turning the heap after a couple of
months, again forming a similar-shaped heap to the original, is usually
necessary. The proper nutrition of the seed bed by fertilizer, minor element
and dolomite application should receive attention.

After filling the seed beds with new or composted soil, and allowing
time for settling under the influence of rain or watering, they are ready
for sowing.

Sowing the Seed

Seed may be broadcast or sown in rows. It is probably better to sow
in rows, since the better air movement reduces Sclerotinia and Phyto-
phthora losses. The rows are sown across the bed and, where convenient,
should run more or less north and south so that both sides of the growing
plants are given equal exposure to the sun. The rows are usually six inches
apart and the seed one inch apart in the rows and one inch deep.

A batten, two to three inches wide, half an inch thick, and slightly
shorter than the width of the bed may be used to make the drills. The
seeds are then placed along the bottom of the drill and the board is used to scrape sufficient soil over them and tamp them down. Each row is marked by a light peg.

Similar battens sunk in the ground practically to their full width form a very satisfactory means of marking the boundary of particular sowings, since at lifting time, when the seed bed will be a dense mass of seedlings, it will be impossible to dig beyond the limits of a given planting without coming in contact with the batten. Each planting should be labelled by a wooden peg.

_Care of the Sown Seed_

Sowing completed, the bed should be mulched to a depth of half an inch to one inch with organic matter, which must be of the short type in order that the seedlings may emerge without difficulty. Partially decomposed bush-scrapings, well-rotted manure, pine-needles, or seaweed in various instances have been found satisfactory. When available, well-leached seaweed is favoured, owing to its freedom from weed seed.

Through the season the main attention is to watering and removing weeds, and the provision of partial shade by lath or brush covers for certain species. Watering is best done in the morning or at evening to prevent leaf-scalding. Overhead protection should be given when frosts are likely.

The main object of care in the seed bed is to produce seedlings of good size for transplanting by the following spring at the latest (for autumn-sown seed this will be the second spring). Under very favourable conditions seedlings from early spring sowing may be forward enough to transplant in the following autumn. For transplanting, the seedlings should have the general appearance of being at least a foot high.

**TRANSPLANTING SEEDLING STOCKS TO THE NURSERY ROW**

The ground for the nursery rows should have been prepared some months in advance, the object being to produce a soil of good tilth and as weed-free as possible. Persistent weeds such as couch-grass should have been eradicated beforehand. Green crops or animal manures should have been incorporated in ample time for them to have broken down completely. This applies especially to lupin and cereal crops, which are apt to keep ground rather open and allow it to dry out, if they were somewhat old when incorporated or if a dry spell followed their incorporation.

Nursery rows are three feet apart and the plants are set about six inches apart in the rows. Thus there are about two hundred plants per hundred linear feet, and the required number of rows may be calculated and be marked out by pegs, some time in advance of the planting operations.

Seedlings in the seed bed are lifted before they start their spring flush of growth. The seed bed at the time should be damp but not wet. In the case of sandy soils it is commonly watered the previous day. The seedlings are lifted by sinking spades from each side of the row so as to cut the
root at full spade-depth. The seedlings are then lifted out and shaken free of soil.

At this stage a rapid but comprehensive sorting is done. All seedlings lacking in vigour together with all bench-rooted or twisted (Fig. 11) and otherwise unsatisfactorily rooted seedlings are discarded. The remainder are graded for size into two grades for separate planting. Root-and top-trimming is carried out at the same time. The seedlings are then placed neatly under damp bags until sufficient have been obtained to move conveniently to the nursery row.

A trench is opened up with a vertical side along the planting line stretched between the marking pegs. A light sprinkling of blood and bone (five pounds per hundred feet) may be spread along the bottom of the trench and pricked in. Different grades are planted in separate parts of the area, to have uniform stocks in the rows to bud.

The seedlings are planted by placing them against the straight side of the trench, returning the soil on the other side and heeling it in firmly. Watering further consolidates the soil round the roots. They should be planted slightly deeper than their seed-bed soil-level, especially on sloping ground, to allow for some erosion. By dealing with small lots of seedlings temporarily held under wet bags, opening up the nursery rows as immediately required, and rapid planting, drying-out of the roots or of the soil is practically negligible.

**Bringing Stocks up to Size**

The object of subsequent care is the production of stocks of a size suitable for budding by the autumn. It consists of watering and keeping down weeds and applying side dressings of nitrogenous fertilizers if necessary. As in the seed bed, Rough lemon seedlings may require Bordeaux sprays as a protection against scab. The stocks are well enough grown for budding when they have reached a minimum size of three-eighths of an inch in diameter, four to six inches above ground-level, where the bud will be inserted, and if this size has not been attained by the autumn the stocks must remain till the following spring.

The preference is for autumn budding. Budding should be started as early as is suitable for the particular stocks, for failures can be patched that autumn. Otherwise they must remain for budding till the spring. Hence, bringing stocks up to size is an important matter.

All stocks are thorny, and it is essential about a month in advance of budding to trim up the stems from ground-level to slightly above the height of budding. Late trimming causes the bark to tighten. Trimming, however, may be done at the same time as budding, although it slows down the work appreciably. In order that foliage will not be lost unduly, stocks should not be trimmed too high, or topped.

**PROVISION OF BUDWOOD**

Whilst seed-bed work is in progress, thought must be given to the future provision of buds—whether they are to be obtained when required from a bud-selection organization or whether the propagator will arrange
for his own supply. In the latter case, if only a few buds are required they can be obtained from an unprepared tree; but if considerable numbers are required the trees to provide them must be selected and prepared.

Preparation of the tree for budwood production in quantity consists of giving it a good thinning-out of the shoots, to stimulate vigour in those that remain. To supply autumn buds the trees should be given the special pruning early in the previous spring (early August in frost-free locations, elsewhere a month later). They will also produce good buds, if required, for the subsequent spring. Fertilizing and pest and disease control should also be attended to with the object of producing satisfactory budwood, but the trees should not be sprayed with Bordeaux mixture or white oil within six weeks of taking the bud sticks, or the success of budding will be lessened.

Budwood should be of good length (at least twelve inches), of good girth or roundness and bearing leaves. The best buds usually come from the middle of the sticks, the basal and apical buds are not often used, the former being dormant and the latter angular.

Such budwood is the early spring growth, the second or third flush of growth previous to budding time. Recent flushes are too angular and unrounded, while older wood has often lost leaves and contains too high a proportion of dormant buds. The latter are so called because they do not readily start into growth on the rootstocks.

Collecting Budwood

The budwood is collected immediately prior to use. Freshness of the buds assures greatest success. After cutting the shoots the portion containing angular wood of recent growth flushes is cut away, leaving the budstick. The leaf-blades are then cut off, leaving the leaf-stalk, and the budsticks are placed under damp bagging (Fig. 13).

If the budsticks have to be dispatched they should be tied firmly, wrapped in thin plastic or in damp paper followed by moisture-proof paper, and wrapping paper, and securely tied and labelled. If budwood has become slightly dry before use, it may be freshened by burial in damp sand for twenty-four to thirty-six hours. It should not be immersed in water.

Budding

Seedling stocks in the nursery row having gained a minimum diameter of three-eighths of an inch at the budding height of four to six inches above ground-level may be budded at any time (providing the weather is fine) while (a) the bark of the stock slips, that is, the cambium is active, after any flush of growth through spring, summer, and autumn, and (b) while buds are available. It is largely owing to the availability of unshot buds in autumn that this is the favoured time for commercial budding. (For smaller-scale operations or for any special purpose, however, budding may be carried out at almost any other time between spring and autumn, while the conditions apply.)

In spring it is often found that some of the buds have started to grow by the time the stocks can be budded; those which have shot to no longer
than half an inch may be used with some success, but longer shoots are unsatisfactory.

Wet weather at or following budding reduces success.

The stocks are budded at a minimum of four inches above ground-level, for trees are required that will be planted with the union distinctly above ground-level, to avoid collar-rot.

![Image showing satisfactory and unsatisfactory budwood]

**Fig. 13.** Satisfactory rounded budwood at left; angular and unsatisfactory at right.

Some growers prefer high-budded trees, that is, those in which the bud has been inserted nine to twelve inches above ground-level, in order to have a greater length of stock above ground-level and thus lessen the possibility of collar-rot.

Budding is carried out with the aid of a budding knife, the essential point being that the blade should be bevelled only on one side and kept sharp. The double-bevelled edge common to most pocket-knife
blades is unsuitable, but in the absence of a proper budding knife it may be ground to the required edge, and it will do good service if the steel is satisfactory. The handles of some budding knives possess a flat tapered bone or horn end, which may be used for opening up the incision before inserting a bud, and the backs of some knife-blades are provided with a lip to do similar service. In the hands of experienced budgers these devices are little used, the point or edge of the knife serving to open the edges of the cut.

Four consecutive steps are involved in the operation of budding, namely, making the incisions in the stock, cutting a bud, inserting it into the incision, and then wrapping (Fig. 14). On a commercial scale the latter operation is often done by a second person following closely on the skilled budger who carries out the three first operations. Wrapping should not be delayed.

The T or shield bud is virtually the only method used, the T referring to the shape of the cut made in the stock, and the term shield to the shape of the piece of bark containing the bud.

In wet seasons the T-shaped cut may be inverted, the method of cutting the bud and inserting it then being adapted to correspond with the inverted cut.

Making the Incision

The incision is made by a downward cut about an inch long followed by a cross cut at the top about three-eighths of an inch long, the latter being made with a slight downward slope of the knife to facilitate insertion of the bud. The bark at the junction of the cuts is freed slightly by a twist of the knife. The cuts scarcely penetrate into the wood.

Cutting the Bud

The bud is now cut from the budstick, which is held with the buds pointing towards the operator. The cut is made starting below the bud and ending above it, yielding a shield-shaped piece about three-quarters
of an inch to one inch long. The budstick must be supported well on the hand, with the forefinger under the bud being cut, in order that the cut surface will be quite flat and smooth, with a minimum of wood. This piece of wood is removed by expert budders, but is better not removed by the inexperienced.

**Inserting the Bud**

Towards the end of the cut the operator grips the bud between the knife-blade and his thumb, and when the cut is completed immediately starts to insert the bud into the incision on the stock. The stub of the leaf-stalk is then used as a handle to push the bud into the full depth of the vertical cut.

In very fresh and free budwood the bud may be cut satisfactorily in a different manner, namely, by making a shield-shaped incision in the bark round the bud; then, using the stalk as a handle, easing the incised area of bark off the wood by a sideways motion; then inserting it into the T-shaped incision on the stock. This method is not adaptable to any but the freshest and freest-working thornless budwood.

**Tying the Bud**

In the fourth and final step the bud is firmly wrapped with raffia, which has already been dampened, cut to required length, and made up into bundles. Tying is done from the bottom in an upwards direction to a distance a little beyond the top of the bud and the cross-cut of the T, leaving merely the bud and stalk exposed. As the successive windings overlap, the wrapping sheds water. In place of raffia, plastic or rubber strips may be used. They are more waterproof, and the latter particularly do not constrict the bud.

Of recent years Mr A. C. Arnot, a nurseryman and grower, formerly of the Department of Agriculture, New South Wales, has revived the practice of waxing the bud, with a distinct improvement in the resultant take. A wax composed of resin two parts, beeswax one part, and mutton fat one part, warmed to liquefy, is used. In wet seasons this acts as a waterproofing material and in dry seasons prevents drying out.

By good cutting and firm tying the active cambium of the shield is closely appressed to the active cambium of the stock, and these meristematic cells of both rapidly grow together and effect a union. If the union is successful, an inspection of the buds in two weeks will show they are plump and green. Under good conditions 90-odd per cent success should be obtained.

**Patching**

Any stocks on which the bud has failed to take may be re-budded or patched. It should be done as soon as failures can be detected with reasonable certainty. If the work is not put in hand immediately the delay may necessitate leaving the patching till next budding season, owing to lack of buds on the one hand or to tightening of the bark of the stock, especially of trifoliata stock, on the other.
Cutting the Tie

Owing to the expansion of the stock and bud it becomes necessary to cut the raffia, or it will constrict the stem. This operation is done when the union is complete and the incision is calloused—not less than three weeks after budding. It consists of an upward cut with the budding knife across the strands of raffia at the opposite side of the stem from the bud.

DEVELOPING THE BUDSHOOT

Autumn buds lie dormant in the stock through the winter. As soon as the top starts to show signs of growth in the spring, the stock is cut back to the bud. Spring buds must have reached the stage of having taken unmistakably before the stock is cut back. On Rough lemon stocks they may be a few weeks behind autumn buds in the start of growth of the bud, but on trifoliata will be later still.

Fig. 15. A good bud take. Rough lemon stocks cut back to the bud in spring; standing stocks represent bud failures.

The stock is cut by secateurs about a quarter of an inch above the bud and in a direction sloping back from it, as illustrated in Fig. 14. The wound usually heals completely in one season's growth of the scion. Figure 15 shows cut-back stocks.

Among other methods of cutting is that of lopping, in which the stock is almost cut through and bent over into the space between the nursery rows, until the bud has made several inches of growth, when the top is completely severed. The method has not been found to have any advantage and is not favoured by commercial nurserymen.

Training the Budshoot

The term training can aptly be applied to the next stage of propagation, since the operations have the object of producing trees of a certain form by the time that they are ready to be transplanted.
As the bud grows into a shoot, it is tied periodically to a small stake inserted alongside the plant, in order that it will produce a straight stem and not suffer injury at the union from wind. Stakes half an inch square and thirty-six inches long are used. The severe heading-back of a stock brought about by cutting to the bud also tends to start a number of buds on the stock, and these shoots should be rubbed off when quite small, as they appear.

**Height of Head for Different Varieties**

The kind of tree required for planting in the orchard is a straight, unbranched stem of a certain length, crowned with branches. The length of stem allowed varies with the kind of citrus, mandarins being topped at eighteen inches, lemons at twenty inches, whilst oranges and grapefruit are headed at twenty to thirty inches, the greater height in the latter case allowing for the more pendulous habit of growth. The branches are produced within some six inches of the cut. Trees may be available for transplanting in the autumn following budding, more usually in the next spring, that is, a year after cutting back stocks to the bud.

**LIFTING AND PACKING THE TREES**

As the period of time between lifting and planting citrus-trees should be as short as possible, the time of lifting should be closely co-ordinated with that of planting.

Lifting should only be done when the soil is damp from recent rains or watering. Even the weather at the time should receive consideration, for trees lifted in cool or cloudy weather from a damp soil and immediately planted in the field under continued cool and otherwise satisfactory conditions suffer the least setback.

Care must be taken at lifting time to keep all varieties or workings distinct and correctly labelled so that no mixture can occur.

**Bare-root Trees**

The bare-root system is almost universally adopted in Australia. This method of lifting has the object of securing the main structural root system intact, together with the accompanying fibre, and there are several methods of proceeding to accomplish this object.

A convenient method is to cut a trench, usually less than one foot away from the nursery row and on either side of it to spade-depth, thus cutting all lateral roots, then to drive the spade below the plants from the bottom of each trench, cutting the descending roots. Sharp spades are necessary for clean cutting of the roots. Plants may then be eased out of the block of soil in which they are standing and shaken free of soil, and then their roots are trimmed.

At lifting the tree should be checked over for faulty root systems or tops, and those that are undesirable in any particular way should be discarded forthwith. The roots should also be looked over for any lifting or root-rot injuries, which should be trimmed off cleanly with the secateurs.
Some measure must be taken immediately to keep the roots damp. They must not be allowed to dry out at all. They may be heeled into damp soil, placed in water for a period of up to one hour, or under damp bags until the required number is assembled.

**Disinfecting the Trees**

At this stage fumigation for the control of pests is carried out. The trees are packed in a fumigation chamber with wet bags over the roots, and are subjected to hydrocyanic acid gas (see p. 219).

As a control for Phytophthora it has been shown experimentally that a hot-water method is successful. Infected trees were completely immersed for ten minutes in water at 117°F, and planted immediately. Losses of 15 to 20 per cent can be expected.

**Packing the Trees**

In the case of trees that are to be packaged and transported some distance, the roots are dipped in a clay puddle bath, which produces a sort of sealing over the roots. They are then ready for packaging. Probably the best form of package is a crate of which the bottom is a tray about one foot deep formed by boards set close together.

After the tray is lined with moisture-proof paper the plants standing with their roots in the tray are packed as closely as possible with moist sawdust, seaweed, or moss among the roots. The top of the crate is a mere frame, of a size suitable for the trees, which is finally covered with hessian. Trees so packaged, provided they are not exposed to very hot conditions, will last two weeks or longer, with watering, before planting in the orchard. Packaging the trees in small lots, with the moist material round the roots, and then wrapping them in hessian or tarred paper, is probably the commonest method.

**Balled Trees**

With balled trees the nursery rows are spaced farther apart to enable more individual attention to be given to each tree. A trench is made all round the tree at a distance of about nine to twelve inches from it, then, finally cutting the last roots, the tree is lifted out with an undisturbed mass of attached soil. This latter is trimmed to a rounded form and lifted on to a piece of hessian in which it is wrapped by drawing up the edges and tying them to the trunk.

The tree is planted with the hessian, which is penetrated by the roots as they grow, and gradually decomposes. The method is rarely used in Australia.

**Advanced Trees**

The commercial grower requires one-year-old trees almost without exception. Two-year-old trees may be acceptable to growers in times of scarcity and in other special circumstances.

Two-year-old trees are usually raised in the open nursery row either by growing them on for a further year without disturbing them, or by trans-
planting them, when the bed is being cleared out, to a new nursery row and giving them additional space, say 12 inches, between the plants.

The trade in more advanced trees is mainly confined to the small holder and back-yarder. Advanced plants are produced by transplanting from the nursery row to a container, usually a used kerosene-tin provided with holes and drainage rubble at the bottom. By the use of a good composted soil, trees can be carried on in these vessels to the second or third year of growth and acquire a good development of the top.

Advanced trees are often suspected of being derived from the unsold poor-grade specimens among one-year-old trees, which should have been discarded at that stage, and no doubt this could be a practice of unscrupulous dealers with unsuspecting purchasers, but the real object of the genuine nurseryman is to employ the principles of potting and to produce a plant of advanced age and structure with all the facilities of easy and ready transplanting afforded by a potted plant.

The more advanced in age and well developed the plant, the greater is the danger of it being pot- or root-bound, and for this reason caution should be exercised when buying plants three or four years of age. Advanced plants should be selected that show or have recently shown free growth of the shoots, and give other evidence of not being root-bound.

On transfer to the site of the planting, the tin is opened out and the soil is pared away round the sides to ascertain if the roots have grown round the tin and will require cutting to enable them to grow out straight into the soil in which they will be planted.

A hole is now dug to the size of the soil-root mass and just so deep that the bud union will be set four to six inches above ground-level. The advanced plant is set in the hole, and the soil is firmed against the sides of the soil mass by the heel and further settled by watering. Alternatively, by shaking and washing the roots free of the soil, the tree can be planted by the bare-root method.
CHAPTER 5

CHOICE OF DISTRICT, CLIMATE, AND SOIL

Prospective citrus-growers would be well advised to recognize a fact amply demonstrated by experienced growers, namely, that suitability of district, climate, and soil is fundamental to success. For commercial production it is desirable in the first instance to make inquiries in an established district. The accumulated experience of growers will be available to show exactly the market outlets, the general suitability over a period of years of the climate and soil, as well as to indicate the general management problems with which an intending grower will be faced. Many amenities for production, such as power, central packing-sheds, transport arrangements, and so on, as well as educational amenities for the family, will also have been built up in the established district.

Areas in marginal districts should be regarded with caution, whilst areas in new districts should be examined carefully from all aspects, and the advice of competent persons should be obtained before embarking on citrus-growing in such localities.

REGIONS AND DISTRICTS

The location of producing centres is shown in Fig. 16, and, to indicate their relative importance, the production data are assembled in Fig. 17.

While many of the districts are scattered and small, there are three outstanding regions, each of which embraces several districts, namely, the Gosford-Sydney, the Murray Valley and the Murrumbidgee Valley regions.

The Gosford-Sydney region, the largest producing area, extends from a little north of Wyong and Gosford to a little south of Sydney, and is confined to some twenty to thirty miles from the coast-line at most. The topography of this region is very diversified and includes many districts: the Wyong lowlands, the Gosford highlands or Mangrove Mountain district, the Gosford lowlands, the Hawkesbury River flats, the Hills district out from Parramatta, the Kurrajong slopes and heights, and the Nepean and Camden areas.

The Murray Valley region, for which the New South Wales, Victorian, and South Australian productions are available in Fig. 17, is the second. The length of the territory necessitates subdivision into a number of regions, namely the Upper Murray eastwards of Swan Hill; the mid-
Murray settlements centred round Swan Hill; the Lower Murray settlements, which include Mildura, Red Cliffs, Merbein, Coomealla and adjacent districts; and the South Australian Murray settlements, which range from Renmark to Mypolonga. The production of the Murray Valley is second only to that of the Gosford-Sydney area.

The Murrumbidgee Valley region, centred on the irrigation areas round Leeton and Griffith, is the third largest region.

Differences in climate and soil are responsible more than any other factor for the characteristic productions and the particular practices in different districts. Certain broad generalizations may be made.

Fig. 16. Location of citrus districts.

In northern districts the fruit is much earlier in ripening than in more southern areas, thus having a marketing advantage, and often presents a special problem of obtaining colour at maturity. The high quality of northern mandarins and the earliness of the Washington Navel orange are well known on southern markets, and high-quality lemons are produced.

In eastern coastal districts, such as the Gosford-Sydney region, a special problem is the control of a mixed population of pests and diseases. While the fruit is of good internal quality, there is a fair amount of skin blemish, and the fruit tends to be of limited keeping quality. In the higher rainfall parts maintenance of soil fertility is a problem. The region is the largest lemon area in the Commonwealth. Valencia orange and Washington Navel orange production are notable. The region also produces appreciable quantities of mandarins, Seville oranges, and Wheeny grapefruit.
Fig. 17. Production of citrus districts.
(Data from Citrus Industry Survey.)

Note: The climate of Gayndah approximates more to inland than to coastal conditions.
In the Upper Murray, Goulburn Valley, and Murrumbidgee regions it is common for concern to be felt about the maintenance of quality in the fruit. This is partly a soils and partly a climatic problem, since it occurs in a climatic region—the eastern part of the Murray Basin. The area includes the latest-ripening and latest-hanging Navel and Valencia orange districts. Lemon- and mandarin-growing are negligible. The pest and disease problem is less complex than on the coast, but the control of red scale is a major problem.

The lower and South Australian Murray districts, with soils comparatively high in bases and with the western Murray-Darling climate, are characterized by high fruitfulness of the trees, high internal and external quality of the fruit, and good keeping quality. Navel orange production in particular is noteworthy, but so also is Valencia orange and grapefruit production. Some mandarins are grown, but lemons are negligible.

Citrus production in the most southerly section, that is in the vicinity of Melbourne, is devoted almost entirely to lemons, and is comparatively free of some of the pests and diseases of more northern districts, but other diseases are more accentuated.

CLIMATE

Citrus fruits require a mild winter and will stand only light frosts. Susceptibility to frost varies with the state of dormancy of the tree. In districts where trees become most dormant, up to 10°F. of frost for a short period can be tolerated in the depth of winter. At the end of autumn and at the beginning of spring, when the trees are making some movement, even light frosts may cause injury.

Citrus fruits require a warm summer, and withstand high temperatures without injury provided other conditions are satisfactory. Being evergreens, they have a higher moisture requirement than deciduous fruits. They are tolerant of humid and arid conditions; humid conditions have a pronounced effect upon the disease situation and other aspects of culture. All kinds of citrus are intolerant of high winds and require protection.

The orange shows very wide adaptability to climatic conditions within the limits stated in general terms above.

Lemon-growing can extend successfully into cooler conditions than suit the orange. As the lemon is very sensitive to frost, however, the winters must be mild; frosts in the winter restrict lemon-growing in inland districts, where the orange does well.

The sour orange is about as tolerant of the cooler range of conditions as the lemon, and stands frost somewhat better.

The mandarin and grapefruit thrive better in the warmer end of the range of climatic conditions to which the orange is adapted. They are somewhat more sensitive to frosty conditions. The lime is in the same category, and is still more sensitive to frost.

The measurement of one aspect of climatic requirement for the different species, namely, heat requirement, will be discussed presently.
Temperature

All citrus fruits originated in the tropics of our near north, a few related genera, in fact, originating in the tropical north of Australia itself, and cultivated citrus fruits are often classified by horticulturists with the tropical and sub-tropical fruit crops.

![Map of Australia showing citrus districts relative to mean annual temperatures.](image)

Fig. 18. Citrus districts relative to mean annual temperatures.

Citrus also grows well in warm-temperate regions, given sufficient water. In Australia, as elsewhere, it has become of more industrial importance outside the tropics than within them. Low temperatures naturally fix a southern limit to culture in Australia. Tasmania and the tablelands of Victoria and New South Wales are too cold in winter or too frosty for the successful culture of citrus, but at altitudes below, say, 1000 feet, oranges in particular may be grown for home use with some degree of success, and below 800 feet are the commercial districts. In general the southern limit approximates to the 60°F. isotherm. An isotherm is a line connecting places with the same mean annual temperature (Fig. 18).

The main area farther south than the 60°F. isotherm that is an exception to this general statement is the metropolitan area of Melbourne, devoted to lemons, which are adaptable to the cooler range of climatic conditions. Several other areas south of the 60°F. isotherm have attempted to develop citrus-growing, but without lasting success.
Fig. 19. Heat indices given in legends, and mean monthly temperatures shown in clock diagrams for four leading Washington Navel areas (A); (B) monthly temperatures of Berri, S.A., and Shepparton, Vic., compared with average of four navel-growing centres given in (A); (C) mean monthly temperatures, heat indices, and rainfall of Gladstone, Qld, compared with Orlando, Florida. The centre of origin of the clock diagrams represents 50°F. Heavy type represents southern hemisphere months.

(Photos: C. Barnard.)
Heat Index

Barnard has investigated the heat indices of typical oversea citrus-growing areas and compared them with some Australian districts. The heat index of a locality is obtained by summing the degrees of mean daily temperature above the minimum required for citrus growth, which is about 55°F. Barnard says,

We find that the heat index calculated in this way for the main grapefruit-producing areas ranges from 4388 to 8172, whilst the mean figure for the grapefruit areas of Texas, Arizona, Florida and California is about 6300. The index for the Navel areas ranges from 2700 to 3400, though they are mostly within the range 3050 to 3400, while lemon areas average a lower index still [about 2000]. [Figure 19 (a) shows heat indices for four leading Washington Navel districts of the world.]

In Figure 19 (b) the composite graph for Navel locations is compared with that for Berri, South Australia. For Navel production and quality the irrigation areas of the lower Murray are outstanding, and the temperature condition of the location for Navel production conforms closely with those which a survey of the best Navel areas overseas would indicate as most desirable. . . . Possibly the most interesting other example that can be taken for a comparison of Australian and overseas areas is the grapefruit. In Australia the temperatures of none of our southern citrus areas approach those of the overseas grapefruit
areas. Berri, with an index of 3020, Shepparton (2420), Griffith (3197), Mildura (3418) and Maitland (3573) fall far short of the average overseas (6000). Bourke, with an index of 5148, approaches the conditions of the desert areas in the United States. By going to Queensland we may parallel the natural rainfall with high humidities and high temperatures of Florida and coastal Brazil.

Barnard found that the heat index and rainfall of Gladstone, Queensland, are comparable with the grapefruit areas at Orlando, Florida [Fig. 19 (e)].

**Extremes of Temperature**

There is no suggestion of a limitation by high temperatures to citrus-growing in Australia, provided that the trees have adequate moisture and protection from wind. With annual mean temperatures in excess of about 70°F, skin colour is not well developed when the fruit reaches the palatable stage.

Low temperatures of the winter in southern districts have effects on growth, one of the most common being the turning of the leaves along the leaf stalk so that the under-surface is exposed to the weather (Fig. 20). Frequently extensive gum-pockets are produced on the under-surface of leaves thus exposed, more so on the sunny side of the tree. Low winter temperatures also condition the tree to frost. Frost as a limiting factor to citrus-growing is discussed at length in Chapter 12.

![Fig. 21. Citrus districts dotted relative to mean annual rainfall.](image-url)
Wind

Protection from wind damage should be considered in the selection of a site and during the development of an orchard. The question is discussed in Chapter 6.

Rainfall

Citrus districts in the main are marked out by the occurrence of an annual rainfall above thirty-five inches along the eastern, southern, and western coasts, or the availability of irrigation to supplement the lighter rainfall of the inland districts (Fig. 21).

Fig. 22. Seasonal incidence of rainfall in citrus districts.
As well as a sufficient total rainfall, distribution is of considerable importance. Rainfall records which are arranged graphically in Fig. 22 show that citrus is grown in various types of seasonal rainfall, which may be grouped in the following five classes:

1. High summer maximum represented by the northern districts of Queensland. With this type of rainfall the districts are subject to dry spells in the spring, even where they have a high total annual rainfall, for example, Cardwell. In districts with low total rainfall, for example, Gayndah, irrigation is necessary.

2. More uniformly distributed rainfall, as in a narrow strip of the central coast of New South Wales, which includes the Gosford-Sydney areas. These areas are nevertheless subject to considerable fluctuation in the incidence and intensity of rainfall, as well as to wide variations in the total annual rainfall, as shown by the annual totals for Gosford which are given in Fig. 23. These areas are subject to dry springs, although this is not particularly evident in Fig. 22. Supplementary irrigation obtained by pumping from rivers, streams, or dams, or from the metropolitan

![Fig. 23. Annual rainfall, Gosford, N.S.W., 1920 to 1953.](image-url)
water-supply, is desirable. It is essential in the parts of the region with a low total rainfall. Owing to the seasonal fluctuations in soil moisture, underground drainage is as desirable as supplementary irrigation, if root-rot is not to exercise an intermittent check upon the health and cropping of the trees.

3. Winter maximum type, low in total precipitation, typical of the western part of the Murray—Darling River system. In all these districts the rainfall between spring and autumn is insufficient to sustain citrus-growing without systematic irrigation. Occasionally heavy rains are experienced and trees will suffer from root-rot unless the surface and underground drainage is adequate. Wet winters are likely to occur on the average of one year in five.

4. Winter maximum type, with higher total precipitation, such as the north-east districts of Victoria, Melbourne, and Adelaide. Citrus can be grown without irrigation or with limited facilities, according to the particular location.

5. High winter maximum, represented by the Western Australian districts, particularly in the south. When wet conditions prevail approaching harvest-time, water-spot and brown rot of the fruit are problems. Supplementary irrigation is often desirable to tide over the dry summer. Wide spacing of the trees is used in the north to cope with this condition.

Notable citrus districts are located where the rainfall is of summer incidence, others where it is “uniform”, and yet others where it is of winter incidence. These conditions materially change the emphasis on cultural practices.

**Humidity**

When the districts are divided into humid (coastal) and arid (inland) areas the main effects of humidity and associated rainfall are seen. Barnard\(^1\) has aptly summarized the effects:

> Humidity very materially affects the quality of the fruit and not all varieties to the same extent or even in quite the same manner. Generally speaking, under conditions of low humidity, colour is well developed and the fruit of good, clean outward appearance. Under conditions of high humidity, the rind tends to be thinner, and the fruit juicier, which means good internal quality, but, because of a higher incidence of insect and fungal spotting and blemishing, a poorer external quality.

Fruit from humid areas tends to have poorer keeping quality than that from arid areas, which seems to be associated not only with the presence there of the fungal causes of decay in greater number and variety, but with the development of a rind that is more subject to invasion by them. Fruit ripening under moist conditions is apt also to develop water-spot, and, if handled while wet, to show oil-spotting.

**SOIL**

In the sections in Chapter 3 on resistance to root-rot and suitability to soil of rootstocks, the range of conditions to which the different stocks...
are adapted was described, and it was indicated that a stock may be selected to suit a particular condition. Nevertheless, the range of soil conditions embraced is not very wide. Whereas the climatic range in Australia to which citrus is suited is great, the soil range is restricted.

In Australia citrus-trees are grown for the most part in sandy soils and sandy loams of good depth, and to a lesser extent in somewhat heavier soils, if they have reasonable depth and are permeable by virtue of good structure. The fruit is often of somewhat better internal quality when not from the lightest of soils, and in the case of grapefruit on the lower Murray it is noticeable that the eating quality is better from trees on the heavy grey soils than on the light, red soils.

Physical Aspects

Depth is necessary to give good natural drainage below the root zone and good aeration, which are unfavourable to Phytophthora development. The soil should not have impediments to drainage in the form of minor impervious layers of silt, clay, or hard-pan, which may well occur in light soils, especially those of alluvial origin as on creek flats, or bands of heavy marl, which occur in some sandy Mallee soils.

Roots will not penetrate through the fine lime layer, nor the layer of nodular or more massive limestone that occurs in some Mallee soils, and therefore any lime layer should be at a good depth.

Sandy soils being naturally poorer, depth for depth, than heavier soils in their moisture and nutrient-supplying properties, depth is also necessary to assure the maximum moisture supply and nutrient supply of which the soil is capable. If the bulk of the citrus-root system is unnecessarily shallow, the tree must survive on the moisture and nutrients available in and supplied to such a shallow layer. Free drainage below the root zone assures the maximum exploitation in depth of which the soil is capable. The soil moisture and nutrient supply to the root will be increased by utilizing the maximum depth of the root zone.

Sandy soils have other qualities that are of benefit to citrus. Owing to their lower moisture capacity, sandy soils are warmer, warming up earlier in the spring and retaining the warmth of autumn. This factor may be of some importance in providing a longer growing season for the roots. They are also well aerated.

Physical characteristics of the soil—sandy texture, depth, and free drainage—are therefore of primary importance.

Chemical Aspects

Citrus roots will tolerate soils of divergent chemical qualities. In Fig. 24 citrus districts are related to Prescott's Soil Map of Australia, in which the occurrence of the Great Soil Groups is shown. On the one hand citrus is grown in the acid podzolic soils of the humid coastal districts, and on the other in the neutral to alkaline soils of the Mallee, as well as in the soils of the Red Brown Earth group, which are neutral to slightly acid. Associated with this range of soils and their reaction or pH is a wide range in concentration and proportion of nutritive elements.
Very acid soils and alkaline soils are likely to produce nutritional disturbances (Table XVII). Unless it can be seen on expert advice that nutritional defects may be rectified economically, very acid and very alkaline soils are to be avoided.

A reaction of the soil between acid and slightly alkaline (pH 5-5 to 7-5) is favourable to Phytophthora and therefore less suited to susceptible stocks. The resistant stock trifoliata is best suited to this range and is much less suited to a reaction below pH 5-0. In practice certain adjustments of pH to the fertility requirement and the rootstock can be made (Chapter 9).

**Salt**

Salty soils should be avoided. Salt is likely to occur in certain locations and certain soil types. Examples of the latter are given in Table IX. Irrigation water that is not free or virtually free of salt should not be used. Among the salts, sodium carbonate (black alkali) is the most injurious, sodium chloride (common salt) is next, followed by sodium sulphate (Glauber salt), and lastly magnesium sulphate. Common salt is the most common cause of injury.
Citrus-trees are among the most sensitive of plants to injury from salt. Lemons are among the most susceptible of fruit-trees, together with figs, apricots, peaches, prunes, apples, and pears. Oranges are less susceptible in company with almonds and olives. The mulberry and the grape are least susceptible.

Rough lemon rootstock is the most susceptible, and sweet and sour orange are the most resistant to soil salt, other stocks being intermediate. Lemon is also more susceptible than orange to sodium carbonate and sodium sulphate. Leaves beginning to show salt effect approximate to 0.5 to 1.0 per cent salt (dry weight).

Read carried out an extensive investigation of salt damage to citrus at Tresco, Victoria, as a result of which he concluded that when the concentration of chlorine exceeded 30 parts (equivalent to 48 parts of common salt) per 100,000 parts of dry soil, the soil was unsuitable for the growth of citrus.

Chlorine concentrations of the order given in Table IX were found on a salt-affected grove:

<table>
<thead>
<tr>
<th>Depth of soil (inches)</th>
<th>Chlorine concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 2</td>
<td>332</td>
</tr>
<tr>
<td>2 to 12</td>
<td>36</td>
</tr>
<tr>
<td>12 to 24</td>
<td>31</td>
</tr>
<tr>
<td>24 to 36</td>
<td>18</td>
</tr>
<tr>
<td>36 to 48</td>
<td>12</td>
</tr>
<tr>
<td>48 to 60</td>
<td>10</td>
</tr>
<tr>
<td>60 to 72</td>
<td>8</td>
</tr>
<tr>
<td>72 to 84</td>
<td>7</td>
</tr>
<tr>
<td>84 to 96</td>
<td>6</td>
</tr>
</tbody>
</table>

Other Aspects

Choice of soil will be assisted by a knowledge of the more detailed effects of soil conditions on root distribution and on root parasites.

Effect of Soil on Root Distribution

Studies of the main root system of citrus-trees clearly reveal that soil conditions affect the depth and spread of roots. Depending on soil conditions, 90 per cent of the roots may be in the first foot, two feet or three feet. Hence statements often made that the root system of citrus is quite shallow can only be accepted with the proviso that the root system can extend just so far as the environment is satisfactory (Fig. 25).

On the Murrumbidgee irrigation area in a soil consisting of sandy loam to 18 inches, below which was a light clay, investigations showed that the root zone was confined to 24 inches.
Fig. 25. A contrast in rooting systems. Stumps of orange-trees grown on the river-bank at Gosnells, W.A. The vigorous rooted stump at left was grown on deep alluvial soil with the permanent water table over eight feet deep. The stump on the right was grown in the same class of soil, but was not as well drained.

(Government Printer, W.A.)

Fig. 26. Major ramifications of one citrus root and region of dense root growth in a heavy soil. Change in profile from clay loam to clay is shown by a broken line.

(C.S.I.R.O. Journal.)
Lateral penetration was traced in a heavy crabhole soil, like that used for rice-growing. Figure 26 illustrates the extent and ramification of one main root down to fairly small subdivisions. The soil from one tree-trunk to the next was occupied by roots. It was occupied by roots below the depth of cultivation (four inches) to 24 inches. Roots in the top four inches had been destroyed by tillage, and possibly by high temperature. Under the foliage (a distance of six feet or so from the butt of the tree), the roots approached the surface. A few stray roots following down cracks or channels left by roots of the native flora penetrated below the general root zone as deep as 32 inches.

Further studies on citrus-root distribution were made in Murrumbidgee soil types ranging from very permeable sands through heavier sandy loams to impermeable clay loams (Table XI). Often 80 to 90 per cent of the total feeding roots were found in the first foot of soil. Feeding roots rarely went deeper than two feet, although instances were noted where roots must have gone deeper, for they had dried out the soil to three feet and sometimes deeper.

Spurling has studied root distribution in the Murray River irrigated soils. The roots were exposed by cutting a trench across the direction of irrigation, and the roots were then mapped and counted. This method gave a cross-section of roots both inside the drip-ring of the tree and in the irrigation row centre. He found that the trees were not generally deep-rooted, despite the fact that roots may be found at considerable depths when putting down drainage tiles. The relation of depth of rooting to soil type is shown in Table X and Fig. 27. The table shows the percentage of total citrus feeder roots contained in successive depths of a range of soil types under furrow irrigation. Root penetration was definitely limited by the lime horizon in these Mallee soils.

The greater part of the citrus-tree's root system is often under the tree and not in the middle of the row.

Root distribution was also found in these investigations to be affected by cultural practices, including tillage, irrigation, and fertilizing. Effects of different methods of irrigation are shown in Fig. 63.

Root Fibre

The most obvious characteristic of the healthy citrus-root is the great volume of the feeding or fibrous roots often concentrated at shallow depth. These roots are about \( \frac{1}{8} \) inch in diameter, without root hairs but mycorrhizal. They multiply rapidly when conditions are suitable, especially when the organic content is high.

Owing to the evergreen nature of citrus-trees the roots seem to be capable of active growth and absorption all the year round, and new roots are formed in greatest abundance in the warmer months. The fibre is the special prey of the Phytophthora root-rot organism.

**Effect of Soil on Root Parasites**

*Phytophthora*

The damage caused by Phytophthora was described on p. 35. We are now concerned with the main soil condition favourable to it. *Phytophthora*
<table>
<thead>
<tr>
<th>Soil zone</th>
<th>Winkie sand</th>
<th>Deep phase Murray sand</th>
<th>Shallow phase Murray sand</th>
<th>Stony phase Mypolonga sand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil texture</td>
<td>% of total feeder roots</td>
<td>Soil texture</td>
<td>% of total feeder roots</td>
</tr>
<tr>
<td>0 to 12</td>
<td>Sand</td>
<td>45.0</td>
<td>Sand</td>
<td>26.6</td>
</tr>
<tr>
<td>12 to 24</td>
<td>Sand</td>
<td>23.2</td>
<td>Sand</td>
<td>44.8</td>
</tr>
<tr>
<td>24 to 36</td>
<td>Sand</td>
<td>19.4</td>
<td>Sand to sandy loam</td>
<td>20.3</td>
</tr>
<tr>
<td>36 to 48</td>
<td>Sand</td>
<td>8.3</td>
<td>Sandy clay loam</td>
<td>5.5</td>
</tr>
<tr>
<td>48 to 60</td>
<td>Sand</td>
<td>4.0</td>
<td>Sandy clay loam with lime</td>
<td>2.8</td>
</tr>
<tr>
<td>Over 60</td>
<td>0.1</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Restrict root system means reduced crop production.

This soil is not wetted by lateral spread during irrigation.

No roots in the cultivation mulch.
Deep cultivation and inefficient irrigation reduced the root-system on this soil 50% with a similar reduction in crop production.

Fig. 27. Root distribution in a deep and in a shallow soil: (A) Winkle sand; (B) Mypolonga sand. Both are furrow-irrigated. Percentages of roots in foot depths are shown at right.

W = White encrustation of salt on roots.

(Journal, Department of Agriculture, S.A.)
flourishes under wet conditions. In the Sydney areas hundreds of acres died out from root- and collar-rot in the 1860s (Chapter 1), and after the record rainfall of 1950 the loss was well over 1000 acres. The periodical flooding of parts of the Gosford-Sydney and Murrumbidgee areas causes death, serious decline in health, and a grave setback to the productivity of trees.

In addition, and probably more important, there is the effect of the continuous presence of Phytophthora in the soil—actively invading the root fibre and larger root during rainy periods and bringing about a reduction of the rooting system. One result is that in a following dry spell the tree and its fruit suffer unduly from the curtailment of the root system.

The disease develops rapidly in saturated soil. Soils and situations should, therefore, be free-draining. Sandy soils that not only drain quickly but hold a smaller percentage of moisture than heavier soils are least favourable to the disease. Any impediments to drainage such as hard-pan and compacted horizons are favourable to the disease. It develops in over-irrigated soils, or parts of the irrigation block that receive excessive moisture, often near the footlands, but also near eroded headlands or other low spots or areas of slack grade. Re-planting among older trees in the irrigation run are danger spots, unless a resistant stock is used.

The capillary fringe above a water table (p. 190) also provides favourable conditions for the growth of the fungus. For safety the water table should be no closer to the surface than eight feet.

*Armillaria mellea*

Lightly infected trees show little effect from *Armillaria mellea*; increasing infection results in the yellowing and fall of leaves and the death of limbs connected with the infected roots. It is found in acid soils, seldom in alkaline soils.

Infection is due mainly to the rhizomorphs of the fungus reaching fruit-tree roots from those of native timber, even from driftwood long buried in alluvial flats. The rhizomorphs are black bootlace-like growths on the bark of the roots. Infection of the root is also indicated by a mushroom-like smell, a sheath of white fungal tissue growing between the bark and the wood, and the appearance in autumn of clusters of toadstools, which are honey-coloured on top—whence the specific name—and cream beneath.

Bloodwood trees are recognized as an indication of Armillaria-labile country in the east coast districts, owing to the fact that this species is deep-rooted and the roots are slow to rot away, thus harbouring the organism for many years.

*Fruit-tree-root Weevil*

Fruit-tree-root weevil is a serious pest when it becomes well established, and is capable of completely destroying an orchard if the beetles are allowed to breed unchecked for a number of years. On river flats that are subject to flooding, the presence of the beetle may be suspected when trees become thin and sickly-looking. Examination of the roots may
necessitate digging three or four feet under the tree; very often the surface roots are not damaged.

Armillaria and root-weevil are important in more or less circumscribed areas, where they add a more or less calculable risk to selecting a soil, which on other characteristics may be suitable for citrus-growing. Armillaria-affected country is to be avoided. Root-weevil can be controlled, but if Phytophthora is present in addition to this pest they together form a heavy liability on citrus-growing.

Possibilities regarding other root-inhabiting organisms—nematode, larvae of dicky rice and other weevils, white ants—should be borne in mind when selecting a soil.

Occurrence of Citrus-growing Soils

Citrus-growing soils may be correlated as follows with Prescott’s map of soil classification (Fig. 24).

Podzolized or Leached Soil Region

1. Alluvial sandy and silty deposits along river banks, examples being Gayndah and Burrum in Queensland, Harvey in Western Australia, and many other sites within the bounds of this soil region. These districts are necessarily a more or less ribbon development beside streams, for the soils beyond the immediate sandy levee banks may be heavy.

2. Sandy soils derived from the extensive Hawkesbury sandstone strata in the Gosford-Sydney district. The overlying rock in the Hawkesbury Series is Wianamatta shale. Satisfactory citrus-growing extends to soils derived from a mixture of the sandstone and the shale, but soils derived entirely from the shale rock are likely to be too heavy.

The preference for the lighter soil is well illustrated in the long history of citrus-growing in the Gosford-Sydney area. Soil surveys have not been completed in this region, and the story therefore cannot be presented in a simple arrangement of soil types on their suitability for citrus. Since the early establishment of citrus-growing in loamy and clayey loam soils in the vicinity of the Parramatta River, citrus culture has gradually extended away to the light sandy soils. Expanding across the Hawkesbury River into the Gosford area about 1890 to 1900, the bulk of the citrus is now grown there and occupies light and sandy soils. Hillside locations were preferred at first because of their good drainage, warm location, and protection by surrounding hills and timber. In many places the hillside soils are of a depth extending to seven feet of sand, before meeting an impervious clayey layer or glei. As a result, however, of such factors as erosion liability, the higher cost of cultivation on hillsides, and excessive dryness in droughty seasons, citrus-growing extended both down to the creek flats and up to the plateau or mountain soils. Thus there are now soils of three locations in use.

The hillside soils are grey, more or less podzolized and with a yellow subsoil.

The mountain soils consist of a shallow grey layer on a yellow subsoil or are yellow, representing the eroded remnants of deeper soils, and are therefore referred to as truncated podzols.
The lowland soils are grey, rather like the hillside soils, and the alluvial soils beside creeks are recent and likely to have bands of finer materials at variable depths.

3. Grey medium loams such as those used in the vicinity of Melbourne. These soils are heavy when wet and require under-drainage often with a drain between each row of trees, but they dry out quickly with the advent of warm weather.

4. Medium gritty loams in narrow valleys on the westerly slopes of the Darling Range in Western Australia. These soils receive some moisture during the dry summer from the surrounding lateritic formations at higher elevation.

*Red-brown Earth Region*

5. Alluvial sandy and silty soils along river banks, for example, at Narromine and Dubbo on the Macquarie River.

6. Sand-mount sands, derived by wind-blown accumulation of sand, often of considerable depth, for example, Cobram, Barham, Narrandera, and parts of the Murrumbidgee irrigation area (such as Banna Sand—Table XI).

7. Sandy loams and loams, for example on the Murrumbidgee irrigation area, Kyabram, Murrabit. The majority of these soils are much heavier and shallower than the sand-mount sands.

Land use of a range of red-brown soils of the Murrumbidgee irrigation area,\(^5\) given in Table XI, shows a marked preference of citrus for permeability of the soil—due to light texture or good structure, which enables good moisture penetration and drainage—in association with steep and moderate irrigation slopes. Some sandy and sandy loam soils are not first-class citrus land, even with steep slopes, because their permeability is less than desirable; some sandy loam soils are not classed as citrus soils because of their relative impermeability. Hollow slopes eliminate land that might otherwise be suitable for citrus.

The table also provides a good illustration of the soils and slopes preferred for citrus in comparison with those required by other fruit-trees. Citrus is the most exacting crop in its soil-slope requirements. Stone fruits are more tolerant of diverse soil conditions, but are very liable to damage in all flat situations in wet winters; prunes being the least liable to such damage. Pome fruits and vines have a wide tolerance and will do well under conditions that are unfavourable for citrus and stone fruits, being suited often to flat and hollow situations.

*Mallee Soils Region*

Sand-ridges of the Mallee soils region characterized by Murray pine, belah, and hop-bush are highly satisfactory for citrus-growing. The ridges run more or less parallel with one another in a general east-west direction. Very extensive areas of this type of country, eminently suited to citrus-growing, exist in the Murray Valley. Table X gave profiles of some Mallee region soils suitable for citrus-growing. Soil surveys of the irrigated horticultural settlements of the Murray Valley were begun in 1927 and completed in 1941.
### TABLE XI

HORTICULTURAL LAND USE ON MURRUMBIDGEE IRRIGATION AREA

<table>
<thead>
<tr>
<th>Permeability of soil types</th>
<th>Land use class* of soils according to slope†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steep</td>
</tr>
<tr>
<td><strong>Very permeable soils:</strong></td>
<td></td>
</tr>
<tr>
<td>Tenningerie, Wamoon and Banna sands</td>
<td>1</td>
</tr>
<tr>
<td>Tenningerie, Wamoon sandy loams</td>
<td>1</td>
</tr>
<tr>
<td><strong>Rather permeable soils:</strong></td>
<td></td>
</tr>
<tr>
<td>Tharbogang, Lakeview, Ballingall and Merungie loams, Hanwood, Yandera, Hyandra and Yambil (deep phase) sandy loams</td>
<td>2</td>
</tr>
<tr>
<td>Mallee A and B, Yenda and Stanbridge sandy loams, Yenda and Stanbridge loams</td>
<td>2</td>
</tr>
<tr>
<td><strong>Rather impermeable soils:</strong></td>
<td></td>
</tr>
<tr>
<td>Wyangan loam</td>
<td>2</td>
</tr>
<tr>
<td>Mirrool, Bilbul, Griffith, Yoogali, Jondaryan and Willimbong loams, Fivebough sandy loam, Jondaryan clay loam</td>
<td>3</td>
</tr>
<tr>
<td><strong>Very impermeable soils:</strong></td>
<td></td>
</tr>
<tr>
<td>Yambil (heavy and shallow phases) sandy loam</td>
<td>3</td>
</tr>
<tr>
<td>Camatrooka sandy loam, Bilbul, Griffith, Leeton, Beelbangera clay loams</td>
<td>4</td>
</tr>
<tr>
<td>Crabhole</td>
<td>5</td>
</tr>
</tbody>
</table>

* Land use classes are as follows:
  1. Suitable for general horticulture, especially citrus; includes practically all the very permeable soil types, excluding hollow situations.
  2. Suitable for general horticulture; fairly suitable for citrus; includes most of the rather permeable soils with a good slope; it is also suitable for a wide range of orchard crops.
  3. Not suitable for citrus; generally suitable for a range of fruit crops other than citrus; largely comprises the slacker grades of the rather permeable soil group and the steeper slopes of the rather impermeable soils.
  4. Not suitable for citrus or stone fruits.
  5. Unsuitable for any orchard crop.

† Slope definitions: Steep, more than 3 inches per chain (more than 0.4 per cent). Moderate, between 3 inches and 1½ inches per chain (between 0.4 and 0.2 per cent). Flat, less than 1½ inches per chain (less than 0.2 per cent). Hollow, refers to drainable hollows only, liable to waterlogging and salting.

From the crest of the ridge to the depression, a sequence or catena of soils of decreasing suitability for citrus-growing occurs. At Waikerie, for example, it was found that the normal sequence on passing from the crest of a sand-ridge to the hollow between the ridges is Winkie sand and Berri sand, which are excellent citrus soils, then Barmera sand, with
Nookamka sandy loam in the base of the depression itself. In the Waikerie survey¹ is recorded one of those instances when really suitable soils show to advantage. Just prior to the commencement of soil survey the citrus-trees of the Murray Valley, as a whole, suffered from a serious premature defoliation. Whilst the condition was general throughout the settlement it soon became apparent that deep well-drained soils were rarely severely affected. The presence of free subsoil water, salt accumulation, stone horizon, or even an appreciable lime horizon within the usual depth of boring, was always correlated with more or less severe symptoms. Each of these conditions has the effect of encouraging shallow-rooting systems, with the natural result that moisture reserves within the soil are less for these than for normally deep-rooted healthy trees.
CHAPTER 6

SELECTION, DESIGN, AND DEVELOPMENT OF A SITE

SELECTION OF SITE

When choosing a site for the growing of citrus fruit strictly local factors regarding a particular piece of ground are the matters for consideration. These include area, amenities, aspect, protection, the soil, and source of water. If these factors are satisfactory the price must then be considered as part of the capital investment on which it is necessary to obtain a desired annual return. It is with regard to this business aspect of the proposition that the intending grower should be satisfied and should assure himself by obtaining competent local opinion on yields and markets.

The selection of a site usually involves one of three propositions, namely, virgin land, cleared or partially cleared land, or an area already planted with trees. The factors on which an assessment of the site must be made apply in all cases. In the case of an established orchard, the condition of the trees on the property, taken in conjunction with the management they have received, enables an even better estimate of possibilities.

Area

As conditions vary appreciably between districts, it is difficult to be specific about the area required. An area of ten acres of bearing trees should provide a good living in most cases. However, provision must be made for stability of production at this level by having an area of young trees to replace the original area. If the expected life of the trees is twenty years, of which seven are taken up in reaching appreciable bearing, then a new lot of trees should be planted when the first lot is thirteen years of age. A rotational system has been put forward by which if it is desired to maintain twenty acres in bearing, for example, the total area of the planting is thirty-one acres.

With ten acres in bearing, the grower should be able to do most of the work himself, with help at certain times such as when picking, spraying, irrigating, according to whatever are the major practices of the district. The extent capable of being worked on this principle depends on the individual, on proximity of central packing-house facilities, and on the labour-saving methods and machinery employed. Over-capitalization is a real danger with small areas, for certain plant and equipment is the same as for a larger area.
Care of larger areas, exceeding, say, forty bearing acres, is mainly a management occupation, requiring organizing ability, employment of full-time help, and as complete mechanization as possible.

**Amenities**

The location of the area with respect to both production amenities and living amenities, including transport and other community amenities, should be checked.

**Aspects**

All citrus crops require warm, protected situations. The best aspects are those ranging from the east to the north. In the winter-time in central and southern latitudes in Australia, most of the cooling influences are brought by south and west winds. In summer-time heat-wave or scorching conditions are usually accompanied by north-west and west winds. Hence aspects exposed to these influences are to be avoided, or should not be selected without due regard to whether they are naturally protected or whether they can be given protection by breakwinds.

Low-lying frosty situations, which occur in many districts, should be avoided equally as much as exposed situations. In irrigated districts aspect does not enter into consideration to nearly the same extent as on undulating country, but frost pockets should be specially guarded against. These will be better understood by reference to the section on frost in Chapter 12.

**Protection**

A well-protected aspect is necessary also to safeguard against the damage caused by wind (see p. 94).

**Examination of Soil**

Examination of the soil should include slope, susceptibility to erosion, depth, and indications of fertility. If soil surveys applicable to the area are available they can be put to good use when examining the site. Soil requirements have been discussed at some length in Chapter 5, and need not be repeated. The area should be examined by a soil auger or by sinking holes in a sufficient number of places to satisfy the purchaser that good soil conditions for the crop exist for a depth of several feet.

Suitability of slope and susceptibility to erosion are not as important as they were prior to the introduction of contour-planting. Nevertheless, excessive slopes should be regarded with caution, for they erode, if only slowly, with the best treatment, and all operations are done at greater cost and exertion than on reasonable slopes. In humid districts slopes greater than 10 per cent, depending on surrounding conditions, are considered excessive. In irrigation districts the slope will determine whether it may be irrigated by the straight-furrow method, the contour-furrow method, or the more costly spray system.

Timber often provides a very good indication of the suitability of land for citrus. Thus the best citrus sites in many parts of the inland are the sandy rises characterized by Cypress pine or Murray pine (*Callitris* spp.)
and belah (Casuarina cristata) often in association with hop-bush (Dodonaea spp.). Soil surveys in most cases refer specifically to the native vegetation characterizing the different soil types of the sandhills and sand-ridges. On the coast also, native timber is a useful guide. In the Gosford district bloodwood is an indication of Armillaria-liable country, while in the Sydney Hills district land carrying heavy stands of timber is seldom as suitable as more lightly timbered country, owing to the fact that the former is heavier in soil texture.

Under the system of ranging fowls in citrus orchards, land has proved suitable for lemons that has been passed over hitherto as being too poor and stony.

**Water-supply**

In irrigation districts where citrus-growing is not possible without water, right to supply is an indispensable adjunct of the site, and details of the supply should be investigated.

When selecting a site in natural-rainfall or humid districts, the water-supply and the possibilities of water storage should be very closely examined. A good supply of water may be required for sprays alone. If supplementary irrigation is envisaged, a very considerable supply will be required—no less than six inches, or 140,000 gallons per acre to be irrigated, if the demands of a very dry season are to be met.

**DESIGN AND DEVELOPMENT IN HUMID DISTRICTS**

A design for the property as a whole is necessary to the orderly execution of developmental work.

The design should take advantage of the best planting sites, allow for subsequent expansion, give control of the soil-moisture situation both as regards drainage and supplementary water-supply, retain the protection of standing timber and add windbreaks where necessary, and site the position of buildings. In the design, convenience of operation must be borne in mind at all times.

**Sites in a Mixed Citrus Orchard**

In the case of orchards in which different kinds of citrus are to be grown, some consideration must be given to the most favourable position for each. Taking the case of undulating ground in east coast districts, which is suitable for various kinds of citrus, it is usual to plant lemons on the highest ground, and the Washington Navel orange, which is considered to require the best soil conditions, on the low ground. Valencias, mandarins, and grapefruit will be allocated to the intermediate sites. Where low ground is subject to occasional flooding it would be preferable to plant Valencia than Washington Navel, owing to the greater susceptibility of the latter to collar-rot.

The preference for high ground for lemons is interesting. The high ground is likely to be shallower, perhaps stony, and to suffer water shortage faster than lower ground. Since the east coast region is liable
to dry spells in the spring, the spring flowering is not so likely to set heavily, and so later flowering occurs, the ever-bearing habit is encouraged, and the summer crop, which is much more valuable than the winter crop, is more reasonably assured. Moreover, the young fruits that will form the summer crop must pass through the winter uninjured by frost, and the high position in the orchard affords them the maximum advantage in this respect.

Surface Drainage

Blocks and Roads

A site is usually divided for developmental purposes into blocks that may be planted up successively. In humid districts characterized by heavy storms and wet periods, it is especially important that the blocks should be considered in relation to the natural drainage; surface drainage of the area is required without causing erosion. The blocks may be as large or as small as convenient, provided that they conform to the natural drainage features.

Roadways should be designed to serve the blocks; they usually become worn down to a lower level than the blocks, and the table drain of the road will then act as a surface drain.

Diversion Banks

A plan of development is required that will prevent erosion within the block. Whatever the system on which the trees will be planted, cultivation up and down the slope may be required, if only occasionally to destroy weeds. The cultivated surface is particularly susceptible to erosion. Diversion banks at suitable intervals offer a practical solution. The banks are put in at a vertical interval ranging from about three feet on relatively flat ground to eight feet on ground with a slope of ten per cent. The site to be planted is therefore cut up by the banks into areas that may be planted on the contour or square system. The banks may be constructed by the grader-ditcher, the height of the bank being only about six inches. Trees may be planted to about fourteen feet either side of the bank centre. Although most cultivation will be carried out in the same directions as the banks, low banks will permit cultivation across them when necessary.

Surface Drains

An open drain is always placed at the top of an orchard if there is rising ground beyond to intercept the run-off from it. This drain may also serve to cut the roots of adjoining timber or breakwind trees.

Broad-based drains may be formed between rows of trees during or after cultivation (Fig. 36) to lead surplus water clearly away. They should not accelerate erosion. The use of plough furrows for this purpose, with their limited carrying capacity and dangers of blocking and overflow, are one of the worst causes of erosion. The use of diversion banks largely does away with the need for drainage furrows between rows.
Grassed Waterways

Roadways and surface drains should fit into a pattern, since in sharp storms they must carry a considerable flow of water. The final disposal of this concentration of run-off from the orchard should be on to bushland, grassland, grassed natural depressions, or a suitable natural creek. Wide, shallow grassed waterways for storm-water disposal are necessary if erosion is to be avoided. The design should be such as to carry away

* Fig. 28. Laying a drain. In this instance condemned glazed pipes are being used in place of agricultural tiles.

the run-off from the once-in-ten-years storm, the magnitude of which may be ascertained from local soil-conservation officers. McGillivray has discussed the construction by the grader-ditcher of a satisfactory type of waterway for the Gosford district, and recommends the seeding down of the waterway with Rhodes grass at the rate of six pounds per acre plus red clover three pounds per acre.

Underground Drainage

The blocks should be examined for the necessity of underground drains (Fig. 28). Obvious wet spots will require drainage. To examine underground conditions a survey may be made consisting of sinking holes on a grid at regular intervals and plotting the subsoil conditions. There is not much doubt that underground drainage should be practised to a greater extent than it is at present. Underground drainage will always
be of importance so long as Phytophthora-susceptible rootstocks are used. *Trifoliatia* will withstand sites that are subject to short periods of waterlogging, but aeration is interfered with and even this rootstock grows better on well-drained than on inadequately drained sites. Ill-drained sites are quite unsuitable. Two main methods are available, namely, agricultural tiles and mole drains. A third method, the rubble drain, is useful for a small-scale or garden-size project.

*Agricultural Tile Drains*

The essential points in designing underground drainage by agricultural tiles are as follows:

1. Place the drains below the depth limit of the rooting zone, or at the change to a heavier subsoil horizon. Drains should not be laid deeply within a heavy subsoil, for the resistance it offers to percolation will render the drainage of the upper soil inefficient.

2. Allow a minimum fall of a quarter per cent to prevent silting for four inch tiles, half this for six inch tiles. In free-draining soils, level drains laid at considerable depth have proved satisfactory. Steeper falls may be given up to about two or three per cent; beyond this grade, subsidence of the topsoil into the drain is likely to occur.

3. Lay drains across the slope to intercept the flow of water. These are often called intercepting or lateral drains.

4. These drains may lead to a natural waterway. Allow for a clear outfall at the end of each drain.

5. If these drains lead into a main drain, lay the main drain in the direction of the steepest slope. The outlet must also have a clear outfall.

When the drainage outlet cannot be led to a clear outfall, the drains can be constructed so as to empty into a sump fitted with an electrically controlled automatic pump, by which the drainage water is brought to the surface and run away in channels. A large type of sump is referred to as a caisson.

Tiles should be laid commencing at the outfall, and the tile at the upper end of the line should be plugged with cement or other suitable material. The trench may be cut by hand tools or by machine. A trenching spade is used to make the final cut in which the tiles are laid. The grade and alignment should be checked with boning rods. In butting one tile to the rest, rotate it so as to obtain the best fit at the top, and cover each joint with tarred paper or thicknesses of hessian to prevent silting, finally covering the whole with two inches of gravel or "blinding". Excess water gains entry through the joints, not through the pipes as is commonly supposed. Back-fill the trench so that the topsoil goes in the bottom, and arrange that filling reverses generally the natural soil order, thus obviating the possibility of soil compaction above the pipes.

When a lateral meets a main drain, the angle should be less than a right-angle, or a junction box may be used. At any marked lessening of grade a silt-box is required, fitted with a baffle to check the flow of water and enable the deposition of silt.

Properly laid tiles will last a lifetime.
Mole Drains

This form of drainage is carried out with the mole plough, shown in Fig. 29. It is most effective where the mole forms the drain in a heavy enough subsoil to retain the shape for a long time. Excess water gains entrance through the cut made by the coulter drawing the mole, and the fractures that result from the mole being drawn through the soil. In sandy soil the sides of the cut or the mole drain fret away. Mole drains may be effective for many years in suitable locations.

Fig. 29. A mole drain plough. Models for direct coupling to a tractor are now available. (Daniel Harvey Co.)

Supplementary Irrigation

At the same time as blocks are being located with regard to surface drainage, consideration can be given to the run-off from the blocks and the site for a dam. Many humid citrus districts are typically subject to spells of dry weather of greater or lesser duration owing to the strictly seasonal nature of their rainfall, and facilities for supplementary irrigation are an extremely useful standby. Although the provision of the requisite facilities is a costly capital item, it is an excellent insurance. As well as keeping the trees in good condition, the size of maturing fruit is greatly improved, and the setting of the new crop is more nearly assured. Therefore, a site that has possibilities of water storage for supplementary irrigation is highly advantageous. The possibilities of constructing a weir across a small stream should not be overlooked. The services of water conservation authorities may be enlisted to make the best of supplies. Calculations can be based on 22,612 gallons being equivalent to an acre-inch of water. The storage should allow for some six inches per acre, plus the loss by evaporation (obtainable from the Weather Bureau) during the months the water will be required. The spray method, mainly the portable type, which is used in supplementary irrigation, will be described later in this chapter.
Protection from Wind

Protection from wind is a very important aspect of the immediate environment or micro-climate of citrus-trees. Prevailing winds must be studied when selecting the location of an orchard and providing wind-breaks. Wind roses, given by the Commonwealth Meteorological Bureau, show the prevailing wind for various parts of Australia.

Exposure to wind may bring cooling or scorching influences, as pointed out under the heading of Aspect. It also causes mechanical damage to the leaves. When this occurs whilst the leaves are young it prevents their expansion to normal size and shape. Leaves are blown off the trees, and a short period of exposure to heavy winds, or continuous exposure to constant breezes, may bring about defoliation of the windward side, if not of the whole tree. At first the outside rows are affected, but as they lose their leaves the damage spreads to the interior trees of the planting.

Movement of leaves and twigs against young fruits causes abrasions to the skin, which grow with the fruit and result in scars and surface-markings that are causes for the marking down of the quality or the rejection of the fruit. The surface-marking on lemons known as silver scurf is the result of wind damage.

The best protection is afforded by higher country in the direction of the prevailing winds. Belts of natural timber are relied on in many instances as the only protection (Figs 15, 44). It is generally considered that to be a reliable break, belts of natural timber should be no less than a chain wide and should be subject to conditions of natural regeneration. The bush on a country road is seldom to be relied on entirely, because the conditions of natural regeneration do not apply. It is subject to the depredations of straying stock, bushfires, and vandals.

Breakwinds

When the natural protection is inadequate, breakwinds must be planted. They may be placed beside roadways, waterways, or fences, and a one-chain headland allowed between the breakwind and the nearest row of trees.

On the east coast the main species used are Pinus insignis or preferably P. 1aeda, turpentine (Syncarpia laurifolia), and brush box (Tristania conferta). In inland districts the athel-tree, Tamarix aphylla, is very suitable and is quick-growing. Olive and sugar-gum trees and palms have been used. Kurrajong (Brachychiton diversifolium) is unsatisfactory because of root-rot susceptibility.

A breakwind reduces the force of the wind by creating turbulence, whereby part of the energy is dissipated. Protection extends to a distance some ten times the height of the breakwind, protection being complete for five times the height and diminishing for the balance.

Natural timber or planted breakwinds, however, should not be allowed to become so dense as to seriously reduce air drainage from the orchard on the lowest side, especially in low-lying situations. Impeding the air drainage could render the orchard frost-liable in such situations.
Headlands and Fences

Headlands must always be wide enough to allow for the turning of implements, spray equipment, and for harvesting; a width of thirty to forty feet is necessary.

The area to be planted should be fenced to keep out livestock; rabbit-proof fences are very desirable where rabbits, hares or other small animals are pests. The common netted-wire fence is satisfactory, consisting of four wires spaced from the ground at 18 inches, 36 inches, 43 inches, and 50 inches (top of post), the netting being 6 inches underground and 36 inches above ground, with barbed instead of plain wire at 43 inches or 50 inches. The posts may be nine to twelve feet apart, or eighteen feet with two droppers or twenty-four feet with three droppers.

Position of Buildings

Whilst machinery sheds and the fruit-packing shed should not be actually among citrus-trees, owing to the dust menace, a central position is usually desirable. They need not necessarily be adjacent to the residence, although it will obviously be a saving in time if they are not far distant from it. They should be served with electricity for light and power.

Replanting Old Citrus Land

The replanting of land that has previously grown citrus is a matter that increases in importance as the area of suitable virgin land becomes scarce in the older citrus districts.

Close attention should be given to two aspects. One is the fertility of the soil. Old land may have suffered from erosion of soil, impoverishment of its fertility—chiefly organic matter and bases—or in the case of soils heavier than sand, deterioration in structure. A period devoted to soil-building practices, appropriate to the case, is inescapable if it is hoped to raise vigorous trees. A period of two or more years, according to the circumstances, is advisable, in which the area is put down to improved top-dressed pasture or green manure crops, which are adequately fertilized.

The second aspect is the disease condition of the old ground. In most cases old ground will be infected with Phytophthora, and the use of a resistant rootstock—trifoliata—as a replant is recommended. If Armillaria has infected the old ground, it would be unwise to replant it. Soil fumigation with carbon bisulphide, although effective against Armillaria, is prohibitive in cost.

If circumstances permit, the new planting sites should be excavated and filled with new soil, in order to give vigour to the growth of the young tree. Soil-improvement practices should be continued between the young trees.

Clearing New Land

In preparing virgin land, only the blocks to be planted need be cleared, the remaining timbered country serving as a windbreak.

The process of clearing must be carried out more thoroughly than is usually done for the larger-scale types of agriculture. All roots of the green
timber should be removed to a minimum depth of fifteen inches. In districts where Armillaria occurs all roots should be removed.

Clearing may follow the traditional method of felling the timber and grubbing, blasting, and burning the stumps, and this method is employed when timber on the land is saleable, for it pays at least in part for the cost of clearing.

Fig. 30. Ripper bringing up roots, after clearing by bulldozer.

A mechanized method of clearing land by the bulldozer has come into use in post-war years, especially for lightly timbered country. Large tap-rooted trees are left and pulled by a tree-felling winch. Following this the land is ripped two ways, at right angles, by the ripping machine (Fig. 30) to bring the remaining roots to the surface; some supplementary hand-grubbing is usually necessary. The great advantage of this method is its rapidity, and a satisfactory job will result if the ripping has been well done, hand-grubbing faithfully carried out, and all roots collected and taken off the land.

One or two ploughings should now put light-textured virgin land in a friable state suitable for laying-out the orchard.

Soil Protection Prior to Planting

On very light soil, exposure to blowing by wind should be prevented by seeding down with a cereal crop. Rye is commonly used. The laying out and planting of the trees is carried out with this soil cover maintained. In other cases where there is a danger of soil erosion from storms, a
green-manure crop should be sown, in ample time for ploughing in before it is time to lay out the orchard.

One other consideration is necessary when trees on trifoliate rootstock are to be planted. This rootstock does not thrive in acid soils (below pH 5.0). The soil should be tested and dolomite be applied if it is necessary to reduce acidity.

**DESIGN AND DEVELOPMENT FOR IRRIGATION**

Several aspects of design already discussed must be borne in mind when drawing up the design for irrigation culture, and in addition the extra facilities must be allowed to provide irrigation.

In irrigation communities the farm carries a contractual right to a water-supply from the authority in control. The authority may also provide a community drainage system for the disposal of surplus water. Water is delivered to the highest point on the farm served by the authority’s supply channel or pipe-line, and passes through the Dethridge wheel or some other structure which measures the amount that flows on to the farm. The design of an irrigation orchard and the efficiency of the irrigation structures are so important to the permanence of community irrigation farming that in many cases they are provided by the authority. The reticulation of water on the farm and drainage from it into the community system are nevertheless the farmer’s responsibility.

But when a farmer irrigates by means of a permit to pump from a stream he must make his own arrangements for the delivery of the water to the land, for irrigation structures, reticulation, and drainage.

The design of land for fruit-growing under irrigation, therefore, involves more exact planning than in humid districts. Advice and assistance should be sought from the farm design officer of the authority or some other competent person in the event of the grower having to design an irrigated orchard or make alterations to an existing design.

The first necessity is a minor contour map, which is based on levels taken on a one-chain grid and shows contours at three-inch intervals or some other interval suited to the topography of the country.

Design will take into account the position of the farm water-supply structures, whether for spray or furrow irrigation, the division of the area into convenient-sized blocks for watering, and arrangements for drainage from the blocks that will connect with the disposal of the drainage of the entire farm and empty into the community drainage.

There are two main methods of irrigation in use for citrus, namely sprays and furrow, and since each requires a different farm water-supply system and soil preparation they will be dealt with separately.

**Spray Method**

Spray or sprinkler irrigation is becoming increasingly common in citrus plantings in community irrigation areas, and it is the method mostly used for supplementary irrigation in humid or natural-rainfall areas. Companies supplying equipment also provide the design for an effective cover of the area by the installation.
Fig. 31. Spray irrigation: above, portable system; below, permanent system.

(Photos: (a) A. Turner; (b) Gay Rotary Co.)
Water for spray irrigation is pumped into the pipe-lines and released through nozzles. As the water is under pressure, ground higher than the authority's supply channel can be used. This is a great advantage in some districts in which the highest ground is eminently suitable for citrus, but can only be commanded by pumping from the supply channel.

Other advantages of the spray system are that it can be installed on undulating country without the grading and preparation of the soil necessary to surface-flow methods. It can be used on slopes, which would be unsuitable for surface-flow methods, namely greater than three inches to the chain, or where the cross-slope is too great. Spray irrigation permits a greater control over the quantity of water applied than any other method. Hence the spray method is particularly suitable to the shallow rooting of citrus on open porous soil. Spurling has shown in his root-distribution studies (Fig. 64) that spray irrigation gives a more uniform distribution of moisture in the soil, prevents the accumulation of injurious salts beneath the tree, and results in a better distribution of roots in the land between the trees than furrow irrigation.

*Fig. 32. Plan of spray irrigation. Heavy line represents underground main, lighter lines represent laterals, and circles show area of ground covered by each sprinkler, rising from the lateral.*
The chief disadvantage is the expense of installation, which at the present time may range well over £100 per acre, exclusive of labour, for a system with underground pipe-lines. The portable type is cheaper, but when it is used the labour of shifting the pipe-lines is burdensome. One result may be irregular irrigation; for example, if the pipes have been moved through the orchard from one end to the other for one irrigation, and the next irrigation is started from the latter point and the pipes moved back through the orchard, the trees first watered in the first irrigation and last watered in the next will have had too long an interval between irrigations and may show stress. High evaporation is an unavoidable concomitant of all spray irrigation, although it is minimized by carrying out irrigation during the evening. In the lay-out, care has to be taken to allow for wind blowing the spray, by carrying the last outlet to the edge of the planting on the windward side.

The selection of a spray system must be made among the following types: low, medium, or high pressure, or Kook² types. The characteristics of the systems are given in Table XII. The Skinner system, also the Kook, are suitable for nurseries.

For citrus-growing the choice usually rests on one of the medium-pressure type. The real choice, however, is whether to be involved in the labour costs of a portable system or the capital costs of a fixed underground system with overhead sprinklers (Fig. 31). Lay-out of a permanent underground system is given in Fig. 32.

### TABLE XII

**SOME CHARACTERISTICS OF SPRAY IRRIGATION PLANTS**

*Data from Reddock²*

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Type</th>
<th>Type of outlet</th>
<th>Coverage per outlet</th>
<th>Application per outlet per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>lb. per sq. in. 10 to 20</td>
<td>Fixed jet spray; chokeless sprays; butterfly and other rotating sprinklers; rotating arm sprinklers</td>
<td>feet 20 to 48</td>
<td>in. ½ to 2</td>
</tr>
<tr>
<td>Medium</td>
<td>20 to 60</td>
<td>Two opposite nozzles, one of which strikes a weighted or spring-controlled arm; rotating arm sprinklers</td>
<td>35 to 70</td>
<td>½ to 4</td>
</tr>
<tr>
<td>High</td>
<td>60 to 100</td>
<td>“Fire hose” nozzles, rotated by water or oscillating arm</td>
<td>acres ½ to 2½</td>
<td>½ to 4</td>
</tr>
</tbody>
</table>

² Skin and Kook characteristics vary with unit. At 20 pounds pressure per square inch, 100 x No. 1 Outdoor nozzles the coverage is: 20 feet in one direction and on rotation of the pipe-line, 20 feet in other direction; and the output, 60 gallons per hour.
Furrow Method

In the furrow method a permanent water-supply system must be installed and the land must be graded. From the authority's supply, the farm-supply system is mapped out along the highest land, the area is divided into blocks, and surface or underground drainage is provided.

The farm water-supply system for furrow irrigation is of two types:
1. An underground pipe-line or closed conduit, and
2. a ditch or open conduit.

With the underground pipe-line or closed conduit water for the furrows is brought to the surface by risers. Underground pipe-lines have the advantages of being strong permanent structures out of reach of cultivation, they can deliver from a low point by pumping, they prevent the deep percolation sometimes associated with ditches, and water is under positive control, thus allowing of accurate irrigation. Land is not taken up by a series of ditches and headlands. The chief disadvantage of underground pipe-lines is the expense. They are used to only a limited extent in Australia.

Installation in a citrus orchard is shown in Fig. 61. In the vast majority of cases the water-supply system for furrow irrigation consists of ditches provided with outlets or sluice-boxes to permit the flow of water on to the orchard. Another form of open conduit—the flume—is practically unknown in Australia today.

Straight Furrow versus Contour Furrow Method

Inspection of the plan will show where along the high ground ditches are to be located, and also will indicate how the blocks will lie. The next question is whether to plant on a straight-row lay-out or on the contour.

The latter method will be adopted when the contour map shows that the irrigation slope will be excessive (more than three inches per chain), the cross-slope excessive, or when a great deal of earth movement will be necessary to plant on a straight-row lay-out, and the extent of the work will not only be costly but may be deleterious to the soil. In these cases contour planting is advisable, and smoothing of minor irregularities may be all that is required. Thus the first step after clearing and ploughing is either grading or smoothing required for the planting lay-out.

Grading and smoothing. The object of grading is to shape the surface by removing rises and by filling depressions, producing a surface with a uniform slope so as to ensure uniform flow and penetration of irrigation water, and where necessary to provide spoil for ditch-building. It should be done by moving as little soil as possible over the shortest distance; this is on account of expense, and because it is undesirable except in the deepest soils to scrape large amounts of topsoil from one position and deposit it in another. In all but the lightest soils excessive grading also adversely affects soil structure.

Smoothing is a similar operation, used when less soil is to be shifted; it is carried out by the rectangular smoother. Two gradings or several smoothings are usually necessary, with an interval between each to enable settling of the soil and checking of the work done in the previous operation. Rain or a trial irrigation is a useful check on the efficiency of the grading
job, for the water plainly shows high and low spots. The final check is made byboning rods.

Owing to the effect on the soil of grading and/or smoothing, it is desirable to grow a cover crop and plough it in several months before planting time. It will then be rotted down before carrying out any final tillage operation and the actual planting.

_Ditches_

The gravitational supply of water for ditches starts at the Full Supply Level of the supply channel, drops three inches in passing through the Dethridge wheel when it is turning at about full capacity, and assumes a

![Diagram of Ditch](A)

![Diagram of Cement-lined Ditch Section](B)

![Diagram of Earth Ditch Section](C)

Fig. 33. Ditches: (A) Dethridge wheel and farm ditch (cement-lined) in relation to Full Supply Level; (B) cross-section of cement-lined ditch, two inches of freeboard; (C) cross-section of earth ditch, six inches of freeboard.
level at the start of the farm ditch (Fig. 33) which must be three inches above the surrounding soil-level. A minimum of six inches from Full Supply Level to soil-level is therefore required for the land to be irrigable from that level.

The ditches should have six inches freeboard, if of earth, or two inches if cement-lined. The top of an earth ditch will therefore be a minimum of nine inches above soil-level, a cement-lined ditch five inches above soil-level.

![Construction of cement-lined ditch](image)

*Fig. 34. Construction of cement-lined ditch: (upper) screeds in position being checked for level with boning rods; (lower) template in position, used as guide for laying cement on sides of ditch. Sharp corners have been rounded with a curved float.*

*(Photos: Department of Agriculture, N.S.W.)*
Ditches are constructed so that when finished they are partly above and partly below the level of the soil. The former part is called the fill and the latter the cut, and most ditches are cut-and-fill. It is usually better for them to be more fill than cut, thus elevating the water-level of the ditch and reducing the amount of "dead water", that is, water in the ditch below soil-level, which it is advisable to drain off after an irrigation.

Spoil to provide fill is deposited along the site of the ditch in the operation of grading or smoothing as already mentioned. The cut part of the ditch will provide additional spoil.

Sandy citrus soil is often too porous for the successful use of earth ditches, and consequently cement-lined ditches are required. An earth bank is made and consolidated by watering down a furrow cut in the bank. The ditch is pegged out allowing for outlets and any other ditch structures that may be required, and is cut by hand tools, using a template or pattern. It is then lined with two inches of cement mortar made of a 3:1 or 4:1 mix of sand and cement.

Figure 34 shows a cement ditch in course of construction. The method of cement-lining a ditch and the construction of ditch structures are condensed from an account by Myers\(^3\) from experience on the Murrumbidgee irrigation area, the largest furrow-irrigated citrus area in Australia.

Two heavy straight pieces of timber, 4 inches by 2 inches, called screeds, are laid flat and placed parallel to the ditch about 2 inches from the cut. The tops of these screeds correspond to the top of the ditch and are so placed that a lip 2 inches by 2 inches of lining is formed along the edge. Figure 34 (upper) shows the screeds in position, and the men are about to check the level of one screed by using the boning rods on the level pegs previously placed. Note that a boning rod is permanently set on the far peg.

The templates [Fig. 34 (lower)] are laid in the cut, one at each end of the section to be lined, and after the mortar is laid on, a straight edge is moved back and forth over the template. In this way the lining corresponds to the shape of the templates.

In lining with cement mortar, put in expansion cracks similar to those seen in pavements, to prevent cracking of the lining.

It is important to keep the surface of the concrete moist by covering with wet bags, cement bags, etc. This allows the mortar to cure, and so strengthen. About a week is sufficient to allow curing, although on big jobs requiring maximum strength, engineers often specify that the surface be kept from drying out for 28 days. This curing is an important phase of cement work, and many failures are due to the neglect of this point.

Size of ditches. As a 2-cusec Dethridge wheel is the usual type in use for horticultural holdings, it is advisable to provide ditches capable of carrying a flow of 2 cusecs (cubic feet per second). The dimensions to carry this flow vary with the slope and are given in Table XIII. The cross-sections of a 9-inch by 9-inch cement-lined ditch and a 2-cusec earth ditch are shown in Fig. 33.
### TABLE XIII

**STANDARD DITCH SIZES FOR CEMENT MORTAR-LINED DITCHES**

_Capacity 2 cusecs_

<table>
<thead>
<tr>
<th>Slope</th>
<th>Size of ditch</th>
</tr>
</thead>
<tbody>
<tr>
<td>ins per chain</td>
<td>ins</td>
</tr>
<tr>
<td>7½</td>
<td>6 x 6</td>
</tr>
<tr>
<td>3</td>
<td>7 x 7</td>
</tr>
<tr>
<td>1½</td>
<td>8 x 8</td>
</tr>
<tr>
<td>¼</td>
<td>9 x 9</td>
</tr>
<tr>
<td>½</td>
<td>10 x 10</td>
</tr>
<tr>
<td>¾</td>
<td>11 x 11</td>
</tr>
<tr>
<td>Less than ¼</td>
<td>12 x 12</td>
</tr>
</tbody>
</table>

*Note: A 9-inch by 9-inch standard ditch is one with a 9-inch bed and 9-inch depth of water measured vertically. As 2 inches must be allowed for freeboard, the bed will be 11 inches below the coping of the ditch. Side slopes are one to one (Fig. 33).*

**Ditch structures.** A ditch requires checks and sluice-boxes. Myers describes these as follows:

*Checks.* In sloping earth ditches, checks are generally installed at every two or three-inch fall. This is mainly because it is almost impossible to irrigate under such conditions without them.

*Dimensions of the check for earth ditches.* The check should be embedded into the earth at least one foot all round to prevent leaks. In sandy soils more than one foot may be necessary. When in position the check should be as high as the consolidated bank.

The bottom of the opening should be slightly below or at bed level, otherwise the water falls over the lip and scours a hole below the check. The opening itself should be two feet to two feet six inches wide to prevent the need for "pushing" water through and minimize scouring.

This type of undershot check may cause scouring in unconsolidated ditches. Where this danger exists, use overshot checks with removable boards and beach the downstream part of the ditch with stone or an apron of cement to take the fall of water.

*A cement check.* A cement check is very simply made. A flat surface, as a cement or wooden floor, is covered with paper. Pieces of 2-inch x 4-inch timber are laid flat to the proper shape and "tacked" together. The resultant form is half filled with cement mortar or concrete. Reinforcement of 8-gauge wire, wire netting or steel rods, is then laid and covered with concrete. The whole is smoothed off, giving a slab of concrete two inches thick.

Bolts should be let into the cement around the opening to take the wooden frame which will carry an iron door.

*A wooden check.* Tongue and groove cypress pine (*Callitris*) is generally used. The groove around the opening is made by attaching pieces of 4-inch x 1-inch around the opening.
Drop boards are used to open and close the opening. It is important to thoroughly soak the wood with sump oil or some such material.

**Sluice boxes.** Sluice boxes allow efficient and continuous control of the flow to each bay without a lot of patrolling, and make irrigation from earth ditches as easy as from lined ditches.

**Cement mortar sluice boxes.** Cement sluice boxes (or outlets, as they are sometimes called) in earth ditches can be pre-cast or built into a cut in the bank with the earth acting as the outside form. In both types a door slide of grooved redwood with a fairly tightly fitting galvanized iron door gives a leak-proof outlet.

In the built-in type the bed of the sluice box is laid down with the door frame set in place flush with this bed. Inside the two uprights of the door frame two boards (masonite boards do the job quite well) are placed and kept hard against the uprights by means of a spreader board placed between them. To make the set-up quite firm, tie the uprights hard against the boards by looping the two together with twine and tightening. The concrete is then packed between the earth cut and these forms.

*How to get the right bed level.* While an irrigation is in progress, pegs should be put in at each bay so that the top of the peg corresponds to the water level. These pegs will give a precise idea of the level at which the sluice box will give maximum flow.

It pays to have the bed of the sluice box a few inches below ground level to prevent scouring at the point where the cement stops. Some beaching on the downstream side may be necessary and should be put in before scouring has gone too far.

**Another simple type.** A cheaper type can be made by cutting a 5-inch x 12-inch opening in steel plate and fitting a suitable leak-proof door. The steel plate can be driven into the bank and across the opening in the ditch. This type tends to scour more than the type where the water is lead through to the land.

**Dimensions.** A convenient size which will carry the maximum flows likely to be required in orchards is 5 inches wide and 12 inches deep.

**Furrow-irrigation Blocks**

The design of a block for furrow irrigation from a ditch (Fig. 35) provides for the following main features:

1. A head ditch at the top of the slope.
2. A headland of thirty to forty feet to allow for the division of water into the required number of furrows, the turning of implements, and a certain amount of traffic.
3. Rows of trees laid out down the slope with careful regard to the slope and length in order that the block may be capable of being watered correctly for the soil type by furrows. The rows in the block may be arranged on the square, triangular, or contour systems. The important thing is that the rows are on a slope and of a length capable of satisfactory irrigation.6,7
4. A footland similar to the headland, for drainage and traffic.

5. A broad shallow drainage ditch at the lower edge of the footland.

Drainage by deep percolation is depended on in some areas which are provided with a comprehensive system of underground tile drains.\(^4\)

The chief trouble to safeguard against by design, in light soils, is deep penetration or over-irrigation, bringing in its train waterlogging, root-rot and tree decline, or salting. Deep penetration can be avoided generally by planning for large flows down moderate slopes in smooth furrows and for short lengths of run. If it should be found that the penetration is not sufficient it may be increased at any time by an adaptation of the factors referred to, namely, reducing the flow and lengthening the time for irrigation, by increasing the roughness or the size of the furrows, and by cover crops to produce a trashy surface.

On light soils, moderate and steep slopes are used, that is greater than two to three inches per chain (see Table XI, for relation of suitable slope for soil type), and the length of run three to five chains; the flatter the slope the shorter is the length of run allowed. Very steep slopes are subject to scouring. Because the slope and length of rows are fixed to a certain

Fig. 35. View down one land of a furrow irrigation block, showing cement-lined ditch with slide outlet or gate in foreground, distribution furrows in the headland, and broad furrows beside young trees.
extent by the original design this is one question on which the intending grower should be guided by expert local knowledge.

When it comes to planting, the rows will be marked out by plough furrows and the trees will be set in the furrows. The furrow is only put down immediately prior to planting and is used for irrigation for the first season.
CHAPTER 7
PLANTING
PLANTING DISTANCES

Distance apart should be governed by the size to which the trees can be expected on local experience to grow. Older plantings in the vicinity of Sydney were often only 18 feet by 18 feet apart, and today 20 feet by 20 feet is a common distance. On the Murrumbidgee irrigation area 22 feet by 22 feet is the standard distance, whilst in the Murray River districts 24 feet by 24 feet is commonly used. In the natural rainfall area of Toodyay, Western Australia, trees may be seen at 28 feet apart, this distance being employed not to accommodate the size of the tree, but to allow greater soil-moisture reserves per tree.

Some favour has been found in late years for double planting in the rows, trees being half the distance apart in the rows that they are between the rows. The object is to secure greater acreage yields in the early bearing years. Alternate trees in the rows are removed when their size warrants that greater space be given to the remainder.

Number of Trees per Acre

The number of trees per acre on any rectangular system of planting is calculated by dividing the product of the planting distance in feet into the number of square feet in an acre (43,560). For example, 22 feet x 22 feet = 484, divided into 43,560 gives 90 trees per acre. The number of trees per acre at common planting distances is shown in Table XIV.

SYSTEMS OF PLANTING

The systems of planting available are one of the straight-row lay-outs—which give geometrical patterns, namely, the square, which is by far the most popular, or the triangular also called hexagonal or septuple system, which is used to a small extent—and the contour. In any case the trees may be double-planted in the rows running in one direction.

Straight-row Systems

In any of the straight-row systems planting can be facilitated by the use of a planting wire. This consists of a suitable length of 8-gauge or 10-gauge fencing wire, with an iron ring attached firmly to each end, and the length marked off by solder dabs at the planting distance to be used.
TABLE XIV
NUMBER OF TREES PER ACRE AT COMMON AND DOUBLE PLANTING DISTANCES

<table>
<thead>
<tr>
<th>Distance apart (feet)</th>
<th>Square</th>
<th>Triangular</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of trees</td>
<td>No. of trees</td>
</tr>
<tr>
<td>Ordinary planting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>134</td>
<td>154</td>
</tr>
<tr>
<td>20</td>
<td>109</td>
<td>125</td>
</tr>
<tr>
<td>22</td>
<td>90</td>
<td>103</td>
</tr>
<tr>
<td>24</td>
<td>75</td>
<td>86</td>
</tr>
<tr>
<td>26</td>
<td>64</td>
<td>74</td>
</tr>
<tr>
<td>Double planting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 x 10</td>
<td>218</td>
<td></td>
</tr>
<tr>
<td>22 x 11</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>24 x 12</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>26 x 13</td>
<td>128</td>
<td></td>
</tr>
</tbody>
</table>

The majority of irrigated orchards on carefully graded land are laid out on one of the straight-row systems, usually the square, because of the simplicity it affords for irrigation.

The chief disadvantage of a straight-row system shows up in undulating land, for the straight rows take no cognizance of the natural contours of the land, with the result that soil erosion can occur and is difficult to check. The erosive action of run-off may be doubly dangerous to citrus-trees through the loss of soil from the high parts with consequent loss of fertility, and by silting on the lower areas, which carries the possibility of covering the union of the scion and stock, thus rendering the trees susceptible to collar-rot.

**Square System**

In the square system the base line is laid down with stakes along the longest side of the block to be planted, and from it offset lines at right angles are laid off. In the absence of a suitable instrument to give a right angle, the 3-4-5 triangle may be constructed on the base line. The offset lines are sighted to the farthestmost edge of the block, where the distance between them is measured to see that it corresponds with that on the base line, thus assuring that the marking out is square.

The offset lines are as wide apart as can be spanned with the planting wire, and the lines themselves are pegged at the planting distances. When it comes to planting, the wire will be stretched between corresponding pegs on a pair of such lines and a tree will be set at each mark on the wire.
Rectangular System

For an orchard in which the trees are not to be set out the same distance each way, the marking out of a rectangular system is done similarly to the square, except that the planting distance along the base line will be different to that along the offset lines. Generally, the wider distance is allowed across the main slope.

Triangular System

The triangular system is also laid out from a base line, but the offset lines are laid off at an angle of 60 degrees. When instruments are not available to lay off this angle, an equilateral triangle laid on the base line will give the correct direction of the offset lines. The advantage of this system is that it allows 15 per cent more trees per acre.

Contour System

In the contour system of planting, the rows of trees are planted on a sloping or graded contour (Fig. 36). The objects of this system are two-fold: to conserve soil by reducing sheet erosion and gully formation to a minimum, and to increase the penetration of rainfall into the soil by diverting it from steep natural slopes and causing it to follow the gentle slope along the rows of trees.

Fig. 36. Young orange-trees planted in contour rows at Gosford Citrus Experiment Station.
Orchard land is particularly susceptible to erosion, because the bare earth is often exposed for long periods by the cultivation necessary to destroy weeds, and because there is a large amount of traffic on the land from spray and fruit vehicles as well as cultivation implements. At almost every season of the year in some districts some vehicle is traversing the orchard, leaving wheel-tracks that may develop into washes after a single shower of rain. Contour planting is rapidly gaining favour as a step, taken from the very outset, to conserve orchard land and increase the moisture available to the trees. Contour-planted orchards are further discussed in Chapter 10.

![Fig. 37. The "A" frame or contour board.](image)

In regard to what areas in humid districts should be planted, not on the square, but on the contour, the erodability of the particular class of soil and other factors enter into consideration, but, generally speaking, slopes of three per cent or more may be regarded as more desirable for contour than straight-row (square or hexagonal) planting. The conditions that point to contour rather than straight-row planting in irrigation areas have been mentioned in Chapter 6. Advantage should be taken of the assistance available from Departments of Agriculture for the work of laying out a contoured block.

Three methods of setting out the contour system have been used on the central coast of New South Wales:

1. A plan is prepared from a contour survey. Trial designs are pencilled in on the plan until the best is found. The plan is then applied to the field. This work is done in co-operation with the Soil Conservation Service.

2. The operator goes to work with a dumpy level on the site, without a plan, setting out a design on the land and correcting it when necessary.

3. The same as (2), using the contour board or A-frame (Fig. 37) instead of a dumpy level. The A-frame and other makeshift levelling devices are not recommended if the dumpy level and staff are available.

Better work should be done with a plan, though most coastal orchard plantings can be designed efficiently on the spot. A contour plan of a large area gives a clearer view of the whole design, especially when there are changing grades and water-disposal problems. Most of the central-coast designing has been done without contour plans.
The equipment required for method 2 is a dumpy level, surveyor’s staff, 100-foot tape, and a supply of light pegs—about forty pegs to the acre. Two men can do the job provided that one of them has training and experience in the work.

**Grades**

The grade or fall in rows across the slope should not be more than one per cent—one foot in 100 feet. Soil loss may only be small at 1½ per cent, but becomes serious on steeper grades. Variable grades have been applied successfully on fairly regular slopes on the coastal highlands, the grades varying from 0·2 per cent and increasing to one per cent at the outlet.

**Row- and Tree-spacing**

Individual grower preference, diversion banks, and the nature of the site all influence row- and tree-spacing. Row-spacing in contour planting is generally wider than in square planting. The basic coastal planting distance is 20 feet by 20 feet. Adapted to contour planting this becomes 22 feet between rows and 18 feet between trees.

The method of designing, briefly, has been to peg out a base line on the correct grade through the most regularly sloping area on the site. Then, using the 100-feet tape, peg out rows parallel with the base line, above and below it. On regularly sloping sites, four or five rows from the base line can be marked; fewer, if grades change more abruptly. The row farthest from the base line is checked with the level, and corrections are made, spreading the corrections over the other pegged rows if necessary. Correction alters the position of rows or portions of rows, up or down hill, and so varies the row-spacing. Citrus-growers on the central coast are now accepting variations up to four feet in row-spacing. When the land is so irregular that changes up to four feet will not correct grades, then greater variation or broken rows must be accepted.

Pegging out is completed by continuing to mark off parallel rows from corrected rows as from the original base line, checking and correcting as the need arises. Small depressions, mounds, or erosion gullies are ignored in the design.

The design is now marked clearly by ploughing furrows along the rows of pegs. An experienced man can “walk out” small kinks or sharp angles as he picks up pegs ahead of the horse or tractor. Pegs for tree positions are now placed in the plough furrow.

**Planting on Contour Banks**

To further combat erosion, planting on contour banks has been proposed. Banks may be constructed to occupy the site of each planting line (Fig. 38). The banks lead into grassed waterways as described in Chapter 6.

Serious disadvantages of contour-bank planting are the difficulty of wetting the bank by rain or irrigation, and the rapid drying out of the soil in the bank.
Spring is the commonest planting time and allows the trees to complete one season's growth and thoroughly establish themselves before the winter months. Citrus-trees may, however, be transplanted at other times, except possibly during the hottest and coldest months, but extra care will be required when planting at other than the usual and safest time.

Original ground line on slope

Pegs ploughed out. A furrow now marks the row

First cut with ditcher

Second cut with ditcher

Third cut, ditcher tilted steeply

Fourth cut with ditcher

Fifth cut, level position

Section after fifth cut

Sixth cut with ditcher

Seventh cut with ditcher

Bank, after tillage and settling

Fig. 38. Steps in constructing banks, using orchard tractor and grader-ditcher.

(In Agricultral Gazette of N.S.W.)

In districts where frost liability ceases early, such as the east coast districts, spring planting should be done before the trees in the nursery break into their first flush of growth; they will then make all their new growth in the new location. In the Gosford-Sydney region this will be the last week of August. In inland areas frost liability continues later, and danger from hot spells sets in earlier. In this case there are alternative methods; either (a) transplant as soon as frost danger is over, cutting away any new growth on the trees immediately before transplanting, or (b) transplant before new growth is made on the trees, and wrap the transplanted trees as a protection against frost. This is the better method of planting trees on trifoliata stock, which may be set out in such areas as early as mid-August.

Autumn planting is carried out only in districts with mild winters, shortly before the autumn flush of growth starts, usually at the end of
January or the beginning of February. Trees on trifoliata stock should not be transplanted in the autumn.

As planting time approaches, all should be in readiness for the arrival of the trees. We have seen that straight-row lay-outs will be marked with pegs along the offset lines between which the planting wire will be stretched, and a tree set at each mark on it. Alternatively, the whole area may be pegged out and each tree planted with the aid of a planting board, which is a safeguard against deep planting. In contour planting the rows will be pegged out preparatory to ploughing a furrow that will mark the contour row; planting will proceed side by side with ploughing the next contour row, tree distances along the contour row being determined by a measuring rod. Likewise, in irrigated districts the land will be marked out for furrows, which are made as planting proceeds.

If all is not in readiness for the arrival of the trees, it may be necessary to heel them in. Heeling in is to be avoided if at all possible, owing to the extra handling, exposure, and mechanical injury to the roots.

On arrival the consignment of trees should be examined. It should be free of pests and diseases, owing to the precautions taken in the nursery. The principal defects to search for are root-rot and live scale. The presence of live scale will introduce the necessity of fumigation if it was omitted prior to packing at the nursery, or immersion of the plant, top downwards, as far as the nursery soil-level, in white oil one gallon in forty gallons of water.

When trees are to arrive from a distance they will be packed, as described earlier, in crates, the roots puddled and packed in damp seaweed, rotted straw, or sawdust. With attention to watering, citrus may be retained in the crates safely for two weeks. If a much longer delay appears inevitable, then they should be heeled in, although, as stated before, this is not a desirable operation for citrus-trees.

The weather at transplanting time is important. Trees should never be transplanted in unseasonably hot weather, or while hot drying winds prevail. Planting during a spell of cool or showery weather assures success. Where nurseries are only a short distance from the planting site advantage is often taken of spells of suitable weather to transplant trees without puddling or packing, merely transporting the trees, their roots covered with wet bags in a truck, in sufficient numbers to allow for rapid planting.

**METHOD OF PLANTING**

When it comes to unpacking and planting the danger arises of the fibre and roots drying out by exposure to the air. This will be minimized if the trees are removed from the crate only in sufficient numbers and immediately placed in drums of water in which they can be transported on a slide or truck along the planting lines. However, they should not be immersed for long, as mentioned in Chapter 4.

Holes should be opened up only just in advance of planting in order that the soil will not dry out. Large holes are not required; they should only be large enough to accommodate the root system; a diameter of
fifteen to eighteen inches and a depth of eight inches is usually sufficient. A shovelful of well-rotted compost or a handful of blood-and-bone may be worked into the bottom of the hole, but fresh manure or any appreciable quantity of chemical fertilizer is apt to injure root-growth.

Fig. 39. Collar-rot of orange-tree following silt deposition that covered the union: (a) union originally above ground level, (b) silted soil level, (c) extent of bark affected before the tree succumbed.
PLANTING

Now select a tree from the drum, examine it, rejecting any that are malformed or have diseased root systems, wash the puddle off the roots, quickly look over the root system, and prune away any diseased or broken rootlets with secateurs. If the holes have been dug in proper alignment there should be little need to worry about alignment of the tree, although in planting this will be rapidly checked. The most important thing now is to see that the union will be set four to six inches above soil-level, having in mind not only what the soil-level will be after settling, but whether over the years the position is one that will be denuded by erosion or will gain soil by silting. The collar-rot and death of the tree shown in Fig. 39 was due to the latter.

High budded trees will be set with the union correspondingly higher.

Correct depth of planting owes its importance to the greater susceptibility of the scion varieties to Phytophthora than the rootstock.

In planting also spread the roots and fibre well. Starting with the lower roots, work in fine earth with the hand until the hole is partly filled, and firm in well with the foot. Complete the spreading of the upper roots and fibre, covering with soil, and again firm down well with the foot. Leave a shallow basin, to be immediately filled with water. A mulch should be applied, keeping it away from the trunk. Up to twenty pounds of well-rotted animal manure per tree may be used for this purpose.

When planting in plough furrows these are freshly made, as explained previously. Special care is necessary, compared with planting in holes in firm soil, to see that the tree is not set too deeply. In irrigated areas the furrow is connected round the trees and is used for irrigations in the first year.

The tree is thus planted in fresh holes or freshly exposed soil, to the right height, the roots well spread, the soil well firmed, further consolidated by watering, and mulched.

The next point is to look to the top, having in mind the immediate reduction of transpiring surface and the correct heading of the tree.

If the trees have been headed correctly for the variety in the nursery (p. 60), it may be necessary only to prune back the shoots fairly hard and cut the leaves on the remainder of the tree in halves crossways. Sometimes the head is too low, and the procedure then is to select the most upright, vigorous shoot, head it at the right height from the ground for the variety, and cut out other shoots. It may be necessary to tie it to a stake to keep it upright in growth. The leaves are reduced in area as before. Any trees that fail should be replaced as soon as possible; trees on sweet orange stock usually require more replacement than trees on other stocks.
CHAPTER 8

DEVELOPMENT TO BEARING AGE

Development should be promoted in the early years if it is desired to produce a large tree early in the bearing life.

The rate of tree development varies in different regions according to soil and climatic influences, and is a point worthy of inquiry by the grower. For instance, in northern districts young trees make growth at a rate that is phenomenal when compared with some southern standards. Even in districts near to one another differences occur; on the Gosford lowlands trees commonly grow faster in the early years after planting than on the nearby highlands.

Attention to the various practices that promote growth cannot be neglected at any stage, but may be expected to be most productive of results when directed to the few years during which trees are naturally prone to make their most rapid development, that is, the young non-bearing stage and the early years of the bearing stage. The care of young trees at this stage, while they are more or less unremunerative, is of considerable importance.

CARE OF YOUNG TREES

Watering

When rainfall is insufficient, young trees will require regular irrigation or watering. However, watering should not be excessive and should be determined by examination of the soil in the root zone. Under furrow irrigation culture irrigation is provided by the planting furrow, which is diverted round both sides of each tree. This will last at most for one season, after which a furrow is run down each side of the trees. Later, two furrows are used, until eventually all the land between the rows is irrigated. In other circumstances trees may be watered in a basin round the roots from water-cart, spray-cart, drums on a truck, or similar expedients.

Manuring

The manurial requirements to encourage vigorous growth naturally vary from site to site. There are virgin sites in which trees grow vigorously enough without manuring until they are well into bearing. In the majority of cases some fertilizing is desirable to produce a good-sized tree before bearing is allowed.

Fertilizers are applied in spring and autumn, before the growth flushes.
A programme for young growing trees especially recommended for coastal conditions \(^3,5\) employs a complete mixture, with additional dressings of sulphate of ammonia. Proprietary lines of a complete citrus mixture have an analysis of from 4 to 10 per cent nitrogen, 8 to 14 per cent phosphoric acid, and 4 to 10 per cent potash. The following amounts refer to the richer mixtures:

**First year.** Complete mixture 1 pound per tree after planting; sulphate of ammonia 2 to 3 ounces in February.

**Second year.** Complete mixture 2 pounds per tree in late July before the likelihood of spring dryness; sulphate of ammonia 3 ounces per tree in September, 3 ounces per tree in February.

**Third year.** Complete mixture 3 pounds per tree in July; sulphate of ammonia 8 ounces per tree in September, 4 ounces per tree in February.

**Fourth Year.** Complete mixture 4 pounds per tree in July; sulphate of ammonia 8 ounces per tree in September, 6 ounces per tree in February.

In areas where minor element deficiencies are prevalent in the mature trees it would be as well to think of the needs of young trees in this regard. Copper is a particular instance; since young trees are seldom sprayed with Bordeaux mixture their need for copper might be met by a soil application of bluestone.

Additions of animal manures to the mulch applied at planting are beneficial. This manure should be spread evenly over about three feet square, but should be kept away from the trunk of the tree itself.

All fertilizer should be spread in a wide band from the leaf-drip of the tree to avoid injury to the roots. When fertilizer has been placed in a narrow band and has been succeeded by light showers, death of young trees has resulted from the concentration carried into the root zone.

### Destruction of Weeds

Owing to watering and fertilizing, weed growth is often stronger round the tree than in the lands between the trees. Competition from weeds round the young tree should be completely eliminated, and this involves hand work with the hoe. Only careful men should be placed on this work, or the trunk and even low branches will receive bad injuries from the careless use of the hoe round weedy trees. Amongst small trees, weed in the centre of the lands offers no competition to the trees, and it may be retained as a soil cover and conservation practice. Weed in say a three- to four-foot strip from the drip of the leaves, however, is competitive and must be destroyed by cultivation implements.

As the trees grow larger the width of the cultivated strip must be increased.

### Pruning

The treatment given to the tree to form the head, in the nursery and at planting time, has been described.

**Oranges and grapefruit.** Some selection and training of the shoots that are to form the main branches may be done, but generally little attention is given to training young trees of these species. They naturally
form more or less round-headed trees with interior supporting branches of comparatively great strength. Extremely vigorous shoots or watershoots, which greatly exceed the outline of the tree, should be cut out entirely or cut back to the general outline of the tree. In young trees many of the branches formed in the first two or three years in the orchard are slender and tend to droop. Upward development of the top takes place by the growth of strong shoots from the upper sides of the drooping slender branches. The hanging branches should not be cut away or the development of the tree will be retarded, because of the loss of foliage.

Chandler\(^2\) explains the difficulty of positively training citrus in the following terms:

In deciduous and some evergreen orchard species, one can be reasonably certain that dormant pruning of a young tree will cause the new growth to be more upright, and also that if a main branch is left taller and with more room for leaf surface on its lateral branches than other main branches, that branch will be nearly certain to continue larger than the others. With these two responses one can proceed with reasonable certainty of success in giving a tree the form desired, the largest branches where they are wanted and growing in the direction wanted. No such certainty follows pruning young citrus trees: the branch that is left the largest may or may not send up the strongest shoots or make the most growth. And in some citrus species, pruning back the branches may not cause the new shoots to be more upright.

*Lemon and other upright-growing species.* The lemon, however, requires some pruning.\(^1\)\(^,\)\(^4\) Whilst young and vigorous it tends to produce long slender upright growth that becomes weighed down by terminal fruit production, and after the tree starts to bear it is much more open than other citrus. Shoots that have hardened in the upright position before they have set some fruit and bent down, will make the tree too upright and dense; to make the tree less upright they should be removed at their base, as should crossing limbs and strong upright shoots that occasionally arise from the main stem.

Upright-growing varieties of mandarin should not have the hanging branches pruned away, since they are not renewed.

**Desuckering**

Very soon after planting, buds along the stem or trunk start to produce shoots. As these are not intended to provide main branches they are commonly rubbed off when they appear. Provided these shoots remain quite short and do not appear to be robbing the upper structures, there is some evidence that they are useful in promoting vigour of the tree and protecting the bark against sun-scald, by their leaves.

Shoots arising from the stock (suckers), however, are of a very different category, and should be rubbed off in the bud stage or cut off cleanly whilst still very young. Shoots from the stock are very apt to grow straight up through the tree, and in one season may assume the dominant position over the scion variety (Fig. 40). Undoubtedly in many cases the Rough
lemon trees in suburban gardens are due to the dominance quickly assumed by a sucker from the Rough lemon root and the subsequent death of the scion variety.

Protection

Sun and rodents. The trunks of young trees may be wrapped with paper soon after planting as a protection against the sun. This also offers protection against rabbits and hares. However, red scale and collar-rot are likely to develop under protective wrappings and the trunk should be examined fairly frequently.

Whitewashing of the trunk is adopted when protection is required purely against the sun. A good whitewash is made from hydrated lime or dolomite with sufficient water to make it workable, usually three to four pounds to a gallon of water.

Fig. 40. Suckers: Left, one growth-flush of a sucker of Rough lemon; right, the sucker has grown through the young tree and assumed a dominant position in one season.
Trees liable to attack by rabbits or hares may be protected by painting with the following mixture: bitter aloes one ounce; common soap one pound; water one gallon. The ingredients are boiled together for twenty minutes and the mixture is applied cold to the trunk as high as the pests can reach. Application should be repeated if the pests persist. Proprietary repellants are also available.

![Fig. 41. Frost damage to young trees in a low position. (Photo: A. E. Vincent.)](Image)

**Frost.** In frosty locations young trees are very subject to frost injury, and protection against it must be provided, starting in the late autumn or early winter. Various materials are used, such as hessian, or paper wrapped round the trunk, or long straw that envelops the tops as well as the trunks. Cereal straw used at the rate of two sheaves to the tree, or taller material such as maize, gives better protection than hessian or paper. These wrappings must be removed as soon as it is safe in the spring. Figure 41 shows frost damage to young trees and Fig. 42 shows a young tree completely protected by wrapping with cumbungi (bulrush) leaves.

**Wind.** Young trees may suffer from hot dry winds and blown sand in exposed situations. Protective crops may be grown in the lands between the trees. Two rows of maize per land, across the direction of the severest winds, have proved very useful and do not rob the trees while they are small. Cereals—wheat, rye, and oats—are used successfully as a protection against sand blast in the Murray River areas (Fig. 43). Protective crops are neither necessary nor desirable after three or four years.

**Pests and diseases.** If a start is made with clean trees, pest and disease invasion may not be a problem for many years in isolated situations. In closely planted districts the principal pests may soon migrate to new plantings, and control measures as in Table XXVIII should be pursued actively. With correct methods of control on small trees, good success should be obtained.

**Intercropping and Interplanting**

Intercropping refers to the planting of vegetables between the rows of young trees. Crops of potatoes, beans, peas, tomatoes, cabbages, and other vegetables are commonly raised between young citrus-trees for metropolitan markets. Pumpkins, on the other hand, are objectionable owing to their trailing and rampant growth, which adversely affects the
Fig. 42. Protection of young tree from frost by complete wrapping with cumbungi straw, tied to a stake. One-foot intervals on background screen.

(Photograph: A. E. Vincent.)
trees. No disease-transference problem is raised by intercropping as is the case with some stone fruits where Verticillium wilt of tomatoes and other plants may cause black heart in young apricot-trees. However, precautions must be observed not to neglect requirements of the citrus-trees and their ultimate growth for the immediate value of returns from cash crops. The high superphosphate content of vegetable fertilizers is not deleterious to the young trees and has some residual value for subsequent green-manure crops.

Fig. 43. Cereal grown between rows of young orange-trees for wind protection, Coomealla, N.S.W.

Where spray irrigation systems are installed, intercropping with vegetables uses the water falling between the trees, and helps pay for the installation.

Interplanting usually denotes the growth among young trees of longer-term crops than vegetables. Thus in the Nambour district, for example, pineapples are commonly grown (Fig. 44), while in coastal New South Wales, passionfruit is a common interplanted crop in young citrus orchards.

GROWTH

Growth Flushes

There are several flushes of growth during the year. In young lemon-trees there may be as many as five, but in mature orange-trees there are two major flushes, in the spring and autumn, and often a minor flush in midsummer.
The spring flush starts with the advent of rising spring temperatures, it usually being considered that a monthly mean temperature of about 55°F. is critical for growth. The resulting shoots end in blossom buds or vegetative buds.

The autumn flush is more variable in time of appearance and amount, usually being most vigorous after good rain. A good autumn flush is desirable, because from it the spring flush with blossoming and cropping arises.

Thickening follows each flush of elongation growth, proceeding right down the stem and into the roots; the expansion that takes place can be clearly seen on the larger limbs and the trunk as shallow whitish longitudinal cracks. Adverse seasonal conditions can interrupt the completion of the process of thickening, just as they can reduce elongation growth.

**Growth Tissue or Meristem**

The apical end of a shoot terminates in a bud which, owing to death and abscission of the green tip of the shoot, may be, in fact, the axillary bud of the last leaf.

Examination with the aid of the microscope shows that the actual growing point consists of small, similar, closely packed cells, with dense cytoplasmic contents, actively undergoing division. This is the apical growing point or meristem.

This meristem is carried forward always as the growing point, the

*Fig. 44.* Mandarins interplanted with pineapples at Nambour, Qld.
cells formed adding to the length of the shoot. These cells undergo two processes, the first of which is enlargement. Farther back than cells at various stages of enlargement the cells start to differ from one another in their structure. This is the phase of differentiation, the cells becoming more and more specialized farther back until they appear in the pattern of the organized stem—wood within, then cambium, then phloem or inner bark. These changes all take place within a small fraction of an inch from the growing point.

The cambium is meristem tissue, producing new wood cells within and phloem without. It may be visualized as an internal sheath between the wood and the bark, extending from the tips of the twigs to the fine roots. It is responsible for the thickening of stems just referred to. All deep abrasions of the bark, and pruning cuts, are healed by the cambium producing bark that gradually closes over them. The cambium often regenerates green bark on the surface of large superficial wounds.

Towards the outside of the bark occurs a second ring of growth tissue, called the phellogen, which produces an internal tissue that largely becomes crushed, and an external layer of corky tissue that serves in sealing the stem against water loss.

Although citrus-trees are of the class that do not normally shed their bark, corky tissue may flake off, for example, when affected by certain virus diseases. The activity of the phellogen heals this shallow type of bark loss.

The Evergreen Foliage

The citrus-tree is evergreen because the leaves are retained or are capable of being retained on shoots that are two and sometimes more years old, and made up of some three to five flushes of growth. The older leaves become shaded by the extension of new shoot growth, and for other reasons become senile, and they eventually drop off. Under adverse conditions the older leaves fall excessively and the tree becomes very thinly foliaged. In still more adverse conditions, such as drought, flooding, and root-rot and excess salt or boron in the soil, all the leaves may fall and the tree may never recover. Undue exposure of the stem by loss or removal of leaves, without giving protection, is deleterious.

Some fall of leaf, preceded by an extensive withdrawal of nutrients, usually takes place during a flush of growth owing to the demands of the new and rapidly increasing tissue. When the leaf-fall is excessive, a close examination of the possible cause is called for, because the excessive loss will react on subsequent growth and fruiting.

Functions

Leaves start as stem protuberances in the bud. From the earliest stage visible to the naked eye they consist of supporting tissue—the leaf-stalk or petiole that extends into the leaf-blade as the mid-rib. Branches from it divide and subdivide, forming a lacy interconnected network of veins. Beside this supporting function the veins connecting with the wood and bark of stems and roots also act as the arterial system for the translocation up and down of food materials and elaborated food respectively.
Between the veins is spread the leaf tissue, which is organized so as to carry out three main functions: (i) the synthesis of plant food materials into plant foods, particularly the primary step, which is photosynthesis; (ii) transpiration, or the loss of water; (iii) respiration, or the oxidation and release of energy from the synthesized food, which, however, takes place in all living cells.

**Photosynthesis**

In this process green chlorophyll-containing bodies, chloroplasts, situated in the leaf and other green tissue, utilize the energy of light to effect the combination of water from the soil and carbon dioxide from the air, into the first organic compound. The interaction may be written as follows:

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2
\]

The equation shows that one molecule each of carbon dioxide and water form a molecule of this first organic compound together with one molecule of oxygen. A quantitative aspect was given to this reaction when it was determined that the absorption of a minimum of four quanta of light by chlorophyll sufficed for the production of one molecule of oxygen by photosynthesis, therefore one molecule of the organic compound.

As the first carbohydrate formed is the basis for the elaboration of a great variety of materials that enter into the structure and functioning of the citrus-tree and its fruits, it is essential that the factors for photosynthesis should be specially attended to by the grower. The main factor here under his control is the quantity of green tissue, principally leaves, and the intensity of their green colour. Owing to the chemical nature of chlorophyll ample supplies of nitrogen and magnesium are required. The yellowing of leaves by magnesium deficiency is a direct result of insufficient magnesium for chlorophyll maintenance, but any other yellowing of the leaves from zinc and other deficiencies, root-rot, parasitism by insects, and other causes directly curtails photosynthesis. The loss of leaves from lack of moisture, injurious sprays, excessive pruning, and other causes also reduces the volume of leaf tissue and the photosynthesizing potential of the tree.

**Transpiration**

Moisture is lost mainly through the apertures or stomata, which are situated on the underside of the leaves. The evaporation of water is effected by the radiant energy of the sun. The process keeps leaves cool.

Natural loss of water by transpiration through the stomata of the leaves increases sharply after sunrise, reaching a peak four to five hours later. Towards midday the stomata close partially or completely, thus limiting transpiration to some extent, and three or four hours before sunset there is a decided drop in transpiration due to the final closing of the stomata, which then remain closed throughout the night. Leaves in the sun may lose twice as much water as those in the shade.
While the stomata are closed negligible quantities of water are lost, even when conditions such as hot winds are highly favourable for rapid evaporation, but while the stomata are open the loss of water may be so great under such conditions that complete replacement of the amount of water within the tree is necessary every half-hour.

When the percentage of soil moisture falls to the wilting point the midday closing of the stomata comes into operation much earlier and takes place during the third and even the second hour after sunrise.

Unless wilting is relieved almost immediately growth will be affected. Leaves curl and fall. The remaining leaves seem to resume normal functioning immediately, or very soon after, the wilting point is relieved by the addition of water to the soil. But as the result of the previous water-deficit the tree may be badly denuded of its leaves. Soil moisture effects are taken up in more detail in Chapter 11.

**BEARING**

**Start of Bearing**

The young tree often starts to blossom after its second or third year; it may produce blossom in its first year’s growth. Until the tree has thoroughly established itself, as evidenced by good and increasing growth, fruit should not be allowed to develop but should be taken off when small, say when half-inch in diameter.

Trees in mid-latitude and southern districts may be allowed to develop some fruit from blossom that appears in the fourth and fifth year from planting. Trees should bear a reasonable crop from the sixth- or seventh-year blossom, and increase in production for another five to ten years, after which they may increase but slowly or remain more or less stationary in bearing potential.

The faster-growing trees of northern districts may be permitted to develop fruit from the blossom when the tree is two or three years old. In any case the trees should be well grown by local standards, and bearing should be postponed if there is any doubt about the state of development.

On trifoliata rootstock citrus-trees are especially prone to precocity of bearing, and cropping should be prevented until the trees have made sufficient stature, usually five years from planting.

**General Bearing Habit**

**Spring Blossom**

The normal fruiting habit of oranges, lemons, mandarins, grapefruit, and most citrus species is to produce a crop of fruit from blossoms that appear on the spring flush of growth; trifoliata is an exception and is dealt with later. The crop arising from the spring flowers is called main-crop fruit. The crop ripens in the following winter to spring, depending upon the variety. After ripening the fruit may hang on the tree for a period of time, varying with the variety and prevailing conditions, but usually it is harvested before the next spring blossom. With most varieties, therefore, there is a clear-cut annual main crop.
In the case of the Valencia orange the main-crop fruit ripens in the following spring, twelve months after the blossoming which produced it. Valencia is the longest hanging variety and may be held on the tree till the succeeding early autumn—a period of some sixteen months from blossoming. Meanwhile the tree has blossomed again, and thus may be carrying young developing fruit of the current season as well as old main-crop fruit. Therefore in the Valencia orange there are overlapping main crops.

Other Blossom

If the spring flush of growth is frosted at an early age it is common for a second flush of spring growth to blossom and give rise to late main-crop fruits, which attain a good size though they have a thicker and coarser skin.

The summer or autumn flushes if checked in growth by a dry spell frequently produce blossoms that give rise to second-crop fruit. This characteristic excited special comment on the part of several of our early writers. In inland districts generally, climatic conditions are such that fruiting develops predominantly as main crop, the conditions not favouring later flowering, and even when this takes place the young second-crop fruits often fail to survive the winter frosts.

The production of flowers later than the spring blossom is one of the most valuable characteristics of the lemon (see later). Second-crop Valencia oranges are thin-skinned, often valuable. However second-crop Navel and mid-season common varieties are a gamble. When they ripen late and out of season they will usually be found to be thick-skinned and of inferior internal quality. However, since they may sometimes be placed on a bare market they may fetch good prices.

Intermediate and second crops overlap the next main crop and they usually depress both the blossom and the setting of this crop, hence as a general rule it is desirable to prevent the conditions afore mentioned that cause second-crop blossoms.

Continual Blossoming

The fruiting habit of the lemon might be considered to be fundamentally similar to that described above, namely main-crop production and the ability to produce intermediate or second crops, but the tendency to blossom on flushes of growth and individual shoots made subsequently to the spring blossom is much more highly developed, and thus the tree is said to be ever-bearing. This is particularly so in the mild climate of the Gosford-Sydney region or the warmer climate of the Queensland districts, and in such localities blossom and fruit in all stages of development may be found on the trees.

Blossoming from Last Year’s Wood

Trifoliata, like other deciduous trees, produces blossoms from buds on the previous year’s wood. Blossoming occurs before breaking of the leaf-buds; the fruits mature in autumn well before leaf-fall.
Bearing Habit of Commercial Species

Orange

It has been pointed out that in inland districts the orange tends rather strongly to main-crop production, whilst in coastal districts there is a tendency to second-crop as well as main-crop production, and that the second crop if allowed to develop interferes with main-crop production. When bearing is confined to main cropping, and when the trees are maintained in a vigorous condition, most varieties of oranges tend to be comparatively regular year by year in blossom production, although seasonal conditions may bring about fluctuations in actual cropping. There are, however, some exceptions; Valencia oranges show a strong tendency, in inland areas particularly, to develop an alternate blossoming habit (see Table VI). West and Barnard made an extensive study of alternate cropping of Valencia oranges at Griffith, New South Wales, and their conclusions are summarized in the following paragraph:

It is suggested that a moderate thinning of fruit of the “on” crop early in the season constitutes an effective step towards reducing the swing from heavy to light crops in biennially cropping trees. The aim in thinning should be to remove fruits from the most heavily laden branches, and thus even up the distribution of fruit as well as lightening the crop generally. It may also be reasonably assumed that a thinning which removes up to one-third of the crop should not result in a reduction of the total yield from the trees during the season of treatment and the two subsequent seasons. The early harvest in August of portion of the crop or of the whole crop during the “on” year should also contribute to correcting the alternate bearing habit. Again, it would be advisable to make such pickings from trees or branches bearing the most fruit. On the other hand, early picking for export during the “off” season cannot be recommended, as it would probably tend to increase the yield of the following “on” season and thus accentuate the difference between the crops of “on” and “off” years.

Where the crop is to be allowed to hang for late harvesting (January to March) trees in the “on” year should be chosen. In the first place, West and Barnard state:

If fruit of the “off” year is allowed to hang late it grows inordinately large and is thus not so desirable commercially. In the second place the size of the fruit in the following “on” year, which in any case would tend to be on the small side, would be decreased. Thirdly, it would tend to increase the alternation in cropping. Allowing the fruit to hang late during the “on” crop season, on the other hand, not only tends to decrease the size of the fruit in the following “off” year and is thus desirable, but it also tends to diminish rather than to increase the difference in “on” and “off” crop yields.

Lemon

The main crop of the most important varieties of lemons, which are true lemons, is produced from spring blossoms and ripens in late winter—
a period of some ten months. The usual secondary flushes of growth occur in the summer and early autumn and give rise to early-summer and summer-ripening lemons, which are commercially more valuable than main crop, for they arrive on the market during the warmer months. Although the principal crops are the main or winter crop and the summer crop, the ever-bearing nature of the lemon that develops conspicuously in favoured locations can give rise to more or less continuous production.

![Fig. 45. Young lemon-tree at start of bearing.](image)

In inland districts lemons are not widely grown; the lemon is more liable to be frosted during the winter than any other commonly grown citrus species, and as a result the spring flush of growth and flowering on it are likely to be impaired. Winter frosts also cut the fruits developing from summer and autumn flowers which, under milder circumstances, produce the summer crop.

If the lemon is allowed to become principally a main-crop producer it may be prolific but almost certainly it will be unprofitable. In heavy main-crop years the fresh-fruit market quickly becomes saturated. Fruit
is often held on the tree too long, when it becomes large and coarse and effects a drain on the magnesium content of the tree. If serious deficiency occurs bearing may be affected for a season or more.

On the other hand the ever-bearing habit is one of the chief attributes of the lemon from a commercial point of view, and methods to preserve it are of outstanding importance.

Fig. 46. Scald of Glen Retreat mandarin-tree in the heavy crop year.

Reference has been made to the skilful use of location in the Gosford-Sydney region to reduce the spring setting, that is the main crop, thus encouraging the secondary crops.

A practice of considerable importance is that of keeping the fruits picked as they reach a marketable size; this not only enables the best averaging of the fresh-fruit market prices available, but prevents the drain upon the magnesium content of the tree for which ripe and tree-held fruit are responsible.

Methods of thinning unduly heavy spring blossom by hormone sprays are being tried.

In northern districts pruning is regularly employed to preserve the ever-bearing habit, pruning being given after any major pick of the fruit and consisting of cutting back the shoots that have borne fruit.

Highly vigorous lemon-trees, especially of the variety Eureka, produce long shoots that fruit terminally and are weighed down as the fruit develops, producing a rather spreading type of tree. Figure 45 shows the beginning of this habit, at the very start of bearing. Growth is renewed
from buds along the bent-down terminals, and after the fruit is picked the terminals should be cut back, with the object of keeping the tree more compact.

One trouble of the lemon should be mentioned here, for it interferes with the bearing habit. This is the appearance of shell-bark periodically in most districts. An outbreak of the condition does not call for any treatment of the affected trunk, but the improvement of cultural conditions assists in maintaining production from affected trees.

Meyer and Rough lemons are main-crop producers.

Mandarin

The mandarin should be maintained in a vigorous state of growth while young, but in early bearing years the vigour should be steadied down by cultural methods, especially by reducing the nitrogen supply. Unduly vigorous trees are liable to overcropping, following which they may lapse into irregular bearing. Vigorous trees of the Emperor variety are also liable to brown spot in humid areas, as are trees invigorated by pruning.

Glen Retreat and Emperor mandarins tend to crop excessively in some seasons, and the growth on whole trees or sections of the tree tends to "die-back" or "scald" (Fig. 46), with the result that no crop is produced in the subsequent year. While the fundamental cause for scald has not been shown, it is thought to be due to insufficient potash in relation to nitrogen. Pruning is employed to reduce the heavy crop and keep up the vigour of the growth. Annual pruning is regarded as essential to the successful growing of Glen Retreat mandarins in Queensland. Such pruned trees crop regularly and moderately without suffering from die-back, and the fruit is improved in size and sweetness. Adequate soil moisture is essential to satisfactory size in Emperor mandarins.

In general, fruitfulness of mandarins seems to be related to a fine state of balance in the vigour of the trees. Loss of vigour will be reflected at first in small fruit size, and later by failure to bear. Thinning out of the fine twiggy growth, assisted by judicious use of soil improvement measures, are usually the first steps to the improvement of vigour, but they must stop short of making the tree over-vigorous for the reasons mentioned.

Grapefruit

Grapefruit, like oranges, should be maintained in a good state of vigour. More blossom is produced within the leaf canopy than other species, and the "inside" fruit is of superior quality (Fig. 47); also, in this species the heavy bunches of fruit weigh down the bearing shoots to a position within the canopy, the shoots seldom regain a place in the canopy, and due to the shade usually die.

Grapefruit are fairly regular in their cropping habits, but the Wheeny variety resembles Glen Retreat and Emperor mandarins in having a strong tendency to overcrop in some seasons when die-back or scald occurs. Scalded trees fail to crop in the subsequent season. In coastal New South Wales, where Wheeny is grown, some growers regularly prune this variety to prevent heavy crops and the concomitant die-back.
Stem-pit virus may seriously affect the bearing of the true grapefruit varieties. Although the tree continues to crop, the fruit becomes small, thick-skinned, and worthless.

Fig. 47. Bearing habit within the canopy of the foliage of grapefruit.

(Department of Agriculture, Vic.)

MANAGEMENT OF BEARING TREES

Apart from the exceptions mentioned under different fruits earlier in this chapter, the bearing tree should be maintained with a dense canopy of large, healthy, deep-green leaves, with vigorous shoot growth, free from dead twigs; it should show good cropping ability for its size; the fruit should attain good commercial size; the skin should be fine and free from blemish and the pulp juicy and with well-developed flavour. The tree should be free for all practical purposes from pests and diseases. There are no absolute standards of vigour, leaf size, and so forth. The state of health should be judged in large measure by local comparisons, because soil, climate, and other local factors limit the standard of tree that can be maintained economically.

Before proceeding to deal in detail in subsequent chapters with the various cultural practices carried out among bearing trees, it seems advisable to take notice of the salient points in the management of a grove. The outstanding point evident in the management of successful groves is that attention is concentrated on the outstanding problems that prevail in the area, whilst the inevitable routine practices are not overlooked. The main points in the management of a citrus orchard will vary according to the district. In irrigated districts irrigation is necessarily a major practice. In humid districts the grower is relieved of this practice
only to shoulder a possibly heavier burden in pest and disease control. Obviously it is impossible to deal with the salient problems of different districts. Consideration is, therefore, restricted to those of the Gosford-Sydney region. Here there are probably more cultural or management problems than in any other area in Australia. In other areas, management will not only be devoted to different aspects, but generally speaking to fewer and possibly less complex practices. As the practices are described at length elsewhere in the text, details are omitted here. This account is given simply as an outline of the main management problems in one area.

**Seasonal Moisture**

Late winter, early spring, and early summer are apt to be dry. It is therefore necessary to prevent loss of moisture through weeds and cover crops during this period. Weed control is, however, merely a soil-moisture conservation measure. The real solution to the problem of dry springs is supplementary irrigation. This has been discussed on p. 93, following on to spray irrigation on p. 97.

The late summer, autumn and early winter period is apt to be wet, hence green-manure crops can be planted or weed and ground cover can be allowed to come away. Their growth will be beneficial by preventing erosion of the soil during the wet period. The growth also serves a useful purpose in taking up nutrients that may otherwise be lost by leaching during heavy rain, as well as providing cover to the soil at that period.

Phytophthora must be held in check by attention to surface drainage prior to the expected rains. In many situations underground tiles are necessary to drain excess water, which is favourable to this root-rot, out of the soil rapidly enough during periods of heavy rain. Underground drainage has been discussed on p. 91. Acidity of the soil can be regulated in some instances to keep it below pH 5-5, (the range less favourable to Phytophthora), where susceptible stocks have been planted.

**Weed Control and Supply of Organic Matter**

Two main methods have been evolved to organize the weed situation: (a) by turning in the ground cover in July, followed by tillage to keep down the weeds until the late-summer-autumn rains are expected; and (b) by the use of fowls to keep orchards bare of weeds, except in late summer when the fowls may be removed to allow the weed to come as a cover for the expected wet period.

Both these methods provide for the increment of organic matter to the soil, in one case in the form of green crop, in the other as fowl-droppings.

**Manuring and Nutrition**

Complete fertilizer is necessary. Mixtures are used with a ratio of nitrogen, phosphorus, and potash of about 7 : 10 : 5. The fertilizer is split into two dressings, applied mid to late winter and autumn. For the fertilizer to be carried into the soil it must be applied early, with the ploughing-in of the winter green crop, and again before the occurrence
of the heavy rains in the autumn. Two-thirds of it is thrown under the spread of the trees. Autumn fertilizing improves the autumn flush of growth from which the spring flush and blossom for the main crop will arise. Where fowls are ranged, the aforementioned part of manuring can often be discontinued or drastically reduced after about one year.

Minor element deficiencies, copper, zinc, manganese, and magnesium, are prevalent. They are much more successfully treated when they are incipient than when they have developed to a pronounced stage. Copper deficiency is a basic problem, and, if prevented, zinc and manganese deficiency may not occur. Unless copper deficiency has already developed it will be prevented by the copper applied in the Bordeaux spray programme (see below). Zinc and manganese may be added to the Bordeaux spray, when required, to reduce costs of application.

Magnesium deficiency is also a basic problem in the region. For this deficiency, sufficient magnesium limestone or magnesium carbonate is used to provide magnesium, and yet give a minimum alteration in pH of the soil where root-rot-susceptible stocks are in use.

**Spray Programme for Pest and Disease Control**

Owing to the humid climate, pest and disease control forms a conspicuous part of management. Spraying according to a definite programme is advisable as a general rule.

The fungicidal programme starts in the spring.

1. For scab of lemons. One spray of Bordeaux mixture, 6 : 4 : 80 : ½, at blossoming time between half and full petal-fall, and a second spray in January or February.

2. For melanose and other fungal diseases on Washington Navel and other early ripening varieties. Light and medium infections can be controlled by a single spray of 3 : 3 : 80 : ½ Bordeaux mixture at petal-fall. Heavy infections on weak trees can be controlled by this spray, plus a second spray applied six weeks later. Heavy infections on vigorous trees can be controlled by a single spray of 6 : 4 : 80 : ½ at petal-fall.

3. For the control of black spot on Valencia oranges. This programme also controls melanose, sooty blotch, and other spring diseases on trees.

Three sprays of 2 : 2 : 100 : ½ Bordeaux mixture, which are applied at petal-fall, and six weeks later and twelve weeks later. Alternatively a four-spray programme of 1⅓ : 1⅓ : 100 : ½ Bordeaux mixture is applied at petal-fall, and five, ten, and fifteen weeks later.

The regular insecticidal programme consists of a summer spray with white spraying oil, one gallon in forty gallons of water, applied in mid-December. This spray is often combined with the second Bordeaux mixture of the three just mentioned. A second spray may be necessary in February. These sprays are for the control of red, black, yellow, purple, brown and white wax scales.

* See p. 214 for the composition and the reasons for different strengths.
The following sprays may have to be considered, although probably not every year: lime sulphur, three in forty gallons of water in June to July for the control of white louse; white oil, one in forty, mid-February for the control of citrus-bud mite and citrus-rust mite.

Recent work indicates that four pounds wettable sulphur to 100 gallons of the first Bordeaux spray will largely replace the use of lime sulphur in winter for the control of white louse scale.

In addition, sprays for pests of more sporadic incidence may be necessary from time to time. Endeavour is made to combine these with the programme.
CHAPTER 9
MINERAL NUTRITION AND FERTILIZERS

The functions of the top growth in the nutrition of the tree have been briefly referred to in the last chapter. The present chapter deals with mineral nutrition and fertilizing. A few pages at the start are devoted to a brief explanation of nutrition, before dealing specifically with the effects of the various essential elements on citrus trees. The practical aspects of fertilizing are brought together in a concise section towards the end of the chapter.

MINERAL NUTRITION

Mineral nutrition starts with the soil, which for the present purposes is regarded as being made up of inorganic or mineral particles of different sizes, organic matter, water and air. Sizes of the inorganic particles are usually classified as in Table XV.

TABLE XV
RANGE OF SIZES OF INORGANIC PARTICLES
(25.4 mm. = 1 in.)

<table>
<thead>
<tr>
<th>Class</th>
<th>Diameter (mm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone</td>
<td>above 2.00</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>2.00 to 0.20</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.20 to 0.02</td>
</tr>
<tr>
<td>Silt</td>
<td>0.02 to 0.002</td>
</tr>
<tr>
<td>Clay</td>
<td>below 0.002</td>
</tr>
</tbody>
</table>

Colloids and ions are still smaller particles. The proportion of the particles, especially the clay and colloid content, in a soil determines its texture, that is, whether it is a sandy loam, loam, etc.

In sandy soils the particles are arranged loosely into a "structureless" mass. In soils with more clay than a sand or sandy loam the particles are aggregated into crumbs and arranged in a characteristic structure.
that is very important to the maintenance of fertility. Nearly all soils have a loose arrangement of the particles or aggregated particles—for example, they may readily take a footprint—and the preservation of this characteristic is an important feature of their fertility.

Generally speaking, the particles larger than colloids furnish very little directly towards the nutrition of the plant and provide the “masonry” or mass of the soil, but the rock minerals of which they are composed are undergoing the slow process of weathering and degradation ultimately to the smaller particles—colloids and ions.

**Organic Matter**

Organic matter in the soil consists of the dead remnants of leaves, twigs, and fruits from the tree or from weed or cover crops, together with any animal manures, the remains of dead organisms that have inhabited the soil such as insects, fungi, and bacteria, and the multitudes of living organisms of these and other kinds. The latter use the former as food and bring about their gradual decomposition. In the process the nutrients obtained from the soil that entered into their composition are released to it, and complex organic compounds are broken down ultimately to simple compounds such as carbon dioxide and water.

The first stages of decomposition take place readily under favourable conditions of moisture and aeration in the soil, and when organic matter has lost its distinguishing structure it is said to have reached the stage of humus. Humus is therefore an intermediate product, consisting of a mixture of those compounds resistant to attack, mainly lignins and proteins (for this reason often called lignoproteinate), and having a ratio of carbon to nitrogen varying from 20 : 1 to 10 : 1.

While soil organic matter is not necessary to plant growth, for plants can be grown in water or in sand cultures without organic compounds, it serves valuable functions in the soil. These include:

1. Food for organisms, some of which are indispensible for soil fertility, for example, the nitrogen cycle organisms.
2. Improvement of physical condition of the soil. The hyphal threads of fungi and the gums produced by bacteria form the cementing material for soil crumbs, thus bringing about an improvement in structure, aeration, infiltration, resistance to erosion and a stability against influences that tend to destroy structure.
3. Improvement of base-exchange by the colloidal action of humus.
4. The soil organic matter is the storehouse of soil nitrogen.

Valuable as organic matter is in the soil, however, it cannot be overlooked that the total amount in citrus soils is usually small—one to two per cent in sands, somewhat higher in loams, but seldom exceeding six per cent.

**Colloids and Ions**

The particles as small as colloids are important to nutrition. Their size is microscopic and ranges down to one-twentieth of the maximum for clay (0·0001 millimetres or 100 millimicrons).
Mineral colloids greatly predominate, although organic colloids have the greater activity. They are the seat of unsatisfied electric charges, and therefore attract to their surfaces particles of the opposite charge; they have the power of adsorbing on to their surfaces the smallest particles, the ions. These particles are invisible, less than one millimicron, that is, less than one one-hundredth the size of the smallest colloidal particles, and carry an electric charge.

Colloids that carry a negative charge adsorb on to their surfaces the positive ions. The chief positive ions are hydrogen, calcium, magnesium, potassium, ammonia, and sodium. Colloids with positive charge adsorb negative ions such as nitrate, phosphate, and sulphate.

Negative ions are not as firmly held by colloids as positive ions, and they are more readily leached from the soil. Colloids thus act as an intermediate storehouse of many plant nutrients.

**Soil Solution**

Ions on the colloid dissociate into the soil moisture. Ions in the soil moisture may replace those on the colloid. There is a balance between the number of ions in the soil moisture and those adsorbed on the colloid. Also, the proportion between ions of the different kinds—calcium, magnesium, and others—on the colloid is reflected in their proportions in the soil moisture. Soils rich in colloidal particles and having a high proportion of plant nutrient ions adsorbed on to their surfaces thus provide a rich supply to the soil moisture.

The amount of colloids is low in sand and increases with a greater percentage of clay in the soil. Sandy soils, which naturally are low in colloids, thus tend to be of inherently lower fertility than most heavier soils. Colloids also differ in quality. These points are taken up in greater detail in Chapter 10.

The chemicals required by the tree are readily absorbed as ions from the soil solution, and there is some evidence that roots may directly absorb ions from the colloids. As ions in solution are absorbed by plant roots or leached away by rain or irrigation they are replaced from the colloids, owing to the equilibrium just mentioned that must exist between adsorbed ions and those in solution.

When this supply becomes too low for plant needs, fertilizers must be added to make up the deficiency. The part of the fertilizer useful to the plant is the part that is soluble, that is, the part that breaks down into ions and joins the whole system of colloids and ions.

The kind of ions adsorbed on to the colloid is not only important from the viewpoint of supplying plant nutrients, but also affects the physical properties of the colloid and hence soil structure and fertility. Colloid with a high content of calcium and magnesium has beneficial effects on soil structure, whereas one with a high content of sodium has the reverse. One with a high content of hydrogen will give an acid soil solution; where the hydrogen is largely replaced by calcium and magnesium the solution will be the opposite. Partial replacement gives a soil part-way between very acid and very alkaline.

The soil solution is always in process of change, owing to the gain of ions
from the decay of organic matter, the addition of fertilizer, the weathering of rock fragments, and losses from leaching by rain or irrigation water and absorption by plants. Cover crops interrupt the process of leaching by taking up nutrients that might otherwise be lost. They are returned to the soil on decomposition of the plants.

Soil Air

Soil air is necessary to root growth and the life of the micro-organisms. The composition of soil air differs from the atmosphere chiefly in its higher percentage of carbon dioxide. As this latter comes from the respiration of organisms and plant roots and the decay of organic matter, the percentage varies a good deal, but in a fertile soil may be as high as 10 per cent, compared with 0.03 per cent in the atmosphere.

Too high a concentration of carbon dioxide is toxic to roots and micro-organisms. Citrus requires a well-aerated soil—one in which there is ample oxygen and only moderate amounts of carbon dioxide.

Soil Reaction, Acidity or Alkalinity, or pH

The degree of acidity or alkalinity of a soil is most accurately expressed by measuring the content of hydrogen ions. The hydrogen ions come mostly from carbonic acid, which is formed when carbon dioxide dissolves in water and then dissociates into hydrogen and carbonate ions. When acids dissociate, hydrogen is the positive ion always produced, and therefore affords a measure of the acidity of the soil solution.

The common nutritive ions in a soil may be expressed in some commonly understood expression such as pounds per acre-six inches of soil, or they may be expressed technically as parts per million or milli-equivalents per 100 grammes of soil. Hydrogen ions are not expressed in any other way than technically by a figure in the pH scale. Often pH seems to be a meaningless term in its quantitative aspects, and it may be explained that it is simply a technical method of stating the hydrogen ions in the soil solution, the amounts for the different pH units actually being as in Table XVI.

### TABLE XVI

<table>
<thead>
<tr>
<th>pH</th>
<th>1 gramme* of hydrogen ions in—</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>litres†</td>
</tr>
<tr>
<td>10</td>
<td>10,000,000,000</td>
</tr>
<tr>
<td>9</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>8</td>
<td>100,000</td>
</tr>
<tr>
<td>7</td>
<td>10,000</td>
</tr>
<tr>
<td>6</td>
<td>1,000</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

* 1 gramme = 0.035 pound avoirdupois.
† 1 litre = 1.136 quarts (British).
TABLE XVII
SOIL REACTION AND ASSOCIATED FERTILITY EFFECTS

<table>
<thead>
<tr>
<th></th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
<th>10.0</th>
<th>11.0</th>
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</thead>
<tbody>
<tr>
<td><strong>Very strongly acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Strongly acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Moderately acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slightly acid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slightly alkaline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Neutral</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alkaline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Strongly alkaline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Very strongly alkaline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Phosphates fixed
- Phosphates soluble
- Phosphates fixed
- Free lime in soil
- Lime and potash leach
- Iron, aluminium and manganese are soluble
- Iron, manganese and potash tend to be insoluble
- Magnesium deficient
- Excess boron may occur
- Molybdenum deficient
- Salt
- Black alkali
- Bacteria languish
- Desirable bacterial activity
- Nitrogen fixed freely
- Fungi thrive
- Favourable to Phytophthora
The neutral point is pH 7; the number of hydrogen ions is the same as in pure distilled water. As can be seen in the table, at any pH below pH 7 hydrogen ions are more concentrated in the solution and the soil is acid, but above pH 7 they are more dilute and the soil is alkaline.

The main effect of soil acidity does not appear to be due to the concentration of the hydrogen itself having an effect on citrus roots, but is due rather to the influence of the degree of acidity on the solubility of certain ions of other kinds and on the activity of certain organisms in the soil.

The fertility effects under different conditions of pH are summarized diagrammatically in Table XVII. On the acid side (low pH), iron, aluminium, and manganese become more soluble and may give toxic effects. On the alkaline side (high pH), boron, for example, may become increasingly soluble and may produce toxic effects. In alkaline soils also with high calcium content, iron may go out of solution and give rise to the iron deficiency known as lime-induced chlorosis.

The table shows that from about pH 6 to 8 is a very suitable range for bacterial organisms in the soil, while low pH is favourable to fungal organisms. We have already referred to the fact that below 5.5 is unsuitable for the main parasitic organism of the citrus root Phytophthora citrophthora, and from 5.5 to 7.5 is very favourable to this organism.

Altering the Soil Reaction

Concentration of hydrogen in a soil varies somewhat from place to place and from time to time. As the soil dries out between rains or irrigations the concentration of hydrogen ions increases; conversely rain or irrigation dilutes the concentration somewhat. Reaction of the soil may be altered by many practices; lime and dolomite make the soil less acid because they reduce the hydrogen ions in the soil solution, but lime is seldom used in citrus-growing (see under heading Magnesium later in this chapter). Sulphur, aluminium sulphate, sulphate of ammonia, and large quantities of organic matter producing much carbon dioxide tend to make a soil more acid by increasing the hydrogen ions in solution.

Since it is regular practice to apply large quantities of sulphate of ammonia to trees, the effects might be considered in more detail. The ammonia is converted into nitrates by the nitrifying bacteria and absorbed by the tree. The sulphate reacts with bases on the colloids or free lime, or marl, forming sulphate of calcium, magnesium, and other bases, which are gradually leached out of the soil. The loss of bases results in a more acid soil, the extent to which this takes place depending upon the base content to start with. Acid sandy soils are affected most, neutral soils less, and alkaline soils with free lime least. Sulphate of ammonia brings about a rapid acidification in acid coastal soils, less rapid but pronounced in eastern Murray and Murrumbidgee sandy soils as first pointed out by Parbery,11 and a slow acidification in the lower and South Australian Murray areas as recently published by Harris.5
Absorption of Nutrients

Absorption is carried out in the vicinity of the actively growing point of the root, which is also concerned with the uptake of water. Roots do not absorb nutrients in the proportion as they occur in the soil solution. Parbery found no correlation between the available ions in Gosford soil and the composition of orange leaves. Nutrients are absorbed not by simply passing in with the soil water lost in transpiration, nor by a simple process of diffusion from the soil solution into the root, but by a phenomenon of accumulation, by which the root is able to accumulate ions to a concentration that is higher than the solution in which it is growing. This process requires an expenditure of energy. Dissolved in water the essential elements pass through living tissue and ascend principally in the wood vessels to the rest of the plant in the transpiration stream.

In the process of absorption the total of the positively charged ions—potassium, calcium, and so on—taken in equates the total of the negatively charged ions absorbed, such as nitrates, phosphates, and sulphates.

Certain pairs of elements such as calcium and sodium, or calcium and copper, have opposing effects on, or an antagonism to, the permeability of the root, and one may be responsible for limiting the absorption of the other.

When ions of an essential element are lacking or too low in concentration, the lack of this element becomes a factor limiting growth and causes rather definite symptoms of the deficiency in the growth. Another effect of low concentration of ions of some elements is to cause the excess absorption of others. We will notice this effect later in this chapter, under Magnesium.

Essential Plant Nutrients

Several of the plant nutrients have been mentioned. In all fifteen have been fully established as essential to the growth of plants, including citrus-trees. Of these, ten have been recognized for a long time; these are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, and iron.

The essential nature of the remaining five—copper, manganese, zinc, boron, and molybdenum—has been established more recently. These latter are the trace or minor elements, so called because they are required in much smaller amounts than the first group. The reason advanced for their trace yet essential nature is that they are connected not with the gross structure but with the enzyme systems of the plant.

Other elements of interest to investigators are cobalt, fluorine, and iodine, because they are essential in very minute amounts to animals. If these or other elements are eventually proved to be essential to plants, no doubt they will be required in quantities even smaller than those of the present-known trace elements.

Of the essential elements, carbon, hydrogen, and oxygen are obtained from the atmosphere and soil moisture. The remainder are obtained from the soil solution as ions, either positively charged—called cations—
or negatively charged—called anions. Whilst it is not certain in which form some of the minor elements are absorbed, the two groups may be set down as follows:

**Cations.** Potassium, calcium, magnesium, iron, copper, manganese, zinc, molybdenum.

**Anions.** Nitrate, phosphate, sulphate, borate.

**DETECTION OF DEFICIENCY AND EXCESS**

One of the greatest advances of the past two decades has been the identification of deficiency and excess of nutrients by distinctive growth symptoms. The more common occurrence than formerly of these disorders has been ascribed to the change in manurial practice from the use of animal manures and animal offal manures, such as blood-and-bone, to the “artificial” manures used today.

The following brief descriptions will serve as a first guide to deficiency symptoms.

**Leaf Patterns**

**Magnesium.** Yellow-leaf and defoliation develop as the fruit ripens, especially in seedy varieties.

**Calcium.** Resembles magnesium, but is not a field problem.

**Zinc.** Mottle-leaf appears, tending to little-leaf as the trouble persists, and being worse on the sunny side of the tree.

**Manganese.** Manganese mottle-leaf occurs, being worse on the shady side of the tree; leaf size is normal, but if deficiency intensifies, small curled and beaked leaves appear.

**Iron.** The leaves are pale yellow, with the network of veins clearly picked out in green all over the leaf.

**Boron.** Water-soaked spotting of leaves occurs, accompanied by lumpy fruit.

**Potash.** “Burnt leaf” occurs—a banded pattern, green at the base, then yellow, then brown, and dead at the tip. The old leaves fall readily.

**Leaf Colours**

**Nitrogen.** General pale-green colour and small size in recent leaves; old leaves fall readily.

**Phosphorus.** General bronzing of the foliage; uncommon as a field problem.

**Sulphur.** Somewhat like the effect of phosphorus or nitrogen deficiency; mid-rib yellowing; not a field problem.

**Growth Effects**

**Copper.** Occasional giant-leaf; varied aspects of the exanthemous condition, of which brown gum formation in fruits, leaves, or stems is the most consistent.

Excesses of certain elements also produce distinctive effects which are discussed hereafter.
Vein Chlorosis

One other leaf pattern must be mentioned here although it is not a mineral-deficiency symptom: this is a condition of leaf-yellowing in which the mid-rib and main veins are chlorotic (Fig. 48). This leaf pattern is often produced on trees suffering from Phytophthora, Armillaria, or other conditions affecting the root, or whose translocation system is restricted, for example by the branch girdler or by accidental girdling of stems with wire.

Fig. 48. Vein chlorosis or white veins.

Nitrogen

Nitrogen is taken up in the soil mainly, if not wholly, as nitrates, the reserves of nitrogen in the soil mainly being in the organic matter. It is thought possible that the positive ammonium ion attached to the colloidal system may be absorbed on occasion, but usually this form of nitrogen is nitrified before it is available to citrus-trees. Probably nitrates may be absorbed at any time.

In the plant, nitrogen is used in the production of the many nitrogen-
containing compounds, the chief being the chlorophyll in all green tissue and the proteins of the protoplasm in all living cells. Nitrogen, therefore, becomes concentrated in the leaves, growing shoots and roots, meristematic tissue, and bark, whilst the woody parts with their preponderance of dead cells contain comparatively little nitrogen. Entering into those compounds, the nitrogen in the plant becomes insoluble until it is released during any breakdown of tissue to soluble forms, such as occurs in leaves shortly before leaf-fall. Analyses always reveal a small percentage of nitrogen soluble in the sap, showing that a proportion is in the form of mobile compounds which are the units of which the insoluble forms are constructed.

A deficiency of nitrogen makes itself readily apparent if it is limiting the supply for chlorophyll and protoplasm formation. Leaves become pale-green, small and thin, and shoot growth is weak, being reduced in length, and instead of thickening normally remains unduly angular. Root growth is also restricted, but this, of course, is not an observable symptom in a practical way. Leaf-fall is increased; demands are made on the old leaves by the new growth, migration is speeded up, as a result of which leaf-fall is excessive, and thus the nitrogen-deficient trees are usually thinly foliaged. Nitrogen deficiency also reduces the amount of blossom, reduces setting of fruit very seriously, and may result in small fruit that is pale in the green stage. When trees are starved for nitrogen over a period they naturally become stunted.

When trees are temporarily short of nitrogen in an otherwise reasonable supply the effect is to produce motting of the leaf, which gradually bleaches, dies, and falls off. This effect may occur particularly in the summer and give thinly foliaged trees by the autumn.

These symptoms are sufficiently distinctive and widely known not to be confused with vein chlorosis and other instances of pale-coloured leaves or poor growth, which are due to other causes such as root-rot, waterlogging, and the like.

Citrus-trees are among the heaviest nitrogen feeders of fruit crops. This is shown clearly in the average acreage usage of sulphate of ammonia, and in an estimated optimum requirement prepared by Boyle from a lengthy and Australia-wide experience in the fertilizer industry (Table XVIII).

Excessive amounts of nitrogenous fertilizer promote extra-vigorous growth and coarseness of the fruit. They also tend to promote alternate cropping with small fruit in the “on” year.

Dressings with animal manures (high in nitrogen) were recommended by all the early writers on citrus-growing in this country for their value in promoting deep leaf-colour and good growth. Indeed as early as the period of the Select Committee (see Chapter I) several witnesses urged that the “high ammonia” offal from boiling-down works should be used with more discretion. Organic manures were then the only source of a nitrogenous fertilizer, and such organic manures as that mentioned, dried blood, blood-and-bone, Peruvian guano, and stable, dairy, sheep, and poultry manures have been used in turn, whilst they were plentiful and cheap enough.
With the advent of chemical fertilizers, Berri Experiment Orchard first demonstrated the value of sulphate of ammonia for citrus-trees (Washington Navel orange on Rough lemon stock) which were planted in 1912. Immediate response was obtained, and the value of sulphate of ammonia and other chemical nitrogenous fertilizers was soon demonstrated in other States. Recent results from a trial started at Berri in 1920 are given in Table XIX. Large crop increases result from the application of four to six hundredweight of sulphate of ammonia per acre. There was no advantage between blood-and-bone or sulphate of ammonia as the source of the nitrogen.

### TABLE XIX

YIELDS FROM SULPHATE OF AMMONIA DRESSINGS, BERRI EXPERIMENT ORCHARD, SOUTH AUSTRALIA

<table>
<thead>
<tr>
<th>Sulphate of ammonia applied</th>
<th>Average yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1949-50</td>
</tr>
<tr>
<td>cwt per acre</td>
<td>bush. per acre</td>
</tr>
<tr>
<td>0</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>221</td>
</tr>
<tr>
<td>4</td>
<td>238</td>
</tr>
<tr>
<td>6</td>
<td>308</td>
</tr>
<tr>
<td>9</td>
<td>320</td>
</tr>
<tr>
<td>10</td>
<td>297</td>
</tr>
</tbody>
</table>
Phosphorus

Citrus probably resembles other plants which have been found to take up their phosphate supply at the start of seasonal growth. Phosphate is necessary for certain proteins, and so is distributed in the plant in a somewhat similar manner to nitrogen. It is found concentrated at growing points of shoots and roots, in the meristem tissue and in the flowers and young fruits.

Phosphorus-deficiency symptoms, produced in pot culture by Arnot in Australia, agree with oversea work. "The leaves became a dull, slightly bronzed green, and irregular necrotic areas appeared on the sides or tips of the leaves. There was no chlorosis. Leaves were shed readily, and further crops of leaves were often small, and soon developed deficiency symptoms. Few laterals developed and their growth was poor."

Phosphate deficiency has been found to occur in the field only rarely, probably owing to the fact that horticulturists have followed the lead of large-area farmers who, since the initial experience of Lowrie on wheat in South Australia, have been acutely aware of the value of phosphate manuring for annual crops throughout the southern parts of Australia.

Green-manure crops among fruit-trees are usually sown with one hundredweight to one and a half hundredweight of superphosphate, except in the northern districts where little or no response is obtained. Not only is the growth of the green-manure crop improved, but this method of application effects the distribution of phosphates in the soil. Phosphatic fertilizers are fixed in the soil within the depth of ploughing. By applying phosphates at seeding of the green crop, however, they are taken up by the crop, and being concentrated in the root tips they are released on decomposition of the roots, within the rooting depth of the tree.

Complete citrus fertilizers containing phosphates are commonly used in certain districts because they improve the quality of the fruit. A deterioration in fruit quality taking the form of excess rag and hollow centres suggests that phosphate should be tried.

Potassium

Potassium is available to the soil solution from the colloidal system. In sandy soils where the colloidal content is low, potash is liable also to be low, but in inland soils the supply of potash is generally good. There are several grades of availability of potash in the soil. This element is probably absorbed at any time while growth is being made.

In the plant potash does not enter the structural compounds but remains in solution and is therefore widely distributed throughout the plant in a mobile form. The physiological role of this element is very incompletely understood, and further, it is a "luxury" element, meaning that amounts can be absorbed much beyond what appear to be required for useful effects in the plant.

Forty years ago the Potash Syndicate reported good effects on citrus yields from the addition of potash on the light sandy soils of the Hills District, Sydney.

The decided effect of potash on yield and size of fruit on sandy Gosford
soils has been shown in experiments. Starting with trees nine years of age, four pounds of sulphate of potash per tree improved the yield appreciably each year for five years, for which records were taken out of seven, mainly by the improvement of fruit size. It was concluded that in these soils potash was necessary to maintain good commercial size in oranges. Correlated with the increased size from potash was an increase in coarseness of skin texture. Excessive amounts coarsen the skin.

During the war-time shortage of potash a condition known as "burnt leaf" developed in Gosford citrus-groves. Burnt leaf as a field problem disappeared after the war, at the same time as potash fertilizer became available again, and this affords some confirmatory evidence that the condition was largely due to lack of potassium. In pot culture Arnott produced the following symptoms, which are similar to burnt leaf: during the spring and early summer weak shoots developed, many of which soon died; in some cases a necrotic area developed on one side towards the base of the shoot, and extended round it, leading to the wilting and death of the shoot; mature leaves yellowed, became scorched, then were shed; sometimes they yellowed, then browned off from the tip, but the symptoms often developed more irregularly; puckering of leaves occurred, and a severe gummosis developed in the main stem of several trees.

Trees grew very little in pots where potassium and phosphate were lacking and developed symptoms of phosphate deficiency only. The amount of potassium in the leaves from this treatment was 0·3 to 0·4 per cent, whilst from the other treatments lacking potassium it was about 0·2 per cent (see Table XX).

TABLE XX
POTASSIUM AND PHOSPHATE IN ORANGE LEAVES
(Dry-weight Basis)

<table>
<thead>
<tr>
<th>Pot culture</th>
<th>1$\frac{1}{2}$ years after planting</th>
<th>2$\frac{1}{2}$ years after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Potassium</td>
<td>Phosphate</td>
</tr>
<tr>
<td>Control</td>
<td>2·41</td>
<td>0·29</td>
</tr>
<tr>
<td>Phosphate lacking</td>
<td>3·03</td>
<td>0·12</td>
</tr>
<tr>
<td>Potassium lacking, no sodium</td>
<td>0·19</td>
<td>0·35</td>
</tr>
<tr>
<td>Potassium lacking, sodium</td>
<td>0·22</td>
<td>0·39</td>
</tr>
<tr>
<td>present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium lacking and phosphate</td>
<td>0·33</td>
<td>0·11</td>
</tr>
</tbody>
</table>

These figures suggest that the severe symptoms of potassium deficiency in orange-trees (yellow- and brown-banded leaves, and twig die-back) appear when the amount of potassium in the leaves falls below 0·2 or
0.25 per cent on a dry-weight basis. The high concentration of potassium in trees deprived of phosphate did not cause any potassium toxicity.

Potash is applied mainly in ready-mixed fertilizers. Those containing five per cent potash applied at about twenty pounds per tree per annum give a dose of potash of one pound per tree, which is well below amounts that may lead to skin coarsening. Twice or treble this dose of potash is given in some orchards without affecting skin texture.

**Calcium**

Calcium is a positive ion attached to the soil colloid system, whence the roots obtain it in solution. It is probably capable of absorption at any time the root is active.

In the plant calcium occurs as calcium pectate in the structure of the cell walls, as well as combining with some organic acids. It is therefore distributed throughout the plant in the permanent structure—wood, bark, leaves, and roots—and is not very mobile in the plant.

Deficiency symptoms have been produced in pot culture in overseas work, but have not occurred as a field problem. The leaf pattern produced by calcium deficiency somewhat resembles that produced by magnesium deficiency; in addition a striking symptom is the poverty of new root growth. The symptoms were intensified by high potassium and lessened by high magnesium content of the medium. In Chapter 5 it is pointed out that a lime layer restricts the depth of root penetration. Sweet orange rootstock seems to be much more tolerant of soils high in calcium than Rough lemon.

Soils high in free calcium render iron insoluble, bringing about the condition of lime-induced chlorosis that is due to a deficiency of iron in the plant.

As far as is known there are no soils so low in calcium that the addition of calcium purely as a nutrient for citrus-trees is required. It may indeed be quite injurious to citrus suffering from magnesium deficiency, which is intensified by calcium; in Florida calcium has also intensified zinc deficiency.

An aspect of citrus nutrition is just being opened up, however, in which stress is being laid on the importance of the proportion of bases in the soil for a beneficial effect upon the internal and external quality of the fruit; and calcium, as the main base, may acquire a new importance. However, the balance of calcium with magnesium, which should be of the order of 8 : 1 to 10 : 1 according to Florida work, must be observed in order to have maximum availability of the magnesium.

**Magnesium**

Although similar chemically in many respects to calcium, magnesium provides a striking contrast to it in its effects in citrus nutrition. The best-known functions of magnesium are as a constituent of the chlorophyll molecule and its connection with the development of seeds. It is highly mobile, resembling potassium in this respect. The draining of magnesium from the leaves by developing fruits, especially of seedy varieties, results
in yellow-leaf (Fig. 49). Affected leaves eventually fall and cropping declines sharply. Symptoms usually develop in autumn and early winter as the fruit matures. Yellow patches first appear between the veins near the mid-rib and spread into a diffuse yellowing. The tip of the leaf usually remains green, and a wedge of green may remain at the base.

Fig. 49. Magnesium deficiency.

Magnesium deficiency occurs on acid soils and is therefore widespread in east coastal districts; it occurs more sporadically in inland soils, where it may be brought about by the acidifying action of sulphate of ammonia. Parbery first showed the magnesium-deficient nature of yellow-leaf (Table XXI).

The magnesium content of the green leaves is low, but in the yellow leaves is considerably less and the potassium content is abnormally high. There are no significant differences in the ash, iron, sulphate, or phosphate contents of the normal and yellow leaves.

There are many aspects to the correction of yellow-leaf. Magnesium sprays have been ineffective owing to the difficulty of keeping the precipitated magnesium on the leaves, and owing to the poor migration into the leaves and the large amount required by them.

Dolomite is used extensively to correct magnesium deficiency. When yellow-leaf has become well established the dressing of dolomite approximates to 40 hundredweight per acre. Recovery may take two to three years, and should be followed by an annual or biennial dressing of 5 or 10 hundredweight respectively, while there is any danger of yellow-leaf occurring.
Dolomite should be applied three or four weeks before or after sulphate of ammonia dressing, and worked into the soil. Early summer, before a cultivation to destroy weeds, is often a convenient time.

Dolomite is ground dolomite limestone, containing both magnesium and calcium carbonates. A high-grade dolomite should be secured—one high in magnesium carbonate (approximately 30 per cent or higher). The high-grade product is grey in colour, whilst the lower grades with poorer content of magnesium carbonate are lighter in colour.

Low-grade dolomite or lime may aggravate the yellow-leaf condition, probably by widening the ratio of calcium to magnesium beyond the 8 or 10 to one in which magnesium is most available to the tree.

Magnesite, which exceeds 90 per cent magnesium carbonate, has been used when available instead of dolomite. One-third or less magnesite can be used for the same magnesium content as dolomite.

Both dolomite and magnesite have an alkaliizing effect on the soil, and root-rot has to be considered when susceptible stocks are in use. As pH 5.5 to 7.5 is the range favourable to Phytophthora, careful growers in coastal districts with acid soils use the treatments so as not to raise the pH into the favourable range. This is an additional reason for using high-grade dolomite or magnesite—with a high content of magnesium and a minimum alkaliizing effect.

Since fertilizing with sulphate of ammonia has an acidifying effect (see p. 143) and depletes soil magnesium, this acidifying effect should be counterbalanced by the use of dolomite if the soil is becoming undesirably acid and yellow-leaf is appearing. Amounts of dolomite equal to the sulphate of ammonia are required, but applied separately as just explained.
When the acidification occurs in a zone in which all the sulphate of ammonia is applied, as in furrow irrigation, the dolomite application should be restricted to that zone.

Developing seeds deplete the magnesium content of the leaves, and the fruit of seedy varieties should not be allowed to hang late without keeping in mind that the magnesium lost may have to be replaced sooner or later by magnesium fertilizing.

**Sulphur**

This element is absorbed as sulphate, a negative ion, from the soil, and whilst it is usually present in ample quantities it is also being added to continually by use of the sulphates of ammonia, potash, copper (bluestone), and calcium (in superphosphate) and other compounds. No field symptoms corresponding with the sulphur deficiency symptoms produced overseas have been observed, and deficiency of this element is therefore rather of academic interest in citrus.

In the plant sulphur seems to be of about equal importance with phosphorus. It is a constituent of several plant proteins and performs other functions that are not very well understood. The early symptoms of sulphur deficiency somewhat resemble those of nitrogen deficiency, and the growth and leaf size are much affected. Fruits fail to develop full colour, are small with thick rind, and the flesh is somewhat shrivelled and juiceless.

**Iron**

Iron deficiency is usually referred to as lime-induced chlorosis owing to the fact that highly calcareous soils render the iron unavailable. In the plant, iron is necessary for the formation of chlorophyll, although not entering into the composition of this substance. Deficiency of iron therefore manifests itself as a chlorosis of the leaves, leaving the complete network of veins sharply traced in green. In acid soils not producing lime-induced chlorosis it is not uncommon for the autumn-grown leaves to show during winter symptoms of iron deficiency, which disappear in spring without treatment.

Iron deficiency is of limited occurrence, fortunately, for the treatment of it is difficult. Application of iron salts to the soil results in their fixation, whilst sprays are slow-acting. Soil applications of iron sulphate in spring of up to four pounds per tree over a period of years have corrected bad lime-induced chlorosis. Experiments are in progress with other methods of control such as chelated iron formulations, which have been successful in acid soils overseas.

**Copper**

Copper is an example of a trace element that is of great practical importance because of the widespread liability to deficiency in the large Gosford-Sydney region.6

Copper is absorbed as the positive ion. It is not known if it is absorbed more freely from the soil at any particular season of the year, but efficiency
of spraying treatments indicates that it is capable of absorption by the leaves through the year except for the dormant period. In the plant, copper is an essential constituent of certain enzymes that are connected with the function of respiration.

Copper deficiency symptoms are known as exanthema; the symptoms are numerous, do not necessarily occur together, and depend for their expression on the acuteness of the deficiency.

Exanthema was first recognized in Australia from similarity to the condition as it occurred in Florida, under the name of frenching, and its response to copper treatment.

Exanthema is difficult to identify convincingly at the outset. An early sign of exanthema usually missed by the inexperienced is the occurrence of giant leaves here and there among leaves that are somewhat smaller than normal. Giant leaves are evidence that they have aggregated to themselves a supply of copper, depriving the remainder, which are consequentlly somewhat reduced in size. From this stage onwards gum-pockets and multiple buds may appear.

In the orange the production of dark-brown gum-pockets is a reliable symptom, the areas occurring on the leaves, the bark of the shoots, the skin of the fruit, and near the seeds in the carpels. In lemons the gumming symptom is not common, and in mandarins is largely restricted to the fruits.

Once multiple buds appear, subsequent growth is reduced and the tree takes on a bunchy appearance. Instead of a shoot continuing as a single extension, it may show (a) several growths from the terminal and near terminal of the growth flush, giving a "staghorn" effect; these growths will be much reduced in length, angular and showing smallness of leaf; gum spotting will almost certainly be apparent on the leaves at this stage; (b) if pronounced multiple budding has developed, in all probability many short shoots will have been produced therefrom, only one to two inches long, and will have died, giving the so-called "dead match" effect.

Subsequent flushes of growth will show accentuated smallness and paleness of the leaves and possibly evidence of other mineral deficiencies, increased leaf-fall and die-back of shoots. Limbs of the tree may be badly affected, whilst others are making reasonably good growth.

On the clustered shoots the leaves often show chlorotic patterns of magnesium, manganese, zinc, and potash deficiency. These multiple deficiencies are ascribable to the fact that root growth has been restricted. Root examination will show that instead of normal root fibre there is a general poverty of fibre, and the fibre is encased in a sandy sheath, owing to sand-grains clinging to the excessive amount of cork produced in copper-deficient root fibre.

Coincident with the development of the symptoms on growth are effects on cropping and quality of fruit. Fruit setting falls off very markedly. The fruit is small, pale-coloured, more or less blotched by the brown gum production. The skin is hard and very subject to splitting.

The recommended treatment is foliage sprays of Bordeaux mixture, with or without soil applications of bluestone. In the case of the deficiency
being well advanced, persistent treatment will be required to effect a cure. In such cases also, zinc and magnesium deficiencies may be appearing, and will require treatment by the incorporation of zinc in the Bordeaux mixture and soil dressings of dolomite respectively.

Fungicidal Bordeaux spray programmes (outlined at the end of Chapter 7) will check copper deficiency. When the condition is advanced to the stage that it depresses cropping (hence spray deposit on the fruit does not enter into consideration), the programme may consist of four sprays of Bordeaux mixture given in August or September, November, February, and April. Sprays applied just before new growth is made will benefit it through the copper that is absorbed by the old leaves.

Soil treatment alone is not recommended, for the copper uptake in seriously deficient plants is restricted, owing to the limited root growth. Coupled with the spray treatment, soil applications of bluestone are recommended in severe cases, the recommendation being up to two pounds per year per tree applied in eight-ounce dressings at the four times listed for sprays.

Copper deficiency is often accentuated in the sandier soils or when hard-pan or any other physical feature of the soil limits root exploration, and when weed is allowed to be strongly competitive with the trees, limiting root growth and intensifying drought conditions. Improvement of the general cultural conditions is therefore useful in treating copper deficiency.

Zinc

Zinc, another trace element, is of economic importance to citrus culture throughout the interior districts as a simple deficiency. Its occurrence in association with copper deficiency in the Gosford-Sydney region has just been referred to. Its function in the plant is known to be connected with certain enzymes. The fact that zinc deficiency brings about a definite chlorosis of the leaves, which is more apparent on the sunny side of the tree, suggests a connection with the formation and function of the chlorophyll. Strickland and Benton first demonstrated control of zinc deficiency of citrus in Australia.

In the early stages of deficiency the leaves of the latest flush of growth may show an interveinal mottling. This is the stage of mottle-leaf. If not treated, subsequent flushes of growth show more and more mottling until the interveinal areas are chlorotic, the mid-rib and main veins being edged with green. The younger leaves are definitely narrow and pointed. At a later stage of development the new leaves produced will be quite small, narrow, and pointed, and entirely chlorotic. This is the stage of little-leaf (Fig. 50). Die-back of shoots becomes quite apparent as the zinc-deficient leaves fall and shoots die.

Mottle-leaf and little-leaf are usually more pronounced on the tops and the north and north-west side of trees. It will be noted that as the deficiency develops the symptoms become worse on the more recent growth. Zinc is comparatively immobile in the plant, not moving out from the old leaves to the new growth. Zinc thus resembles copper, which also shows increasing deficiency with successive growth, and contrasts
with magnesium, potash, and nitrogen, which migrate from the old to the new leaves.

Zinc deficiency is controlled solely by foliage sprays, which should be applied prior to new growth, preferably at the spring flush, in order that the zinc will be absorbed by the leaves and benefit the new growth.

The spray for citrus consists of zinc sulphate 10 pounds, lime 5 pounds, water 100 gallons, as a first treatment, which may be reduced to 5 pounds, 2½ pounds, 100 gallons, respectively, in maintenance sprays.

Zinc has also been applied, particularly in South Australian Murray districts, in the form of zinc oxide. The practice has now been abandoned as zinc oxide, particularly that manufactured by the French process, is injurious to the tree, causing leaf-fall.

Fig. 50. Zinc deficiency: mottle-leaf on left, little-leaf on right.

Manganese

Manganese is rendered unavailable in alkaline soil conditions, and rendered available in excessive amounts in very acid soil conditions. In the plant the role of manganese is little known; a trace element like zinc and copper, it is required in very minute amounts.

Deficiency

In 1941 it was found that a mild type of leaf-mottling that had been observed for many years on citrus-trees in the coastal districts of New South Wales and in South Australia, was due to manganese deficiency (Fig. 51). The leaf pattern is not as obvious as zinc-mottle, nor is there usually any appreciable reduction in leaf size. The main veins of the leaf
and the tissue adjoining the veins retain their deep-green colouring, but areas of a lighter green colour occur between the veins. Manganese-mottle appears in oranges, grapefruit, and lemons in the coastal districts of New South Wales.

![Image of leaves showing manganese deficiency symptoms]

**Fig. 31.** Manganese deficiency: mottled symptoms on left, beaked leaves symptomatic of severe deficiency on right. *(Agricultural Gazette of N.S.W.)*

Conclusions from an investigation of the condition by Levitt and Nicholson\(^7\) were that:

Foliage showing this type of motiling from Valencia orange and Marsh grapefruit has a manganese content ranging from 4.4 to 11.1 parts per million (dry weight).

Normal foliage has a manganese content of 24.3 to 29.4 parts per million (dry weight).

Following spraying (with manganese sulphate 5 pounds, hydrated lime 2½ pounds, water 100 gallons) leaf colour improved, and subsequent growth lacked the motile symptom. Manganese content of such foliage was 20.8 parts per million in the case of Valencia orange and 34.7 parts per million in the case of grapefruit.

Manganese deficiency unless acute does not reduce leaf size or tree vigour.

Lime and/or dolomite dressings appear to increase the leaf symptoms,
The differences in the type of mottle coupled with the fact that manganese deficiency occurs more on the shady side of the tree, whereas zinc occurs more on the sunny side of the tree, distinguish the two.

The authors later described a more extreme condition. The symptoms in this case included a waved and rolled margin to the leaves, "beaked" tip of the leaf (Fig. 51), and a reduction of vigour and cropping. Spraying half the tree with the aforementioned spray, which corrected the trouble, resulted in the following comparison of the manganese content of the leaves: unsprayed half of the tree, 3 to 2 parts per million; sprayed half of the tree, 81 to 9 parts per million.

Toxicity

Manganese toxicity has occurred in very acid soils towards the northern end of the Gosford region. Navel and Valencia oranges on Rough lemon and trifoliata stocks were equally affected. The condition, known as yellow-top, consists of a yellowing of the immature leaves, which, as they mature, do not assume the normal green colour but become increasingly yellow from the tip. Scorch and browning of the leaf-tip may follow. Leaves fall, leaving the petiole on the stem for a time, but these fall, leaving the twigs bare. Although the twigs do not die the tree makes little or no new growth. A further symptom is a scattered "tar spot" marking on the leaves, the spots being black, more or less rounded in shape, and up to approximately three-sixteenths of an inch in diameter.

Whereas the normal content of manganese is 20 to 40 parts per million in dry leaves, and mature leaves of normal appearance were found to contain as high as 60 to 70 parts per million, yellow-top leaves showed between 60 and 400 and as much as 800 parts per million of manganese.

The condition was controlled by one application of lime at three tons per acre and more slowly by dolomite at the same rate. The dressing raised the pH from between 4 and 5, when the disease was present, to the vicinity of 6·0 or slightly more, when it entirely disappeared.

Boron

In the plant, boron is connected with the proper functioning of meristematic and conductive tissue.

Deficiency

Grapefruit-trees with suspected boron deficiency have occurred in the central west of New South Wales, in areas where boron deficiency of other fruit-trees occurs sporadically.

Symptoms include a translucent flecking of the leaves with or without splitting and cork formation along the veins of the leaves. The fruits develop gum-spots in both the albedo of the rind and in the flesh; these spots give rise to lumps under the skin; the lumpy nature of the skin can usually be felt in the hand. Lumpiness of the fruit is regarded as a primary symptom in Rhodesia and Florida. The fruit may also be hard, misshapen, and small. The leaves are shed prematurely, and badly affected trees show die-back.
Many citrus soils, including most alkaline citrus soils, have been derived from sediments laid down under the sea, which is rich in boron; thus boron deficiency of citrus is of rare occurrence in this country. Boron is rendered less available in alkaline soils; dressings of dolomite or lime have the effect of making it less available. Drought conditions conduce to the development of boron deficiency symptoms.

Toxicity

Boron toxicity is a much more important problem. Penman and McAlpin\textsuperscript{12} found in 1947 that boron toxicity was the cause of a type of defoliation of citrus-trees that had occurred in Murray River districts for many years. Characteristically the leaf-blades fall, leaving the petioles on the trees, and there may be some twig die-back, cropping falls off, and some trees may die. In affected groves a limited number of trees is usually affected, namely, those on the heavier soils.

Leaf symptoms vary from tip-burn and slight tip chlorosis, through mild chlorotic spotting, to extreme chlorosis with tip-burn leaving a wedge of green tissue at the base of the leaf (Fig. 52). Pustule-like elevations occur on the back of the leaves, except in the lemon. As the result of analyses these workers considered “that boron contents up to about 100 parts per million may be taken as normal. Between 100 parts per million and 300 parts per million citrus is usually able to tolerate the boron without showing toxicity symptoms. The range from 300 parts per million to 500 parts per million is one in which signs of injury may or

\textit{Fig. 52. Symptoms of boron poisoning. Left to right: Tip burn and slight tip chlorosis; mild chlorotic spotting; severe marginal and tip chlorosis with slight tip burn; typical pustule-like elevations on the back of leaves.}

(Journal of Agriculture, Vic.)
may not be detectable, but above 500 parts per million poisoning symptoms are prevalent to varying degree."

Penman and McAlpin list citrus varieties in the following decreasing order of susceptibility: lemon, sour orange, mandarin, cumquat, grapefruit, and sweet orange. They reported that Washington Navel and Valencia oranges were more susceptible on Rough lemon rootstock than on sour orange, which was more susceptible than those on sweet orange. Trifoliata was about as tolerant as sweet orange rootstock. Examination of the sources of boron showed that irrigation water and fertilizers apply negligible amounts, and the cause of injury is the native content of the soil.

In virgin Mallee soils it has been found that water-soluble boron content can rise quite sharply from moderate figures, less than 1 part per million in the surface soils to more than 10 parts per million in the subsoils at about two feet deep, coincident with the advent of heavier horizons and lime. This gives a new emphasis to the existing preference for deep sandy soils, with a minimum of lime, for citrus under irrigation.... The fact that boron may increase with depth in our soils also underlines the necessity for full precautions against the building up of the water-table under irrigation and for close attention to drainage and the maintenance of rapid water percolation in citrus soils.

Molybdenum

Molybdenum deficiency has only recently, in Florida, been recorded in citrus—first of any fruit-tree. The symptoms, called yellow spot, first appear as water-soaked areas in the leaves in early spring. In the summer these areas develop into large interveinal yellow spots with gum on the lower surface. Badly affected leaves eventually drop, and in extreme deficiency the trees become almost completely defoliated during the winter. The amount of molybdenum required by trees is extremely small—only about 0·1 part per million in the dried leaves. Deficient leaves show 0·03 to 0·08 part per million. Deficiency has not been recorded in Australia so far.

Increasing the soil pH increases the amount taken up by the tree. At pH 4·2, where yellow spot was very severe, molybdenum content was 0·03 part per million of dry leaf. Raising the pH to 5·6 by liming resulted in normal green leaves, the molybdenum content of which was 0·06 part per million.

FERTILIZERS

The manuring of young trees up to four years of age was discussed on p. 118. After trees enter the bearing period it becomes more difficult to specify manuring requirements, and a considerable amount of reliance must be placed on the appearance and vigour of the trees as a guide to their fertilizer requirements. The first symptoms of deficiencies should be watched for and given the appropriate treatment.

Fertilizers are not a substitute for, but are a supplement to, good soil management methods.
In natural rainfall districts fertilizers should be spread over the rooting area. This will extend to the whole of the area in the case of large healthy trees, or be confined to the vicinity of the tree in the case of small or unthrifty trees. In either case the area under the tree in which root fibre closely approaches the surface should not be neglected, and it is not uncommon for two-thirds of the fertilizer to be applied there. The fertilizer should be spread evenly over the area selected, avoiding any concentrations that may cause root injury. A similar placement of fertilizers may also be adopted under sprinkler systems of irrigation.

In furrow irrigation fertilizer is usually placed in the furrows beside the drip-ring of the tree in order that it will be dissolved and carried into the soil by the next irrigation.

The composition of the usual types of nitrogenous, phosphatic and potassic manures is given in Table XXII.

TABLE XXII

COMPOSITION OF NITROGENOUS, PHOSPHATIC, AND POTASSIC FERTILIZERS

<table>
<thead>
<tr>
<th>Type</th>
<th>Nitrogen</th>
<th>Amount of fertilizer to supply 100 pounds nitrogen</th>
<th>Phosphate</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>lb.</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Nitrogenous—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate of soda</td>
<td>16</td>
<td>625</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphate of ammonia</td>
<td>20</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dried blood</td>
<td>12</td>
<td>833</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood-and-bone</td>
<td>5</td>
<td>2000</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>46</td>
<td>217</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphatic—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superphosphate</td>
<td>4</td>
<td>2500</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Bone dust</td>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Potassic—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphate of potash</td>
<td></td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Potash salts</td>
<td></td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>Muriate of potash</td>
<td></td>
<td></td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>Mixed composition—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castor meal</td>
<td>4·5</td>
<td>2222</td>
<td>2·3</td>
<td>0·7</td>
</tr>
<tr>
<td>A citrus mixture</td>
<td>10·0</td>
<td>1000</td>
<td>10·0</td>
<td>5·0</td>
</tr>
</tbody>
</table>

Rate and Time of Application

Nitrogenous fertilizers. These fertilizers are applied at the rate of 1 to 1·5 pounds of nitrogen per tree per annum in the case of oranges and grapefruit, according to the size of the tree and the planting distance. One pound for medium-sized trees, planted at distances of 20 feet by
20 feet, is equivalent to 109 pounds of nitrogen per acre. One and a half pounds for large trees, planted at distances of 24 feet by 24 feet, is equivalent to 113 pounds of nitrogen per acre. Very large and productive trees may be given 2 pounds of nitrogen per tree. If planted at distances of 24 feet by 24 feet this is the equivalent of 150 pounds of nitrogen per acre.

The amounts of the different nitrogenous fertilizers to give these quantities of nitrogen can be readily calculated from the column in Table XXII which shows amounts to supply 100 pounds of nitrogen.

Time of application may vary with climatic conditions. In inland areas there is a tendency to apply all the nitrogenous fertilizer in winter (July), unless a cover crop is to be turned in, when a light application may be spread over it before ploughing in spring. Autumn applications tend to prevent the autumn growth from hardening properly and make it somewhat more frost-susceptible.

In milder districts, where the latter does not apply, dressings should be applied before each growth flush, to gain the full effect on new growth, with an extra allowance for the spring flush, which carries the main-crop blossom. If this latter sets well there is less likelihood of the undesirable second-crop blossom that occurs on the coast. The amount is therefore split as follows: three-fifths of the total amount in July or early August and two-fifths of the total in January to February. Of the latter quantity, a small amount may be given as a November dressing to assist the light summer flush of growth, and the rest in January to February for the autumn flush.

The July to early August application is distributed over the green crop or cover before turning in, when it safeguards against a nitrogen deficiency during decomposition.

Sulphate of ammonia is the principal nitrogenous fertilizer, and must be nitrified before the nitrogen is available to the tree. This process is reckoned to take three weeks after the fertilizer has been dissolved in soil moisture. The acidifying effect of this fertilizer is discussed under Soil Reaction and Magnesium in this chapter.

Nitrate of soda does not require nitrifying and is available to the tree immediately it is dissolved in the soil moisture. It has been used to some extent in humid districts. In irrigation districts it has been observed to have a deleterious effect on soil structure, owing to the sodium remaining after the nitrate is absorbed.

Urea has been used as a soil dressing, although per unit of nitrogen it is rather costly. Recently it has been used as a spray at five to ten pounds per hundred gallons of water, supplementing soil dressings, for many sprays would be required to satisfy completely the nitrogen requirements of full-grown citrus-trees.

Offal (blood) and castor meal are other common sources of nitrogen that require nitrifying. Part of the nitrogen may be applied in these and other materials of mixed composition, the balance as the purely nitrogenous manures.

As nitrogen is the nutrient required in largest quantities, the amount of a mixed fertilizer to apply is governed by how much of the nitrogen
is to be applied in it and how much supplemented by the addition of a purely nitrogenous fertilizer.

For *lemons*, the same amount of nitrogen for the size of the tree, or slightly less, is used, but it should be distributed differently, so as to promote ever-bearing, that is, before the flushes that give the intermediate-crop blossom. The spring dressings should not be excessive, otherwise main-crop setting will dominate the later flushes and settings.

For *mandarins*, since excessive vigour is undesirable the amount of nitrogen can usually be cut to about half that used on oranges, the quantity being adjusted to promote sufficient but not excessive vigour. Autumn applications are best avoided because they reduce fruit quality and favour the development of mandarin scald.

**Phosphatic fertilizers.** Phosphates should be applied to stimulate green-manure or cover crops by application at seeding and before germination respectively. Superphosphate is the principal material and is used at the rate of one to one and a half hundredweight per acre, the usual time being January to February for winter green cover, or July for spring cover crops in northern districts. The former may be combined with the nitrogenous application.

**Potassic fertilizers.** Muriate or chloride of potash is the form usually available. This fertilizer is generally applied in mixtures containing three to five per cent potash, and since the rate of application is governed by the nitrogen content the amount of potash applied is usually small, about one pound per tree.

If it were applied singly, probably larger amounts would be used on bearing trees in coastal districts, although the amount must stop short of coarsening the skin of the fruit. When potash has been shown to be required, four and five pounds of sulphate of potash per annum have been used on young trees. There is little evidence that potassic fertilizers are beneficial in inland districts. As potassic fertilizers are readily soluble, they should be applied in split dressings, with the spring and autumn nitrogen applications.

Potash seems to be of special benefit with mandarins, and should be included with nitrogenous applications to counteract scald.

**Magnesium fertilizers.** The rate and time of application of dolomite, or magnesite, together with other aspects of magnesium fertilizing, have already been dealt with (p. 151).

**Copper, zinc, and manganese fertilizers.** See pp. 154-9 for the discussion of these nutrients. For convenience the composition of sprays for these deficiencies is given herewith.

**Bordeaux mixture:**

<table>
<thead>
<tr>
<th>Copper sulphate</th>
<th></th>
<th></th>
<th></th>
<th>1½ to 3 lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrated lime</td>
<td></td>
<td></td>
<td></td>
<td>1½ to 3 lb.</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td>100 gals</td>
</tr>
</tbody>
</table>

**Zinc spray:**

<table>
<thead>
<tr>
<th>Corrective spray—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulphate</td>
</tr>
<tr>
<td>Hydrated lime</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

* The tolerance for copper sulphate of citrus-trees is not great, approximating to four sprays using 1½ lb., three using 2 lb. per annum.
Maintenance spray—

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc sulphate</td>
<td>5 lb.</td>
</tr>
<tr>
<td>Hydrated lime</td>
<td>2½ lb.</td>
</tr>
<tr>
<td>Water</td>
<td>100 gals</td>
</tr>
</tbody>
</table>

Manganese spray:

Corrective spray—

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manganese sulphate</td>
<td>5 lb.</td>
</tr>
<tr>
<td>Hydrated lime</td>
<td>2½ lb.</td>
</tr>
<tr>
<td>Water</td>
<td>100 gals</td>
</tr>
</tbody>
</table>

These sprays leave a mineral residue on the leaves. When a deficiency spray for zinc or manganese is to be combined with a fungicidal Bordeaux spray, an effort is made to reduce the total of the solid ingredients. Formulae are variable for these combinations, but there must be sufficient lime to preserve an alkaline reaction in the spray. (See zinc-Bordeaux mixture, under Septoria spot, in Table XXVIII.)

Excessive residues are objectionable for reasons connected with the effective control of scale insects and the health of the tree.

**Mixed fertilizer.** In inland districts nitrogenous fertilizers are commonly used alone for the tree, superphosphate for the cover crop, and a zinc maintenance spray is given to the tree in alternate years.

On the other hand, mixed fertilizers are commonly used in east coast districts. Nitrogen is required, phosphate is less available in the acid soil, and potash content in sandy soils is low. Leaf size and colour, productivity and fruit quality are superior where a mixed fertilizer is used than when nitrogen is used alone.

Various mixtures are available. Common mixtures of nitrogen, phosphorus, and potash approximate to the ratio of 5 : 10 : 5. The dressing is based on supplying nitrogen to give one pound of nitrogen per tree, and in this case is 20 pounds per tree: this mixture also gives 2 pounds of phosphate and one pound of potash. The dressing is split, three-fifths being applied in July to August and two-fifths in January to February. The late-summer dressings can be applied so as to benefit cover-crop germination.

A common rule for applying mixed fertilizers is one pound per year of the tree's age up to ten years, then an extra pound per year of its age from eleven to fifteen years, so that at fifteen years and onwards the tree is receiving 20 pounds.

**Animal manures.** Trees almost invariably respond well to dressings of animal manures, and the root fibre will be found to proliferate remarkably in a very short time after the dressings are given. They are applied over the land after tillage in the spring or autumn, forming a mulch, and are only turned in when weeds become troublesome. As it is usually impossible to obtain enough animal manure to satisfy nutritional requirements of a large area of trees, it is preferable to apply a liberal dressing to small areas, and cover eventually the entire area on a roster.

Composition is variable, depending on moisture content and the bedding material and treatment, and ranges from ½ to 1½ per cent nitrogen,
about $\frac{1}{2}$ to 1 per cent phosphate, and $\frac{1}{2}$ to $\frac{3}{4}$ per cent potash. To supply 100 pounds of nitrogen per acre the dressings required are:

- If 1 per cent nitrogen, .. 20,000 pounds, or about 9 tons per acre.
- If 1 per cent nitrogen, .. 10,000 pounds, or about 4$\frac{1}{2}$ tons per acre.
- If 1$\frac{1}{2}$ per cent nitrogen, .. 7,500 pounds, or about 3$\frac{1}{2}$ tons per acre.

Stable manure is commonly in the first category, sheep manure in the second, and fowl manure in the second or third category (Table XXIII).
CHAPTER 10

SOIL MANAGEMENT

Objectives of soil management include the conservation of the soil, the control of weeds, the addition of organic matter, and the maintenance or improvement of soil fertility under the special conditions of a citrus planting. Fertilizing is essentially a part of soil management, but as a matter of convenience has been discussed in the final section of Chapter 9. Irrigation, which is a major aspect of soil management in some districts, forms the subject of a subsequent chapter.

Special Conditions in a Citrus Grove

Owing to the permanence of the planting, only the land between the trees can be worked. While trees are young a large part of the land remains available for soil management practices, but as the trees enlarge the area steadily declines. The increase in breadth as well as in height brings about greater shading of the area, which militates against green-crop growth. The increasing shade makes conditions increasingly favourable to methods of non-tillage that leave the soil undisturbed.

The leafy canopy of the tree shades out weed growth, provides the beneficial effect of soil “cover”, and gives an increasing area of ground beneath that is spared from certain detrimental effects of tillage. The widening trees cause a real problem in furrow irrigation, because of the larger and larger area of land beneath that cannot be irrigated without special attention to its increased permeability.

Certain peculiarities of citrus-trees must be borne in mind continually in soil management. One important aspect is the shallow nature of the fibrous or feeding roots. When these are cut by tillage implements the tree sustains a loss of its moisture- and nutriment-gathering system, and it may show adverse effects that persist until the fibre is re-established. Observations of these effects as much as anything have turned growers’ thoughts to non-tillage methods of soil management. Since citrus fibre will develop right to the surface in suitable conditions, it is advisable in management methods to consider how these few inches of topsoil may be utilized by the fibre.

Another aspect of the root-soil system, which has been of high importance for ninety years, is consideration of the effect of any given practice on the root-rot situation, either immediately or ultimately. The need to keep the union well above ground-level, not allowing it to become covered as the result of cultural methods, is one of these considerations that must always be borne in mind, to reduce the possibility of collar-rot.
Soil management methods also have to be adapted at times to the degree of susceptibility of the trees to frost injury. In the case of light frosts, damage to the tree can be avoided by soil management methods, which will be described in Chapter 12 under Heat Conservation. Other aspects of the tree's requirements that dominate soil management practice, namely, its high requirements of nitrogen and water, are associated with its evergreen nature.

Tillage that forms mounds round the trees is very undesirable, because the mounds reduce moisture penetration, shedding moisture towards the land centres and possibly increasing erosion. Neither should tillage form basins or low spots round the trees, because the ponding of water in them conduces to root-rot.

**Soil Conservation**

The foundation of erosion control on hillsides consists of contour-planting, diversion banks, and grassed waterways, as referred to in Chapters 6 and 7. Since the late 1930s, when the first contour blocks of citrus-trees were planted, the use of this method of planting has steadily increased. Diversion banks are increasing in favour.

As well as preventing erosion, contour planting conserves moisture in dry years by increasing infiltration. Figure 35 shows the effect in dry years, and it can be seen that each furrow slice has formed a small rill for carrying water across the land on the gentle fall of the contour. Light showers of rain have every opportunity to soak in, and the loss from run-off is very low. In wet periods a surface drain in the centre of each land may be employed to carry off excess water without erosion.

Cultivation and traffic in the orchard should be directed along the contour rows. The wheel-tracks left by any vehicle or tillage implement on steep grades are a fruitful source for starting erosion, hence crossing the contours defeats the object of the planting. If for any reason it is desired to plough or cultivate across the contours then this operation should be immediately followed by working along the contour rows.

Weeds may become something of a problem in the tree lines. They are of some benefit in holding up the imperceptible wash across the lands, and the tree lines tend to become built up by the deposition of silt. In time, therefore, on steep slopes the land tends to become somewhat terraced. This, however, is far preferable to the loss of soil by erosion. The chief drawbacks to such terracing are that the union may tend to become covered with silt on the upper side of the slope, and that soil is lost on the lower side. Terracing may be minimized but not prevented entirely by the use of the hillside plough, always throwing the furrow uphill. Soil movement downhill is best corrected by the use of the grader blade or similar implement.

When the foundation of sound soil conservation has not been provided for in the lay-out, some other practical methods of arresting or minimizing erosion, such as the leaving of strips of weed or cover crop across slopes, may be of assistance in some instances, although it must be remembered that the weeds compete with the trees and they may become firmly established and form a fire hazard. The building of contour banks through
an orchard already planted in a straight-row lay-out—by depositing loads of soil on the correct contour grade—can be carried out if those odd trees are removed that will be so close to the bank that they will have their union covered with soil.

**Moisture and Weed Control**

Soil-moisture control is a most important aspect of culture; the evergreen trees make considerable demands for soil moisture, yet the root will not stand excess water. It has been pointed out that notice should be taken of these requirements of citrus-trees from the outset, in the design and development of a site and in the planting system adopted (Chapters 6 and 7). Proper attention to drainage takes care of one of the main difficulties about soil moisture. If drainage is good then the main concern is to provide against dry periods.

The maintenance of sufficient soil moisture requires close attention, especially in the lighter soils. There are several methods available:

1. The control of weeds, especially in anticipation of seasonal dry spells. Weed control relative to seasonal rainfall for one district has been described on p. 135.

2. The improvement of rooting depth by drainage, lowering of water table, and improvement of structure in heavier soils.

3. The improvement of infiltration. Production of a trashy surface is the main method of quickly increasing infiltration in existing groves. Cover crops produce beneficial effects, but over a longer period. Advocacy of adding organic matter to improve the water-holding capacity of a soil has been called into question of late. The longest experiment—at Rothamsted Experiment Station—has shown that the addition of fourteen tons of farmyard manure annually for a century has only increased the moisture-holding capacity of the soil by three-quarters of an inch, and that only in the ploughed layer.

4. The provision of supplementary irrigation (see Chapter 6).

5. The provision of irrigation, not neglecting the winter, when dry soil conditions make the trees more susceptible to frost (see Chapter 11).

**Addition of Organic Matter**

Organic matter requires renewal, because it is lost by decomposition. A long-accepted principle in citrus soil management has been the need for turning in organic matter annually, whether in the form of weeds, green crop, or animal manures. Certain experiments on the control of weeds by kerosene sprays and non-tillage cast doubt on this concept, at least for young trees on new ground. Still, there is no question of the value of organic matter for the soil (see Chapter 9).

**Maintaining Fertility in Light Soils**

Light soils are prone to develop deficiencies, especially of nitrogen, owing to the low organic matter content; also of the bases, potash and magnesium; and of minor elements, copper, zinc, and manganese, and iron in some cases. Changes in pH are more rapid if the reserve of bases
in the soil is low. Soil structure changes are not troublesome. On the slightly heavier soils the nutritional problems are less, but the soil structure and drainage problems are usually increased.

Maintenance of fertility is a more continual problem in some districts than in others. Native fertility varies according to the amount of fine particles and the location. The clay and other colloids acting as a store-house of positive ions (for example, calcium and magnesium) and also of negative ions, play a dominant role in fertility through their amount, quality, and base saturation.

The amount of colloid is lower in sandy than in heavier soils, hence sandy soils have the lower reserve of nutrient ions.

Quality refers to the composition of the colloid. Kaolinite has a low ion-holding capacity, montmorillonite has a greater capacity, and organic colloids the greatest. Kaolinite is found in coastal podzolic soils, whilst montmorillonite occurs in inland red-brown earths (Fig. 24), and this provides a reason why sandy soils of the east coast may lose their fertility more rapidly than equally sandy soils in inland districts. The organic colloids, although of high quality, are low in total amount in sands.

In the inland sandy soils not only is the colloid of better quality, but a higher proportion of the exchange capacity is occupied by important basic ions—calcium, magnesium, and potassium, etc.—and in a balance evidently suitable for tree growth.

On acid sandy soils under heavy rainfall conditions and subjected to prolonged leaching, much of the mineral nutrient is located in the natural vegetation. Clearing, and burning or decomposition, restore the bases to the soil, and young citrus-trees grow well until the soil-supply is depleted. This is a further reminder of the continued need for bases (and nitrogen) in such soils.

**SYSTEMS OF SOIL MANAGEMENT**

The individual soil practices such as green manuring, tillage, etc., are usually combined into some definite pattern or system of annual management. The pattern is repeated year after year, with the introduction of such variations as have the object of maintaining a soil fertile for citrus.

Soil management has undergone considerable evolution. The methods used in citrus culture are of five main types: (a) green manure and tillage; (b) volunteer weed and tillage; (c) clover and tillage; (d) clover cover or sod and mowing; and (e) non-tillage systems.

**Green Manure and Tillage**

The green manure aspect consists of (i) winter green manure, or (ii) summer green crop. The winter green-manure crop, usually of field peas, lupins, or tick beans, is sown in the autumn and turned in during the late winter or early spring. The period between spring and autumn is one of intermittent tillage to control weeds. It finds its best development in areas of assured winter-type rainfall or water-supply. The success of the green-manure crop depends on the proper preparation of a moist
seed-bed and sowing the seed with superphosphate. Assured rainfall or irrigation is necessary to permit the satisfactory early development of the crop. Successful turning in of the crop depends upon an assured moist soil to enable ploughing under at the right time and to hasten decomposition. Figure 53 shows a crop of blue lupins ready to be ploughed under. Note that a few flower-heads are showing.

![Figure 53. Green manure crop of blue lupins, just prior to ploughing in.](image)

In the northern districts of the east coast, with a summer-maximum type of rainfall, summer green crops are used and the winter period is devoted to tillage.

**Volunteer Weed and Tillage**

In natural-rainfall districts practical difficulties often arise with the raising of green-manure crops; the extra work associated with the formation of a seed-bed and seedling and the expense of seed and superphosphate are too often not recompensed by a satisfactory crop. Very often, too, the absence of timely rains when it is time to turn in the crop means that the soil is too dry to plough, and the crop, continuing to grow, forms a hazard to the growth of the trees. This particularly applies to winter green-manure crops, when the spring growth, blossoming, and fruit setting are endangered.

In these unreliable climatic conditions dependence is placed very often on volunteer weed instead of a sown crop for supplying the organic matter. A dressing of one hundredweight of superphosphate per acre in autumn improves the quantity of weed and also tends to bring about an improvement of the quality of weed by encouraging clovers. With
volunteer weed it is essential to turn it in early and follow with sufficient tillage to control weeds until the next volunteer crop is required to germinate.

**Clover and Tillage**

Winter legumes, such as burr clover in the inland areas and suitable clover on the coast, may be encouraged by superphosphate to such a stage that the system becomes one of clover and tillage. These clovers germinate in the autumn from self-sown seed of the previous year, grow through the winter, making most growth in the spring, and die in early summer after seeding. Vetch is similar in its growth habit and can be used similarly to these clovers.

**Clover Cover or Sod and Mowing**

In this method clover species are used that give a year-round cover to the soil. Instead of tillage being practised to control weeds, mowing is carried out from time to time and the mowings allowed to lie. Spray irrigation is more or less indispensable for success. This system is used to a very limited extent.

**Non-tillage Systems**

Various non-tillage methods have been steadily gaining favour over the past decade owing to the fact that all systems in which tillage is used result in the destruction of more or less root fibre. Weed control is gained by either sprays of kerosene or ranging fowls in the orchard. Another method of non-tillage, the use of a mulch sufficiently heavy to smother weed growth, is a very old practice rarely met with today, yet it may have important possibilities because of the recent discovery that heavy mulching has a beneficial effect on soil organisms.

**Kerosene Sprays**

Although in practice to some extent overseas, the use of kerosene for spraying weeds is only at the experimental stage in Australia. It consists of spraying weed seedlings with power kerosene to maintain a bare weed-free surface.

In an experiment at Griffith Research Station, Washington Navel and Valencia oranges planted in 1941 were given this treatment from 1947 in comparison with some conventional systems of management and sod. As the trees are young, only early results are available. Results were first reported after four years' growth, and these show that up to that time the oil-sprayed plots had given the largest trees, with high yields of good-quality fruit, but some deterioration in soil structure had been observed. Sod plots gave the worst trees. All differences between treatments could be attributed to nitrogen supply. The outcome of this experiment will be watched with the greatest interest, since the oil-spray treatment runs counter to a long-accepted principle in citrus-soil management, that is, the need for an annual turning-in of organic matter.
The ranging of fowls in citrus orchards has been the most spectacular development of the past decade as a system of managing citrus soils in the vicinity of metropolitan markets of the Gosford-Sydney area (Fig. 54). It is not to be recommended for inland districts owing to the dangers of wind erosion and increase of red scale. Briefly, the method consists of setting up houses, each supplied with self-feeder and a water-supply, at suitable intervals through the orchard, thus taking advantage of the natural habit of the domestic fowl to range to only a limited extent round its permanent roost, food- and water-supply. A six-foot wire-netting fence round the entire area provides all that is necessary in the way of restraint and gives protection against predatory dogs and foxes.4

Fig. 54. Fowls in an orange orchard, showing type of houses with self-feeders containing dry mash.  
(Agricultural Gazette of N.S.W.)

Pros and cons of ranging fowls. The successful conduct of this method depends primarily on a correct understanding and management of the fowls for the conditions of the citrus grove, and that neither interest is sacrificed for the other. When this balance prevails, the system has many outstanding advantages, namely:

1. Monetary return from the eggs.

2. Control of weeds by the fowls when correct ranging is carried out. Old-established plants of some weeds such as Paddy’s lucerne and lamb’s
tongue are not eaten by fowls, not brought under control, and some tillage is necessary to get rid of them. On the other hand, certain difficult weeds such as couch, kikuyu, and nut-grass can be brought under control. Tillage can be drastically reduced or eliminated. Some hand-work is required for cleaning out the surface drains.

3. A great improvement in tree condition, which is attributed to the fertilizer from the fowls and the fact that roots come right to the surface of the soil and can benefit from light falls of rain.

4. Special value on shallow stony soils in which lemons are frequently grown and cannot be cultivated in the normal manner.

5. The great saving in cost of production, since most conventional soil-management practices, such as cover crops and tillage, are abandoned. Even manuring may be abandoned after the first season, or greatly reduced owing to nutrients, introduced in the fowl feed, being added to the soil by the droppings.

6. Control of some pests such as Fuller’s rose, dicky rice, and apple-root weevils, and the subjugation of snails.

The chief disadvantage of having fowls in citrus orchards is that scale pests may increase, owing to the extra dust raised by the fowls; this disadvantage can be minimized by ranging the minimum number of fowls per acre that will control weeds. Another disadvantage is that lemon scab and brown rot may increase. Erosion should be watched, for ranging fowls throughout the year could result in the complete destruction of cover on the soil. Erosion is not as severe as might be expected from bare ground, because the surface becomes compacted by the birds’ feet and the action of their droppings. This compaction, of course, reduces the infiltration rate of the soil, and while light rain is adequately absorbed, heavy rain will result in run-off.

Management of the fowls can be so adjusted that ground cover is encouraged for the rainy season as a safeguard against erosion. At Gosford stock may be removed so as to allow cover to grow from January to March—the period of autumn rains.

As far as the soil management of citrus is concerned, perhaps the most interesting effect is the manurial one. The production of manure by adult birds is in the vicinity of 140 pounds per annum, 75 per cent moisture basis, equal to 6·2 tons from one hundred birds per annum. Generally speaking the houses should be situated on the upper ground, for rainfall will bring about the transport of the manure to lower trees. The ranging of the fowls, however, ensures a good distribution of the manure; the continuous addition of manure, together with the continuous control of weeds, is largely responsible for the beneficial effects on the trees.

The percentage composition of fresh poultry manure and floor litter manure, together with the absolute amounts of the nutrient supplied from one hundred birds, is shown in Table XXIII.

Stocking rate, housing and breeds. The stocking rate should be such as to control weed. It varies from 60 birds per acre on the light sands, through 100 birds on sandy loams, to 150 birds per acre on heavier loams.
### Table XXIII

**NUTRIENTS IN FOWL MANURE**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fresh fowl manure</th>
<th>Floor litter six months' accumulation</th>
<th>Without floor litter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Composition²</td>
<td>Nutrients from 100 birds per annum</td>
<td>Composition³</td>
</tr>
<tr>
<td>Moisture</td>
<td>75 %</td>
<td>1 lb.</td>
<td>24 %</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>1.47</td>
<td>205</td>
<td>3.0 %</td>
</tr>
<tr>
<td>Phosphate (P₂O₅)</td>
<td>1.15</td>
<td>161</td>
<td>2.6 %</td>
</tr>
<tr>
<td>Potash (K₂O)</td>
<td>0.48</td>
<td>67</td>
<td>1.4 %</td>
</tr>
<tr>
<td>Calcium (CaO)</td>
<td>1.37</td>
<td>191</td>
<td>..</td>
</tr>
<tr>
<td>Magnesium (MgO)</td>
<td>0.19</td>
<td>26</td>
<td>..</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>5.0 p.p.m.</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>

The houses should be situated on the highest ground, because fowls range better downhill than uphill from the house; they range freely to the extent of some two hundred feet downhill, but only about forty feet uphill.

For range conditions the house should allow floor space at 1½ square feet per bird, the perches at 9 inches per bird, and nesting space. A suitable house for seventy-five birds or fewer can be constructed 18 feet long by 6 feet wide, with a skillion roof 6 feet high in front and 5 feet at the back. The front is netted and aligned so as to face north or east, thus giving protection from the south and west. Nests are placed so as to be accessible from the front or one end. It is preferable to provide the houses with a deep-litter floor, to absorb the droppings. Automatic water-supply and feeders save work.

The same-sized house may be used for the different stocking rates by varying the distance apart to suit the soil, being farther apart on lighter soil. Alternatively, the houses may be placed a similar distance apart and the length of the house altered so as to accommodate the required number of birds for the stocking rate.

A distance of about two hundred feet between houses is sufficient to prevent "drifting" of the birds from one house to another.

The favoured type of bird is a cross-bred from a Leghorn rooster and an Australorp hen, this cross being more amenable and less flighty than the pure Leghorn and yet more active than the pure-bred Australorp.
Tillage amongst citrus-trees must always be governed by the fact that the trees are surface-rooting. Therefore the tillage must be as shallow as is consistent with the object of the operation being carried out at the time, whether it be, for example, the turning in of green crops, destruction of weeds, or cultivation of the soil prior to furrowing out for irrigation.

![Tillage implement](Photo: Lightning Implements Pty Ltd.)

The implements mainly used for tillage are the mouldboard plough, offset disc cultivators, and spike harrow, spring or rigid tyne cultivators, or rotary hoe implements. The offset disc can be provided with a hood (Fig. 55) to facilitate working under the tree.

In those systems of management involving tillage there is a green-manure crop or a volunteer crop of weed or clover to be turned under. The mouldboard plough makes the most successful job of turning under the greenstuff, but in doing so brings about a greater or lesser amount of fibre destruction. It also depends on the right moisture content of the soil to make a satisfactory operation. The alternative is simply to cut down this material by the rotary hoe or the scalloped disc, both of which partially incorporate the material and leave a trashy surface that facilitates rapid infiltration of water. Disc and rotary implements, moreover, do not depend to such an extent on correct soil-moisture content for satisfactory performance. Whilst the trash remains, the same type of implements must be used. Only after it decomposes may tyne harrows or cultivators be used without the difficulty of clogging.

Under furrow irrigation culture, tillage is followed by furrowing out. The object is to obtain a rapid decomposition of the material and have a free-working surface to facilitate the furrowing out. A form of tillage that gives a coarsely trashy surface is therefore not generally desired, especially in open sandy soils in which it increases the soakage rate too much. Furrowing out entails much stirring of the soil during the season, and it is an easy step to excess cultivation. The effects are discussed in Chapter 11.
Under natural-rainfall conditions tillage operations are completed by attention to the surface drains.

**Green-manure Crops**

A green-manure crop is one that is grown between the rows with the object of producing as great a bulk as possible by the correct time for ploughing in. As such, green-manure crops are in contrast with cover crops; cover crops are frequently misnamed green-manure crops and vice versa.

In order to obtain the objective of a green-manure crop, favourable conditions for sowing, growth, and turning in, as discussed under Systems, should be reasonably assured by the rainfall of the district. Irrigation assists materially in the direction of assuring that the conditions referred to will be favourable.  

Preparation for sowing should be arranged with forethought to the turning-in stage of the crop. The best time to turn under green-manure crops to ensure rapid decomposition is when they are at the flowering stage, and therefore the greatest bulk possible is required by that stage.  

The crop should be brought to the stage of bulk and flowering when

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*Fig. 56. Drill for sowing green crop and fertilizer, with furrowers attached.*  
(Photo: A. E. Vincent.)
climatic conditions are likely to favour ease of ploughing under and rapid decomposition, and when the rotted material will be of benefit to the growth of the tree.

Preparations should be made for seeding in good time. In the case of winter green-manure crops they should be sown early, namely in February, or early March at the latest, to take advantage of the remaining warmth of autumn, which will promote good growth before the onset of winter.

Fig. 57. Turning in green crop of blue lupins by rotary hoe. (Photo: Howard Auto Cultivator.)

A good seed-bed should be prepared by tillage, the seed drilled in or broadcast and harrowed in, usually with the application of one hundred-weight of superphosphate. Clover, rape, and other small seed will be more evenly sown if mixed with the superphosphate; in this case they must be sown without delay or the germination will be impaired.

Under irrigation the sown ground should be irrigated. Furrowers can be attached to the drill and the cover-crop seed can be irrigated immediately after seeding (Fig. 56).

In east coast orchards a winter green-manure crop should be turned under not later than July, and in inland districts one month later. It is ploughed in this early to allow release of nutrients, to prevent the crop from drying out the ground, and to anticipate a dry spring, when the ground may become too dry to plough. This latter consideration does not apply to irrigation areas, in which the first irrigation of the season is
usually available in August. The crop is nevertheless turned under early to permit decomposition and the release of nutrients for the spring growth of the trees. A nitrogenous fertilizer applied over the crop at the time of ploughing in is good practice, because the process of decay may lock up available soil nitrogen for a short period and the trees be short-supplied with this essential element at the critical spring-growth period. The regular spring fertilizer can be applied in this way, or sulphate of ammonia, or on the coast nitrate of soda, at the rate of two hundredweight per acre, can be used. Figure 57 shows a small rotary hoe turning in a fair crop of blue lupins, forming a trashy surface.

**Crops used**

Legumes are favoured owing to the fact that they have approximately double the nitrogen content of cereals, provided that the roots develop abundant nodules which are evidence of the presence of the organism that supplies the legumes with their extra nitrogen. On a dry-weight basis legumes average in the vicinity of three per cent nitrogen and cereals one and a half per cent. The higher percentage in the legumes represents the amount obtained by the nodules from the air. Thus one ton (dry weight) of legumes turned in represents sixty pounds of nitrogen per acre, of which about half is a real addition to the soil.

Sometimes the prostrate legumes such as peas and tares are sown with a cereal, usually oats. The legumes, climbing the upright-growing cereal, are less subject to rotting than a tangled mass of prostrate growth. The mixture is also of improved nitrogen content.

Common green-manure crops and their rates of seeding when sown by drill are as follows:

**Winter green-manure crop**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rate of Seeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand blue lupins</td>
<td>½ to 1½ bushels per acre</td>
</tr>
<tr>
<td>Tick-beans</td>
<td>1 to 1½</td>
</tr>
<tr>
<td>Grey field-peas</td>
<td>1 to 1½</td>
</tr>
<tr>
<td>Purple vetch</td>
<td>20 to 25 pounds per acre</td>
</tr>
<tr>
<td>Subterranean clover</td>
<td>6 to 8</td>
</tr>
</tbody>
</table>

When mixed with cereals, half the amount of legume seed is sown with one bushel of cereal.

**Summer green-manure crop**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rate of Seeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowpeas</td>
<td>1 bushel per acre</td>
</tr>
</tbody>
</table>

Cereal green-manure crops have special values. They may be sown later than legumes, they provide a soil cover quickly, suppress weed growth, and produce a trashy surface which is especially valuable for improving infiltration of moisture, reducing erosion, and reducing wind blowing of the soil.

**Seasonal Cover Crops**

Bulk is not an essential feature of a cover crop, which has the primary purposes of covering, protecting, and holding the surface soil and improving soil structure. Cover crops may be turned under at the correct time for green-manure crops, when it can be said that they simply serve
the purpose of an ordinary green-manure crop. But as a rule a true cover crop will be allowed by design to grow longer into the season and thus effect a longer period of soil cover. If it makes excessive growth and becomes competitive with the trees before it is intended to commence tillage, it may be cut by the mower or lightly disced.

Seasonal grasses and clovers constitute the usual seasonal cover crops. Of these the winter clovers such as burr and subterranean are to be preferred owing to the fact that they are legumes and have a seasonal growth well adapted to summer tillage. They germinate in the autumn (February), improved germination and subsequent growth being obtained by the use of one hundredweight of superphosphate just prior to germination. They grow to some extent through the winter and make their most rapid growth and come into flower in the spring, after which they dry out or “hay off” during November to December. This material, which contains the seeds of next year’s crop, can be incorporated lightly into the soil by disc or rotary implement. In most inland districts burr clover seed is naturally abundant and merely requires to be encouraged with superphosphate and to be allowed to germinate by the early cessation of tillage (early February). It may in some cases be necessary to seed down by broadcasting at the rate of six to eight pounds of seed per acre, with one hundredweight of superphosphate.

A good germination of clover more or less smothers autumn weeds, and the only period in which they can come is during the summer.

Fig. 58. Mower used in sod culture.
(Photo: Scott Bonnar (Aust.) Pty Ltd.)
If the hayed-down material of a good clover cover is allowed to lie undisturbed it forms a mulch, which may smother summer weed. If it is disturbed, weeds will come and must be controlled by tillage.

In comparatively shallow soils it has been found that cover crops cannot be used extensively because they increase the infiltration rate excessively.

**Perennial Cover Crops or Sod**

This method represents the extreme of cover cropping. The sod may consist of grass and clover and is only practicable when there is an assured water-supply, distributable by spray irrigation. As no tillage whatever is practised, any excessive seasonal growth is controlled by mowing alone (Fig. 58). The mowings are allowed to lie, and this in itself tends to suppress a too active growth of the sod.

Perennial cover crops are the least successful method of management for citrus growing, and after a fair trial they have usually been abandoned for green manure and tillage, clover cover and tillage, or volunteer weed and tillage.

**Resoiling**

Any necessity for resoiling is evidence that conservation farming has not been practised, but there are many hillside orchards in which the topography of the land, coupled with a straight-row lay-out, makes it inevitable that erosion will take place, and some resoiling must be done periodically. When necessary, resoiling brings about very considerable improvement in the trees and the cropping. Loads of soil are first of all dumped into eroded places such as the ploughing finish-outs; if time permits one or two loads may be dumped on the lower side of trees, thus providing a better cover to the roots on this naturally more erosion-susceptible side of the tree. Some of this soil is thrown under the tree, without, however, covering the union. As a general practice the loads of soil are spread by the shovel just sufficiently to facilitate subsequent operations. Avoid forming mounds under the trees, for reasons explained early in this chapter.

**Drainage Furrows**

A definite part of citrus orchard management in humid districts is the provision of drainage furrows between the trees after tillage operations. The type of furrow required and the danger of plough furrows were mentioned on p. 90. In the next chapter, under Furrow Irrigation, special reference will be made to the practice of attending to drainage furrows.
CHAPTER 11

IRRIGATION

About half of the Australian citrus crop is grown with the aid of irrigation. In the arid or semi-arid irrigation districts the markedly seasonal rainfall is either of winter type as in the Murrumbidgee and Murray areas, or of summer type as in the Gayndah district. In neither case is it sufficient to sustain the tree in the dry season. The culture of the crop in such districts is absolutely dependent on supplied water during the drier months of the year. The term irrigation applies to the practices associated with water application under these conditions. Another term, supplementary irrigation, is restricted to the application of water in humid districts where smaller quantities are required for the purpose of tiding the trees over a dry spell.

Fig. 59. Authority's water-supply channel in course of construction, Loxton, S.A.

Design and development of a site for irrigation were discussed in Chapter 6, where it was also pointed out that in irrigated districts the supply of water is under the control and direction of a governmental authority (Figs 59, 60). Many of the districts are organized on a community basis, water being supplied to growers in rotation during the spring, summer, and autumn. Other districts and areas are irrigated by individual pumping
from a stream, under permit from the State authority, and in these circumstances the grower makes his own arrangements for irrigation facilities. Irrigation has been achieved not without loss and hardship (Chapter 1).

The systematic application of water as irrigation has raised many problems that do not invite the same consideration under humid conditions. In humid districts farmers accommodate their practices within the framework of the natural-rainfall conditions. The soils are different, water tables, waterlogging, and occasional flooding not having the same dire
effects in the acid soils of humid regions as they have on a neutral to alkaline soil that has been formed under arid conditions. In irrigated districts moisture must be regularly replenished, and large quantities are required of it during the season. The continual work involved in regular irrigations throughout the hotter part of the year demands that it be capable of being performed with the greatest possible economy of effort. Good facilities are required. Economy in the use of water is necessary, since the dangers to the orchard investment attending the improper use of water are serious and call for as complete an understanding as possible of the soil-moisture situation. Considerable researches have been carried out in all irrigation areas throughout the world in order that irrigation practices should be based on a knowledge of the water relationships of the soil.

The aim of irrigation is to replenish the soil moisture as it approaches the wilting point to the depth of rooting. The fulfilment of this aim will provide the needs of the tree, obviate the penalties of under-irrigation—
restriction of the depth of rooting and too frequent irrigations—and
avoid the evils of over-irrigation—waterlogging, seepage, and salting.
The practical difficulty is to effectuate these aims on all occasions in
community or privately operated irrigation.

REPLENISHMENT OF SOIL MOISTURE

Infiltration

Infiltration or the entry of water downwards into the soil is usually
rapid at first and slows down in time, owing to the swelling of the colloids,
the inward resistance to penetration offered by the fine pores, the less
ready exit of air, and the general puddling of the surface. Sandy soils

Fig. 61. Installation of orchard underground pipeline with risers, for furrow
irrigation.

(Photo: A. E. Vincent.)
have a high infiltration rate or permeability—as much as eight inches per hour—whereas heavy soils may be as low as one inch per hour. Permeability decreases during the irrigation season.

It is important to adjust the rate of application of water to the infiltration rate of the soil. The infiltration rate may be affected a great deal by both irrigation and management practices.

Fig. 62. Completed riser with concrete apron to prevent scouring as water is directed to furrows. A home-made device is here used to regulate the flow of water.

*(Photo: A. E. Vincent)*

**Field Capacity**

After the cessation of irrigation in a soil free to drain, the moisture saturating the pore spaces passes downward, leaving a film of moisture round the soil particles and in the finest pores, which is held by them with a force resisting or stronger than the pull of gravity. The moisture that passes down wets a further depth of soil by forming a film round the particles, until eventually no further downward percolation of water can take place, for it is all held in the film round the particles of the wetted soil with a force greater than gravity. This condition occurs twenty-four to forty-eight hours after applying water, and the soil that has been so wetted is then at field capacity. Beyond the wetted area the soil has not gained any moisture from the irrigation.

Water wets a soil only to its field capacity, and is unable to wet it to a percentage lower or higher than its field capacity, if it is free to drain—unless very exceptional circumstances prevail. A certain amount of water always wets the same depth of soil if it was dry to start with. As a general guide it can be taken that an inch of irrigation will wet about five to
six inches in clay loams, six to eight inches in loams, and nine to twelve inches in sandy soils.

**Evaporation**

The exposed surface of a wetted soil soon loses moisture to the air and quickly becomes dried out to a depth of a few inches. This loss is quite unavoidable, and evaporation does not do the harm, formerly credited to it, of drying out the deeper soil, unless cracks develop, which of course may permit the escape of water vapour from considerable depths.

Mulching with surface litter, on the other hand, will prevent the loss of water by evaporation from the first few inches of soil.

**Wilting Point**

The soil moisture is drawn on by roots of the trees, weeds, or any other plants, until they are unable to reduce it any further and the plants wilt. This is termed the permanent wilting point of the soil. It has been shown repeatedly in investigations that plants wilt at the same moisture percentage whenever it is reached. The definite nature of the permanent wilting point has been explained by the force holding the film moisture at this stage. As the film of moisture is reduced by plant roots it is held more tightly by the soil particles and in the finer pores or capillaries of the soil until the force holding it is greater than that operating in the plant (see p. 127). Whereas the soil at field capacity holds water with a force of about 14.5 pounds per square inch (one atmosphere), at the permanent wilting point the force is in the vicinity of 230 pounds per square inch (sixteen atmospheres).

Soils at the stage of wilting point are said to be dry, although there is still a good deal of moisture in them, but such moisture is quite unavailable to the tree, and the only way of relieving wilting is to replenish the soil moisture.

**Movement of Soil Moisture**

The movement of moisture from a wetted zone to one with less water, even as low as permanent wilting point, is extremely slow, and for all practical purposes only the moisture in the immediate vicinity (within one inch) of the root fibre is available to the plant. Unoccupied soil cannot be regarded as a reservoir from which water will move towards the tree. All the soil in the possible root zone should be occupied by roots. Where a water table with its capillary fringe exists at no great distance below the rooting depth of the soil, some upward movement of soil moisture can take place.

**Available Moisture**

The soil moisture between field capacity and the wilting point is that which is used by the plant, and it is appropriately known as available moisture. It is the available moisture that must be replenished at intervals. Soil moisture content is brought by irrigation to field capacity; plants draw on it, reducing it to the permanent wilting point.
There is some difference of opinion as to whether or not moisture is equally available throughout the range of available moisture, that is, whether it is more available near field capacity and less available near the wilting point.

In soils fully permeated by roots it has been shown that moisture is fully and equally available throughout the range, but the soil is naturally not always thus fully explored.

Data on root distribution (Fig. 27) shows that roots do not necessarily fully occupy the root zone. Some 90 per cent of the roots may be found within one, two, or three feet of the surface, depending on the soil. The root zone may be restricted also by Phytophthora, method of irrigation and soil conditions resulting from cultivation, application of sulphate of
ammonia, and salt concentration. Figure 63 shows effects from furrow and sprinkler systems of irrigation.

In heavier soils and in soils in poor condition citrus-trees do better in the higher range of the available moisture than in the complete range. Juice content of the less juicy varieties, such as Thomson Navel, has been observed to be higher when water has been kept in the higher part of the available moisture range than when the trees have been allowed to reach the permanent wilting point periodically. Under severe evaporating conditions occurring suddenly, such as heat waves, recently watered trees show obviously less stress than those whose soil-moisture supply must have been nearing the wilting point.

On the other hand, when evaporating conditions are mild, as in winter, it is commonly observed that citrus-trees seem capable of drying out the soil to a greater degree than during the summer. The explanation for this must be that as the evaporating conditions are least at this time of the year, the tree roots have a longer period in which to exploit the lower range of soil moisture to the wilting percentage as well as to extend into neighbouring moist soil laterally or in depth than in the summer, and so can maintain a supply of water to the tree, which would be quite inadequate to maintain it without wilting for even a brief period in summer.

Fruits may decrease in size during a period of stress and resume growth on the replenishment of soil moisture. These observations support the concept in citrus of the occurrence of degrees of water-stress governed by the severity of the evaporating conditions, on which it is asserted that the irrigation needs can be indicated better by a suitable evaporimeter than by tests for permanent wilting point (p. 200). The black pan evaporimeter, which more closely approximates to the evaporating conditions surrounding the foliage than the standard meteorological evaporation tank, is used for this purpose.

**DESIRABLE AND UNDESIRABLE IRRIGATION**

**Adequate Irrigation**

Correct or adequate irrigation of citrus-trees consists of a repetition several times during the season of the process of applying sufficient irrigation water to wet the soil to field capacity to its depth of rooting, when the soil is approaching the wilting point. Irrigation carefully adjusted to these objectives is sometimes called controlled irrigation. Recently there has been a tendency to use water-stress as an indication of the need for irrigation, but past experience has always laid emphasis on a very judicious use of irrigation, allowing the soil to dry out well, that is, to approach wilting point, between irrigations. Exceptions are when light irrigations are required.

**Light Irrigation**

If the soil has a moisture percentage above the permanent wilting point, less irrigation water will be required to wet the depth of rooting. If half the available water has been used when an irrigation is about to be given,
then half the usual depth of irrigation water is required to fully wet the soil. This type of irrigation is called a light irrigation and is used on several occasions such as when green crops are being sown and when it is necessary to take an irrigation in the rotation, say in anticipation of heat-wave conditions, although the grower knows that his soil is not dried out.

Under-irrigation

If, on the other hand, a soil has dried out to the permanent wilting point, and a smaller irrigation is given than is necessary to wet the full rooting depth, then a shallower depth of soil will be brought to field capacity. The deeper roots are then in soil remaining at the permanent wilting point, cannot obtain water from the soil, and if exposed to this condition for some length of time they may die and the tree become shallow-rooted. More frequent irrigations than normal become necessary if the top growth of the tree is to be maintained.

Over-irrigation

When irrigation wets the soil beyond the depth of rooting, the moisture in the rooting zone is reduced to its permanent wilting point in the normal way, but the wetted area below is not drawn on by roots and therefore it still remains at its field capacity. Wetting beyond rooting depth takes place occasionally under the most careful irrigation, without doing harm; in fact, it has this to recommend it as an occasional occurrence; it ensures that the rooting possibilities of the soil will be fully exploited in depth.

But the regular wetting of soil deeper than rooting depth is attended by the worst evils of irrigation—waterlogging, seepage, and salting. The mechanics of waterlogging can be seen if we assume a simple case of a uniform soil, say six feet in depth to an impervious layer, with a depth of wetting of ten inches per inch of irrigation water. If it takes three inches to wet the root zone of the tree, a depth of say two feet six inches, to field capacity, and four inches are applied, then the extra inch wets approximately another ten inches below rooting depth to its field capacity, but is not used by roots. At each subsequent irrigation three inches will replenish the root depth and the extra inch will pass below, wetting additional ten-inch depths each time. On reaching an impervious layer in the soil these downward increments must cease and the addition of water saturate a band of soil above the impervious layer. The difference between field capacity and saturation is usually small, and so small amounts of water cause comparatively large rises in the water table, unless they are able to seep away by lateral movement.

Water Tables

*District water table.* This is the name applied to the level, varying from fifty to a hundred or more feet below the surface, at which ground-water occurs in a district. The district water table can be raised over a period of time by the downward percolation of irrigation water. Ground-water in arid districts is often highly charged with salt and should never be allowed to rise enough to establish connection with soil moisture.
Perched water table. This is the type most commonly referred to simply as water table. It is one that is built up on an impervious layer at no great distance from the surface, the soil below the water table being saturated or waterlogged.

Capillary fringe. The moisture content of the soil just above the water table is a little less than saturation and tapers off over a distance of some three feet above the water table to field capacity. The fringe may supply a limited amount of water to wetted soil above by capillarity. For citrus-trees connection of the fringe with wetted soil is undesirable because of the favourable conditions it creates for root-rot (see p. 82) and for the rise of salt.

Water table is tested by inserting into the soil a length of two-inch galvanized iron downpipe to a depth of eight feet or more. It is considered that the water table should be kept below eight feet as the capillary fringe of three feet leaves only five feet of soil as a safe margin for the root zone and some temporary rise and fall in the water table and its fringe.

Waterlogging may be augmented by seepage from higher land, or from adjoining properties that are not carefully irrigated, or from other sources of deep penetration of water. Water table investigations must look to the source of the trouble. If the contributing causes are strictly local, the orchardist may correct waterlogging by several means.

Strict control of irrigation as to depth and frequency may give a satisfactory solution, and coupled with dry winters has repeatedly given a very satisfactory reduction of water table. Water tables may be reduced by deep-rooting plants such as lucerne, grown along headlands and similar places where they do not compete with the trees, and are not in the irrigation run where they would increase soil permeability and deep penetration.

Underground or tile drainage must be entertained if other methods are unavailing, but the expense is considerable.

Salting

The rise of dangerous concentrations of salt (mainly sodium chloride) to the soil surface from depth occurs when the capillary fringe connects with the depth of wetting by irrigation. Salt diffuses from depth through the waterlogged zone into the capillary fringe and into the irrigated depth; the evaporation of moisture at the surface results in the concentration of the salt at or very near the soil surface. See Table XI for high concentrations of salt which may occur at the soil surface, and see the adjoining discussion for some other aspects of salt in soil. Under furrow irrigation lateral spread of salt from the irrigated centres to the tree rows occurs. Fig. 64 shows advanced defoliation as a result of lateral salt movement.

When an orchard is tile-drained the salt may be leached down by a heavy irrigation and passed out through the drainage, and the removal of amounts varying from twenty to sixty tons of salt per acre by this means have been obtained.

In the absence of tile drainage, reduction of the water table to twelve feet or so will permit the use of irrigation to leach slight accumulations of
salt from the topsoil below the root zone. Subsequent irrigations, however, must be carefully controlled to prevent rise of the salt. Flooding by heavy rain, especially in wet winters, effects a good deal of leaching of surface salt, provided that water tables were at a low level beforehand and the wet winters do not bring the capillary fringe into the irrigated depth.

Fig. 64. Defoliation caused by salting in Marsh grapefruit. (Photo: E. C. Levitt.)

DISTRIBUTION OF WATER TO TREES

The farm-water supply for spray and furrow irrigation methods was described in Chapter 6. It remains to discuss the distribution of water from the supply system.

Spray or Sprinkler System

The pattern of spray thrown is either circular or rectangular, and the nozzles of adjoining spray-lines are staggered to enable a certain overlapping of the pattern from each jet (Fig. 32). The design for the area is provided by the supplying company. Sprinkler systems, especially
the overhead types, are subject to wind, and the system should be carried to the outside row on the windward side. The rate of application of water by sprinkler irrigation is known from the discharge of the pump or the delivery of the spray-heads, as specified by the manufacturers.

**Furrow System**

The furrow system is mostly supplied from farm ditches (see Fig. 35), although underground conduits with risers are employed to some extent (see Figs 61 and 62). Water enters the ditch from the channel supply via the Dethridge wheel. The flow, and acre-inches supplied, are shown in Table XXIV.

**TABLE XXIV**

DELIVERY OF WATER BY THE 2-CUSEC DETHRIDGE WHEEL

<table>
<thead>
<tr>
<th>Wheel revolutions per minute</th>
<th>Acre-inches delivered per hour (equals cubic feet per second, or cusecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0·25</td>
</tr>
<tr>
<td>2</td>
<td>0·50</td>
</tr>
<tr>
<td>3</td>
<td>0·75</td>
</tr>
<tr>
<td>4</td>
<td>1·00</td>
</tr>
<tr>
<td>5</td>
<td>1·25</td>
</tr>
<tr>
<td>6</td>
<td>1·50</td>
</tr>
<tr>
<td>7</td>
<td>1·75</td>
</tr>
<tr>
<td>8</td>
<td>2·00</td>
</tr>
<tr>
<td>9</td>
<td>2·25</td>
</tr>
<tr>
<td>10</td>
<td>2·50</td>
</tr>
</tbody>
</table>

*Fig. 65. Very broad furrower, used for semi-flooding. (Journal, Department of Agriculture, S.A.)*
The stream from each outlet or sluice-box in the farm ditch is subdivided into a number of furrows. These may vary from four V-shaped furrows through a fewer number of broad-based furrows, to a double or a single wide watering bay per land. Thus by definition they range from true furrows to a border type of irrigation, but here they will all be referred to as furrows.

The V-shaped furrows have a depth of about nine inches and a width at the top of twelve to fifteen inches. Broad-based furrows are about six inches deep and twelve to eighteen inches wide at the bottom, eighteen to twenty-four inches at the top. Still broader furrows may be made (Fig. 65).

Furrows are put down, after tillage, with various implements that crowd the loose soil to either side—furrower, broad-based furrower, or crowder and newer implements (Fig. 67). When there is trash or cover on the surface, furrows may be cut with a disc implement.

Fig. 66. Large flow in furrows.
(Journal, Department of Agriculture, S.A.)
Fig. 67. Furrowing implements: (a) V type, (b) broad furrower, (c) bullet, (d) disc and smoother, (e) bomb, (f) disc and pipe smoother.

(Journal, Department of Agriculture, S.A.)
### Table XXV

**Time for Primary Flow to Reach Footland**

*(After Diercks.*)

<table>
<thead>
<tr>
<th>Details</th>
<th><em>Paringa</em> sandy loam</th>
<th><em>Barmera</em> sandy loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of furrow (chains)</td>
<td>5½</td>
<td>7½</td>
</tr>
<tr>
<td>Grade (inches per chain)</td>
<td>2</td>
<td>1½</td>
</tr>
<tr>
<td>(with slight hump half-way)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Implement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-type furrower</td>
<td>45 min.¹</td>
<td>18 min.²</td>
</tr>
<tr>
<td>to half-way</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bullet</td>
<td>16 min.</td>
<td></td>
</tr>
<tr>
<td>Bomb</td>
<td>18 min.</td>
<td></td>
</tr>
<tr>
<td>Broad-based furrower</td>
<td></td>
<td>15 min.³</td>
</tr>
<tr>
<td>Modified disc and smoother</td>
<td></td>
<td>7 min.³</td>
</tr>
<tr>
<td>Disc and pipe smoother</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ The stream reached the half-way hump in forty-five minutes, filled the V-furrows, overflowed, and flooded the headland and had to be cut off.
² Very narrow wetted profile.
³ Broad wetted profile.
⁴ V-furrows would not take the volume of water required to overcome uneven grade. Furrows had to be continually built up and an unsatisfactory irrigation was concluded after five hours flow to reach the footland.

Furrows may be used several times, so long as they permit the required flow of water and give the required infiltration, after which the ground usually must be tilled again and fresh furrows put down.

The furrows are put down in the lands between the leaf-drip of the tree rows. The ground under the trees, if watered at all, is watered separately from the lands, owing to the practical difficulty in the case of trees whose skirt sweeps the ground, and the fact that the soil there usually has a markedly higher soaking rate.

Only as many lands are watered at the one time as can be wetted satisfactorily by the flow of water available, and as can be patrolled by the operator.

Each furrow wets a strip of land. Conditions of irrigation are required to give the depth of wetting necessary, to give a uniform depth of wetting throughout the length of the furrow, and to give lateral soaking enabling complete wetting underground between the furrows (Fig. 66). Small streams give over-deep penetration at the headland, insufficient at the footland, and poor lateral soaking (Fig. 68). Excessively large streams do not give the necessary depth of wetting before the water has overflowed and
flooded the footland. The problem of each irrigator is to obtain the flow per furrow for his conditions that will enable him to obtain the objectives set out.

Use of Primary Flow and Large Furrows

In sandy citrus soils in which the soakage rate is high and deep penetration is to be prevented, the object in general is to use large furrows and a large flow per furrow in order to get the water down to the end of the furrows rapidly and then shut off the flow. This type of flow is called primary. The process is then repeated with a succeeding set of furrows.

In a study of the light soils of Loxton it was concluded that the irrigator should aim to get a good primary flow in each furrow so that the stream reaches the footland in from twenty to thirty minutes. To obtain a good primary flow down the furrow, a full stream (eight revolutions per minute of the Dethridge wheel) should not be split over more than forty outlets at once. On sands, this number should be reduced to only thirty outlets open at the one time. If more outlets than this are open the smaller streams saturate the headlands before reaching the footlands.¹

Suitable implements for making large smooth furrows to carry a large primary flow have been evolved in Australia (Fig. 67). The effect of furrow implements for achieving the object of getting the water to the end of the furrow rapidly, is shown in Table XXV.

Use of Secondary Flow

In heavier soils with a lower soakage rate, after primary flow has been

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¹ The number of outlets should be reduced to thirty instead of forty on sands.
achieved it may be necessary to cut down the flow from the outlet for a
time to a secondary, or soakage, rate of flow in order to get sufficient
penetration, before cutting off the flow.

Number and Size of Furrows

The number and size of furrows to use vary with the conditions of the
orchard. The most influential factor may be steep slope in one case,
high soil-soakage rate in another, and so on. The chief or governing
factor must be sorted out in each case and given the most consideration.
The number and size of furrows to use depend upon the factors govern-
ing flow, which are (i) head or flow of water; (ii) type of soil; (iii) size
of furrow; (iv) slope of irrigation run; (v) length of irrigation run; and
(vi) shape and roughness of furrow.

Head or flow of water. It is advisable to use as large a flow as possible
in the ditch and from the outlet, in order that large flows may be obtained
in the furrows. A small supply must be concentrated into a few furrows.
On moderate slopes (two inches per chain) it is desirable to keep the
furrows full, to obtain desirable good lateral spread and uniformity of
penetration. On steeper slopes, where full furrows cannot be maintained,
use more furrows or broad-based furrows.

Type of soil (that is, its soakage rate). The higher the soakage rate,
the fewer and larger the furrows used. In the most permeable soils spraying
is the most satisfactory method.

Size of furrow. As large a furrow as possible, that is, one suited to the
head of water and the soil-soakage rate, is employed in order that large
flows per furrow can be obtained. Whilst V-shaped furrows are suited to
moderately permeable soils on flatter grades, broad-based furrows are
more suitable on more permeable soils. They give better lateral soakage
for the depth of penetration (Fig. 69).

Slope of irrigation run. The flatter the slope, the fewer the furrows;
and the steeper the slope, the more furrows. Change of slope or soil
type in the irrigation run is a common cause of different penetration.

Length of irrigation run. The longer the length of run, the fewer and
larger are the furrows consistent with wetting the ground, in order to get
water down to the end of the run.

Shape and roughness. Any factors that increase the roughness of the
furrow or offer obstruction, such as clods, trash, and cover crop, slow
down the flow and increase infiltration. In the case of cover crops new
furrows may be cut by disc implements in order to prevent the excess
infiltration that may occur from old furrows when clogged with cover
crop. Furrows can be smoothed to reduce the roughness factor by special
furrowing implements (Fig. 67). New furrows permit greater infiltration
than old furrows.

DEPTH OF WETTING

Since correct depth of wetting is of such vital importance reliable
tests are needed. The depth of wetting may be ascertained by the use of
several methods: (a) the soil probe, (b) the soil auger, and (c) a trench.
The probe consists of a length of ½-inch to ½-inch round steel welded to a cross-piece handle. When pushed into the soil it penetrates the wetted soil but cannot be pushed into the dry zone below. An advantage of the probe is that it can be used while irrigation is in progress.

The common soil auger consists of a one-inch wood auger welded to a length of round steel, with a cross-piece handle. It is screwed into the soil and the core of soil brought up in the auger from successive depths is worked between the fingers. Wetted soil is plastic and binds together in the hand. Unwetted soil is crumbly. The four-inch Jarrett auger may be used for the same purpose.

A trench, revealing a cross-section of the land, is particularly useful to examine the depth of wetting in conjunction with the lateral spread from furrows.

The area sampled should fairly represent the application and should exclude any possible augmentations by leaf-drip, ponding, or any other unrepresentative accumulation of water on the sampling site.

As mentioned earlier it will usually be found that depth of penetration per inch of irrigation water into a previously dry soil is nine to twelve inches for sands, six to eight inches for loams, and four to six inches for heavier clay loams.

Irrigation practices that increase penetration are: (i) smoothing and regrading to produce a suitable slope for the soil type; (ii) suitable flow of water for the slope; (iii) new furrows rather than old; (iv) furrows with rough surfaces; and (v) watering through the cover crop in old furrows.

Irrigation practices that decrease penetration are: (i) slope too steep for the soil type; (ii) flow of water as large as possible for the furrow, provided that flooding between furrows is not allowed to occur; (iii) cutting new furrows in cover crop instead of using the old furrows; (iv) use of old furrows; (v) use of clean furrows; (vi) smoothing of furrows by the use of the bullet, bomb, or similar smoothing devices.

Soil management methods may be adapted to increase or decrease penetration. The grower can adopt one set of practices to facilitate penetration or another set of practices that will retard it. He may need to vary his soil management practices to suit the prevailing soil conditions. Certain aspects of fertility should be mentioned first. Ample soil moisture from irrigation coupled with the summer heat of inland districts brings about rapid decomposition of organic matter. Regular applications of nitrogen fertilizer are the usual practice; nitrate of soda is inadvisable, since it has a deleterious effect on soil structure; sulphate of ammonia is the common nitrogenous fertilizer, but it cannot be used indefinitely without attention to the acidifying effect of this fertilizer and the loss of bases (calcium and magnesium) from the soil (see p. 143).

Regular irrigation brings about leaching not only of nitrates but of the basic nutrients. When leaching and fertilizer practice result in acidifying the soil, the loss of bases may occur to the extent that deficiencies—for example, of magnesium—show in the trees. The loss of bases is deleterious to soil structure, and consequently to the infiltration of irrigation water.
Practices that increase penetration are (i) decreasing the amount of tillage, (ii) increasing the period of non-tillage, (iii) growing of green-manure crops or cover crops, (iv) other practices that lead to a gain of organic matter and bases, and (v) the use of gypsum.

Penetration is decreased by clean cultivation and other practices that lead to a loss of organic matter and bases. Considerable tillage of the soil tends to decrease penetration for several reasons: one is the loss of organic matter; another is the loss of soil crumb structure through the mechanical effect of tillage, by excessive aeration (which depletes organic matter), and by the absence of green cover from the soil, which is, therefore, more exposed to raindrop effects. When structure has deteriorated water will have a slaking effect, the soil will run together more rapidly in the ploughed depth, and perhaps the finest clay particles will tend to be washed down to the depth of cultivation. Excessive tillage may create a plough sole immediately below the depth of cultivation, this being more likely to occur if the soil is cultivated when rather too wet. If a plough sole is formed, aeration is affected and it possibly has the poisonous effect of sealing carbon dioxide below the cultivation depth.

In addition, excessive cultivation alters grades and creates ridges and depressions in the headlands and footlands, especially the latter, which results in the impounding of water near the trees (which is a serious threat to the health of citrus).

**FREQUENCY OF IRRIGATION**

Frequency of irrigation should be such as to wet the root zone just before the onset of wilting or of stress. A frequency that allows drying out of the soil between irrigations tends to check Phytophthora development. The extra aeration may be beneficial.

In practice frequency of application is limited by a number of considerations, of which the availability of water on the roster system is perhaps the most important in irrigation communities. If water must be applied before the permanent wilting point has been reached, then in order to prevent deep penetration a light irrigation must be given. On the other hand, if water is applied at unduly long intervals, then the trees will have been at the permanent wilting point for some time and their growth affected for want of available water.
Indications of when to irrigate, on the basis of incipient wilting or stress, are as follows:

1. Failure of the fruit to maintain a normal increase in size. See p. 254 for further details and method of measurement.
2. Temporary or incipient wilting of the trees. When leaves show permanent wilting the soil has usually been at wilting point for some little time.
3. The moisture condition of a core of soil brought up by the soil auger. Such soil will be crumbly and have no plasticity when worked in the hand.
4. Wilting of weeds growing in the vicinity.

Gypsum blocks and electrical methods have been used experimentally to determine the wilting point of the soil.

Seasonal Requirements

The amount of water loss from the tree depends upon (a) the extent of the transpiring surface, (b) the severity of the transpiring or evaporating conditions, and (c) any control exercised by the plant through closure of the stomata.

The extent of the transpiring surface. Owing to their evergreen nature, citrus-trees are not remarkably different at different seasons of the year in the extent of their transpiring surface, and in this respect contrast sharply with deciduous trees. Unusual variations in the transpiring surface, however, will be introduced by excessive leaf-fall, frost, or other causes of suddenly reducing or increasing the amount of foliage.

The severity of the transpiring or evaporating conditions. The transpiration of water is lower in the dormant period and higher during the summer months. This is the main factor. The transpiration rate from the leaf approximates broadly to the evaporation rate from a free water surface (evaporimeter), being greatest under conditions of high temperature and turbulence brought about by wind. A combination of hot drying winds with high temperatures, as occurs in December to January heat waves in inland districts, form the most intense evaporating conditions.

Control exercised by the plant through closing of the stomata (see p. 127). The stomata close when wilting occurs. They close at night. They also exercise a small measure of control when they partially close in forenoon hours, although this seems to be of limited importance.

Owing to the operation of these three factors, the frequency of irrigation required is least in the winter, most in the summer, and intermediate in the spring and autumn (Fig. 70).

Early in the irrigation season, starting August to September, evaporating conditions are low and irrigations may be spaced as widely apart as four, six, or more weeks, especially if some rain falls and augments the soil-moisture supply.

As the weather warms up in summer, evaporating conditions increase in severity, the likelihood of rain lessens in southern districts, and the
trees become entirely dependent upon irrigation for soil moisture. Then the frequency of irrigation must be increased and in midsummer may be fortnightly, or less during the heat-wave period. After the hottest month (January) frequency of irrigation is again gradually reduced in conformity with the reduction in evaporating conditions.

![Monthly irrigation requirements of Washington Navel orange-trees on Rough lemon stock, based on data for four seasons.](Journal, Department of Agriculture, S.A.)

After the last irrigation of the season (April to May in southern districts) the trees depend on natural rainfall alone. Citrus should go into the winter period with a low water table, resulting from carefully controlled irrigation during the previous part of the season, yet with adequate soil moisture in the root zone. This latter should be supplied by the last irrigation, otherwise the trees and the fruit may receive a marked setback if the rain anticipated during the winter is less or later than normal. In this case the fruit will be lower in juice content and total soluble solids, and the trees will be more subject to frost injury.

After the last irrigation, surface drains should be cleared out, so that if undue winter rainfall occurs it can quickly get away into the community drainage system.
MAINTENANCE AND ALTERATION OF IRRIGATION FACILITIES

It is a matter of experience that all irrigation lay-outs require maintenance and attention, and that many are capable of change for the better. The more perfect the original lay-out, the less will be the necessity for change, but there is always the need to maintain the system in efficient order. If faults become apparent, then an adaptation of some factor in design, practice, or management becomes necessary to correct it. Two instances will now be quoted, one illustrating a lack of maintenance and the other a case for alteration in design.

The tree itself reflects the efficiency of irrigation lay-out and practice. It will sometimes be found that the trees, although quite healthy, are smaller at the headland or footland. If soil type does not seem to be responsible, the difference is probably due to the amount of water supplied to the trees, and indicates the need to secure better penetration of water where the smaller trees are situated. In the furrow method there is considerable latitude for doing this by operating on the factors that effect the flow in furrows (see p. 197).

The second instance concerns the occurrence of unhealthy trees; owing to the high susceptibility of the root to injury from wet soils, water table, and salt, citrus is probably the most sensitive of trees to unfavourable irrigation facilities.

Unhealthy trees are usually found on eroded headlands, silted footlands, low spots, and where soil type changes from a lighter to a heavier one in the furrow run. The occurrence of unhealthy trees from any of these causes indicates very probably that an alteration in design is necessary to give better control of irrigation.

Smoothing

Irrigation and cultural operations alter the original slope: some tillage implements throw the soil towards the tree continually and prevent the formation of satisfactory furrows at this point. Once the trees are of good size, large-scale earth movement by grading is no longer practicable. Smoothing, carried out regularly, will maintain the original irrigation slope, level the surface, and contribute largely to obtaining that uniform penetration of water for which a correct irrigation slope was designed in the first place. The operation should be carried out when the soil is dry, that is, when the soil is approaching the permanent wilting point. If the operation is done when the soil is moist there is a danger of compacting the sub-surface soil.

Control of Weed in Supply Ditches

The most troublesome weed is *Paspalum digitatum*, seeds of which are brought in continually in the irrigation water. The best method is to remove them by chipping when young in order that they may never gain a foothold.

Cement-lined ditches require least maintenance. Cracks should be filled in with cement mortar to prevent paspalum from taking root.
Weed on the banks by the cement lip should be cut down, for rank growth trailing in the ditch will appreciably slow down the flow of water.

Earth ditches provide the greatest footholds for weeds. Weeds reduce the original capacity and slow down the flow, and cleaning the weed makes the ditch more and more a cut ditch than was intended, thereby increasing the amount of “dead water” that must be drained out after each irrigation. Eventually such a ditch must be ploughed up and remade.

Spraying with power kerosene or some of the newer weedicides has proved the best method of control for established ditch weed.

Grazing with sheep provides an excellent control, and the resultant short turf may make a good ditch surface. Grazing can only be done at the cost of fencing off the ditch or tethering the animals.

Provision of Surface Drainage

In the irrigation areas that depend on surface drainage, the drainage ditch at the footland of an irrigated block should be broad and shallow. It is then capable of tillage for weed destruction.

Drainage ditches should be kept in efficient condition as to grade and freedom from weed, not only in irrigation seasons but also during the winter.

Drainage provisions for winter should be made as follows: plough a furrow down the land connecting with the footland drainage. Clean out the footland drainage. The outlet of the farm drainage ditch should be eighteen inches above the bed of the community drain, as a safeguard against the backing-up of water in the latter during wet periods.
CHAPTER 12

PEST, DISEASE, AND FROST TREATMENTS

PRINCIPAL PESTS AND DISEASES

Citrus plants are subject to a formidable array of pests and diseases of a parasitic nature. The more commonly occurring are listed below, being grouped according to the obvious feature of their incidence. In addition to the parasitic organisms there are disorders due to deficiency, excess, or imbalance in nutrition and climatic influences, which are discussed elsewhere, and there are diseases and disorders of harvested fruit, known collectively as wastage, which are treated in Chapter 14. Viruses have been mentioned in Chapter 3.

PESTS

PESTS OF ROOT, TRUNK, AND MAIN LIMBS

- Fruit-tree root weevil
- Longicorn beetle
- Fruit-tree moth borer (branch girdler)
- Elephant beetle
- White louse scale

Baryopodus squalidus
Disterna plumifera
Cryptophasa unipunctata
Orthorrhinus cylindrostris
Unaspis citri

PESTS OF LEAVES AND TWIGS

(a) Chewing:

- Fuller’s rose weevil
- Grey striped weevil
- Orange butterfly caterpillars
- Citrus gall wasp

Pantomorus godmani
Perperus insularis
Papilio anactus and P. aegeus
Eurytoma felli

(b) Sucking:

- Citrus black aphid
- Mealy bugs
- White wax scale
- Pink wax scale
- Brown olive or black scale
- Hemispherical scale
- Soft brown scale
- Circular black scale
- Pulvinaria scale
- White fly

Toxoptera aurantii and Aphis citriecidis
Pseudococcus spp.
Ceroplastes destructor
Ceroplastes rubens
Saissetia oleae
Saissetia hemispherica
Coccus hesperidum
Chrysomphalus ficus
Pulvinaria cellulosa
Aulacaspis citri

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PEST, DISEASE, AND FROST TREATMENTS

PESTS OF FRUIT OR OF FRUIT, LEAVES, AND TWIGS

(a) Sucking insects and mites:
- Dicky rice weevil
- Red scale
- Yellow scale
- Purple or mussel scale
- Thrips
- Rust or Maori mite
- Bud mite
- Bronze orange-bug
- Spiny lemon-bug

(b) Chewing insects:
- Citrus tree-hoppers
- Snail

(c) Fruit-piercing or -puncturing:
- Queensland fruit-fly
- Mediterranean fruit-fly
- Orange fruit-borer (light-brown apple-moth)
- Orange moth

Diseases

(Causal organism is shown in brackets.)

DISEASES OF ROOT, TRUNK, AND MAIN LIMBS

- Root-rot (Phytophthora citrophthora)
- Collar-rot (Phytophthora citrophthora, P. parasitica)
- Armillaria root-rot (Armillaria mellea)
- Nematode root injury (Tylenchulus semipenetrans)
- Non-parasitic: Lichens, green algae

DISEASES OF LEAVES AND TWIGS

- Twig die-back and blight (Sclerotinia sclerotiorum and spp. of Ascochyta, Fusarium, Alternaria, Septoria)
- Leaf-spot and -blight (Phytophthora citrophthora)
- Pink disease (Corticium salmonicolor)
- Non-parasitic: Felt fungus (Septobasidium pseudopedicellatum)

DISEASES OF FRUIT MAINLY, OR OF FRUIT, LEAVES, AND TWIGS

- Black spot (Guignardia (Phoma) citricarpa)
- Melanose (Diaporthe citri)
- Scab (Sphaceloma fawcettii)
- Septoria spot (Septoria depressa)
- Sooty blotch (Gloeodes pomigena)
- Fly-speck (Leptothyrium pomi)
- Brown spot of mandarin (unidentified)
- Non-parasitic: Sooty mould (Capnodium citri)
Diseases—continued

FRUIT ROTTS

Brown rot (Phytophthora citrophthora)
Green mould (Penicillium digitatum)
Blue mould (Penicillium italicum)
Grey mould (Botrytis cinerea)
Stem-end rot (Diaporthe citri)
Cottiony rot (Sclerotinia sclerotiorum)
Black rot of navels and centre rot of lemons (Alternaria citri)
Other rots (spp. of Diplodia, Dothiorella, Colletotrichum)

Whilst the pests and diseases are numerous, fortunately there are comparatively few main pests and diseases of a given citrus variety in a particular location, owing to the operation of host specialization, climatic adaptation, the effect of seasonal conditions, and other aspects of the incidence of the organisms. Practices associated with pest and disease control therefore vary remarkably in different regions, and often in different districts.

**Host Specialization**

Some pests and diseases are common on various kinds of cultivated citrus. Others specialize on certain species or even on certain varieties. Thus gall wasp is particularly severe on lemons and grapefruit; bud-mite on Washington Navel orange and lemons, much less so on Valencia orange, grapefruit, or mandarins; lemon scab attacks lemons, mandarins, and their hybrids, not oranges or true grapefruit. Black spot attacks all varieties of citrus but only becomes manifest as a serious economic disease on Valencias; Washington Navel and other early-ripening oranges are harvested before the development of the latent infection that results in skin-spotting. Brown spot is a disease confined to certain mandarin varieties.

**Climatic Adaptation**

Among citrus pests and diseases there is a very considerable degree of climatic specialization. This is evident between northern and southern districts. Circular black scale and Pulvinaria scale are common in south-east Queensland, but scarcely extend southwards. Citrus rust or Maori mite is worse from Queensland down to Moorlands than in a southerly direction. Bronze orange-bug extends from Nambour as far south as the Gosford-Sydney region, neither north nor west of this zone. White louse and purple scale extend down the east coast districts as far south as the Gosford-Sydney region, seldom south or west of it. Thus whilst the most southerly areas are not concerned with certain troubles, other diseases such as anthracnose and citrus pit are rather peculiar to them.

As well as the differences between north and south, the pest and disease situation divides broadly into that obtaining in the humid coastal citrus districts and that prevailing in the arid and semi-arid inland areas, mainly an east-west division. In the former the variety of pests is greater and includes a number of scale insects (among which white wax scale is usually
PEST, DISEASE, AND FROST TREATMENTS

important), and leaf-eating weevils, which do not occur inland. Fruit-fly is predominantly a coastal pest. On the coastal belt the variety of diseases also is greater, including such diseases as black spot, melanose, scab, fly-speck and -blotch, and the epiphytic lichen, none of which is an economic problem inland.

In inland districts, whilst growers are relieved of the variety of pests, they face a problem controlling the predominant pest, red scale; whilst they are also relieved of the variety of diseases, they must deal with the predominant disease, Septoria, which is of no account on the coast.

Owing to this climatic specialization, the importance of obtaining local expert advice in the matter of pest and disease control can scarcely be over-emphasized. Local spray programmes are obtainable from the Department of Agriculture and are based upon the regularity with which pests and diseases make their appearance in a particular location.

Seasonal Conditions

Variations in the spray programme for a given locality are brought about by the effect of seasonal conditions on the development of pests and diseases. Thus in the coastal districts in mild moist seasons white wax scale assumes the proportions of the dominant scale, whilst in hot dry years, white wax decreases and red scale increases. Prolonged heat-waves or a succession of minor heat-waves decrease the population of all scales.

The humidity of the season also affects scale-parasitizing fungi, for example Sphaerostilbe. It is necessary for a grower to keep a close watch on the seasonal march of pests and diseases in his grove, particularly at those stages that will afford a guide to the likely prevalence of the pest and disease for that season.

Orchard Factors

Among other factors affecting the occurrence of pest and disease are the health and age of the tree. Melanose, black spot and white louse scale are worse on aged and weak than on young or vigorous trees. Dust from traffic or ranging fowls in the orchard affects the insecticidal and fungicidal programmes.

METHODS OF CONTROL

Methods of control may be classified in several ways, but the classification under the four main headings—exclusion, immunity, eradication, protection—is useful, for it indicates the purpose of the operation. Each method of control is employed against citrus pests and diseases, and examples are discussed in each case.

Exclusion

Exclusion is the method of preventing the entry of a pest or disease into trees or areas that are free from them. From the national or industrial point of view the prohibition on the importation of citrus fruits or plants into Australia, which came into operation in 1932, is a most important method of preventing the introduction of pests and disease; by strict
quarantine measures many diseases such as citrus canker, and pests such as citrus red mite, which are prevalent in other parts of the world, have been excluded from entry into this country.

Exclusion or quarantine is also practised on a district level; for example, in New South Wales, under the Irrigation Act a virtual quarantine exists for the protection of the Murrumbidgee irrigation area.

From the orchardist's point of view many control measures are efforts to exclude pests and diseases, for example: (i) selection of budwood against virus; (ii) fumigation of young trees or dipping in white oil to exclude pests from a new planting; (iii) planting the young tree so as to maintain the union well above ground-level in order to exclude Phytophthora from the scion, which may otherwise develop collar-rot; (iv) skirting of trees to prevent the contact of the lower limbs and fruit with the soil, which assists in excluding Phytophthora as the cause of brown rot; (v) destruction of weeds which afford a means of communication between the soil and the tree, and prevent root weevil from gaining access to the tree by that means.

Immunity

Immunity consists in the use of varieties resistant to disease. To achieve this object, we must clearly distinguish between varieties that escape disease, those that tolerate disease, and those that are resistant or immune.

Varieties that escape disease. For example, Washington Navel oranges escape black spot because they are picked before the environmental conditions are favourable for the development of the latent causal organism, although if they are allowed to hang late they may develop the disease, showing that the variety is inherently susceptible.

Varieties that tolerate disease. Rough lemon rootstock, for example, is tolerant of several virus diseases, such as scaly-butt or stunting, tristeza.

Varieties that are resistant or immune. The facts already referred to under host specialization show that there are degrees of susceptibility to various pests and diseases on the part of a particular variety. So far immunity is being used only in its application to disease control; an outstanding example being the use of trifoliata rootstock for its Phytophthora immunity. The use of this stock is an endeavour to place citrus on the same footing with regard to a resistant rootstock as apples (for woolly aphid resistance) and grapes (for phylloxera resistance). Another use of immunity that is purely in the experimental stage is mild-strain protection, in which it is being investigated whether infection with a mild strain of a virus will protect the scion from more severe or multiple-strain infection. Varieties resistant to certain diseases have been produced overseas, for example Perrine lemon resistant to lemon scab and wither-tip, but so far varieties resistant to important diseases have not been bred in Australia. It may be cited, however, on behalf of varieties originating in this country, that Wheeny grapefruit is symptomless on infection with stem-pit virus, and that Imperial mandarin is resistant to brown spot.
Strictly speaking, eradication is the method by which pests and diseases are completely eliminated. When a new pest or disease occurs in a previously free area, this is the first method contemplated officially. The eradication of citrus canker in Australia when it occurred many years ago in the far north, and in South Africa, are examples. The Argentine ant eradication campaign being carried out in New South Wales and Western Australia aims at the eradication of a potentially serious problem of citrus orchards, as it is in California.

Fig. 71. White louse, causing bark splitting.

Two main methods whose aim is eradication are hygiene and biological control.

Hygiene. The practice of sanitation or hygiene in the nursery, orchard, packing shed, and market is eradication in aim, but in the nature of things is only partially eradication in practice. Hygiene practices include (i) disinfection of diseased material, (ii) removal of diseased plants and plant parts, and (iii) sterilization of the soil.

The hot-water treatment of infected young trees to eradicate Phytophthora is an example of disinfection.

Removal of diseased plants and plant parts, such as cutting out diseased orchards as required by law in the various States, cutting out dead wood, picking up and destroying fallen fruit and other infected material producing the inoculum for reinfecting healthy tissue—all these practices aid other methods of control. The clearing out of tree centres of dead wood deserves special mention. In a normally healthy tree it will often be found that shade and the effects of pests and diseases lead to the weakening or death of certain shoots. As the canopy of foliage expands, the less vigorous shoots become completely shaded and die out. Wood-inhabiting fungi such as Phomopsis, Alternaria, etc., may be directly responsible for the death of certain shoots, whilst the attacks of white louse, red scale, branch girdler, and wood borers may be responsible for the weakening of parts of the tree, loss of vigour, and death of shoots.
It is therefore a desirable practice periodically to clear out from the inside of the tree all weak, dead, and diseased shoots, cutting them back to completely healthy wood. The prunings should be raked up and burnt.

Soil in seed-beds may be sterilized so as to eradicate damping-off fungus.

Biological control. Cottony cushion scale never assumes the proportions of an economic pest in Australia, owing to natural parasitism by the Rodolia or Vedalia beetle and the parasitic fly Cryptocephalum iceryae. Mealy bugs likewise are controlled by natural parasitism in Australia.

Few other examples of complete biological control can be quoted; on the other hand, insect predators such as the steely-blue ladybird beetle, which feeds on scales, constitute a serious check on pest development. The effectiveness of predators must be kept in mind in spraying for pests so as to avoid using a spray that will injure the predators as well as the pests. The limitation of DDT for control of citrus pests lies in this direction.

Scales are also subject to fungal parasitism, for example, by Sphaerostilbe and others. While these bring about some destruction of scales they are not regarded as a serious check when conditions favour scale development.

Protection

Protection consists of three general methods; (i) alteration of environment; (ii) improving the vigour of the plant; and (iii) the use of insecticides and fungicides.

Alteration of environment. Temperature, humidity, and other environmental factors are very important for the development of parasitic organisms, and differences of environment as between the coast and inland have already been noted as the main factors for the different incidence of pests and diseases in these contrasting regions. In recent years the effects of environment on the two most important citrus diseases of coastal New South Wales districts have been described in very considerable detail by Fraser and Kiely. The importance of alterations to the environment as a control measure may be exemplified by Armillaria disease, in which exposure of the roots for an indefinite period is the main means of control, and by Phytophthora root-rot, in which drainage and the adjustment of pH create a soil environment less favourable to the disease organisms. Suppression of dust aids in the control of scale pests.

Improvement of plant vigour. Improving the growth of trees by cultural methods appropriate to the case is a very important method of protection in many instances. Melanose is essentially a disease of declining trees, and black spot is much more difficult to control on old and weak trees. Scales are usually more severe in their effects on weak trees. Cultural methods that improve the vigour of the trees therefore may mitigate the effects of certain pests and diseases.

Use of insecticides and fungicides. While all the methods of pest and disease control listed in the foregoing are of obvious importance, the most important method of control is still the use of insecticides and fungicides. These may be defined as substances used as sprays, dusts, fumigants, and other preparations, which bring about the death of pests.
and the organisms that cause the disease. Substances used effect this control in a variety of ways. Fungicides usually give a protective coating to the fruit, leaves, or stem, as the case may be; insecticides either poison the chewing insects or kill by contact with the insect.

Fig. 72. White wax scale. Mature scale on stem. Young scale at correct stage for oil spraying, lining the mid-rib and veins of leaves.

When treatment of a variety of pests and diseases is required, a programme of fungicidal and insecticidal sprays is employed, and considerable attention must be given to the interaction of sprays and fumigation in conjunction with the tolerance of the tree. The main components in a spray programme for one district have been outlined, as an example, towards the end of Chapter 8.

INSECTICIDES AND FUNGICIDES

Bordeaux Mixture

Bordeaux mixture is prepared from copper sulphate or bluestone, and lime and water. White spraying oil is usually added as a sticker. The formula as written, for example, 2 : 2 : 100 : ½, always refers in that order
to the constituents mentioned: 2 pounds of bluestone, 2 pounds of hydrated lime, 100 gallons of water, and half a gallon of white oil.

Preparation. The pulverized or "snow" form of bluestone is now preferred because of its ready solubility. The weighed amount is placed in the sieve over the opening of the spray-vat and washed in with water. After adding the bluestone, water is run into the vat until it is nearly full.

Large crystalline bluestone dissolves more slowly. When it is to be used it is weighed into a coarse-meshed bag and suspended in water in the vat until it dissolves. Alternatively it may be dissolved in a separate vessel, which must be of wood, earthenware, or copper, for bluestone rapidly corrodes iron or galvanized-iron vessels.

The lime used may be either fresh stone lime (quicklime) or hydrated lime, which is now favoured owing to its greater convenience. The latter must be good-quality new season's product or the resultant Bordeaux will be of low quality and the lime will settle out. The amount of hydrated lime to be used is 1-3 times that of stone lime; in the small amounts used for sprays 1·5 is the factor adopted, for example, six pounds of hydrated lime equals four pounds of stone lime.

The quantity of hydrated lime is weighed into a dry container and then stirred into a bucket containing sufficient water to make milk of lime. If stone lime is used it is slaked with sufficient water to make milk of lime.

Then, setting the agitator going, add the milk of lime and rinsings of the bucket through the sieve to the bluestone dissolved in the spray-vat.

It will be noted that each ingredient is well diluted before mixing, and one of the ingredients must be diluted to the maximum extent. The mixing of strong solutions gives a coarse-grained precipitate that settles out readily.

For steel spray-vats, add the milk of lime first and dilute to the maximum extent, then with the agitator running, add the appropriate quantity of dissolved bluestone.

White spraying oil is added last to the mixture. Measure out half a gallon (per hundred gallons of spray) into a bucket, break down to an emulsion with about a gallon of water, and add through the sieve.

Filling the vat to the "full" level completes the operation.

Uses. Bordeaux mixture is the general-purpose fungicide used on citrus-trees. It is used as a spring and summer spray for those diseases with an infective period during that time, such as black spot, melanose, and lemon scab. On the other hand it is used as an autumn spray for some other diseases, such as Septoria spot, brown rot, lemon pit or blast, and anthracnose, and for snails. Bordeaux is also used for control of exanthema or copper deficiency.

Precautions. Certain precautions must be taken when using Bordeaux mixture. These are as follows:

1. Strength. Only weak Bordeaux mixture is used on citrus-trees compared with the strengths that can be used on pome and stone-fruit trees. Further, the total amount used in the season must be limited, for excessive amounts cause a chronic injury, especially to oranges, which
shows up as a general hardening of the trees and a reduction in the quality of the fruit. Vigorous and young trees will stand more Bordeaux mixture without injury than old or weak trees, and this is reflected in the spray programmes recommended, for example, for black spot.

2. Accumulation of residues. Bordeaux mixture deposits a layer of colloidal basic copper sulphate over the sprayed surfaces of leaves, fruits, and shoots, together with other solid residues from the mixture. The accumulation of residues from repeated or heavy Bordeaux spraying and other sprays with solid ingredients increases the problem of scale control.

Fig. 73. Distortion of lemon leaves by citrus-bud mite.

3. Combination with nutrient sprays. Residues are aggravated when zinc and other minor element sprays are added unless the solid ingredients are reduced; for example, see zinc-Bordeaux mixture, under Septoria spot, in Table XXVIII.

4. Fumigation for scale control. This cannot be carried out after Bordeaux sprays, but may be done as late as three to four weeks before them with safety. In districts where spring-summer routine Bordeaux sprays are necessary, fumigation as a method of scale control is superseded by the use of white oil. In some districts where autumn Bordeaux sprays are required, fumigation can be used, provided that it precedes the Bordeaux spraying. Fumigation is safe after the use of zinc-Bordeaux mixture.

5. Lime-sulphur cannot be used after Bordeaux in the same growing
season without causing some tree injury, but can safely be used before it. When a spring-summer Bordeaux programme is necessary, summer sprays of lime-sulphur must be omitted. Lime-sulphur sprays are then applied in the dormant season only, if necessary to give control of white louse or wettable sulphur may be combined with the first Bordeaux spray.

6. Bordeaux and oil sprays (for scale control). White oil can be safely combined with Bordeaux mixture or can be used immediately afterwards. White oil with soda added for late spray of white wax scale, however, can cause a heavy leaf-fall after Bordeaux mixture. It is therefore desirable to spray early for white wax, thus avoiding the addition of soda. Red oil applied up to three months after Bordeaux causes tree injury. This injury can be practically eliminated by adding soda, either washing-soda crystals or soda ash.

_Bordeaux Paste and Zinc-Bordeaux Paste_

Bordeaux paste for painting wounds is made from 1½ pounds of copper sulphate, 1½ pounds of quicklime (2 pounds of hydrated lime), 2 gallons of water, or similar proportions for smaller quantities. As in Bordeaux mixture, the bluestone is dissolved first and milk of lime is added to it. Where fumigation is employed a zinc-Bordeaux paste is used consisting of 1 pound of zinc sulphate, ¼ pound of copper sulphate, 1 pound of fresh hydrated lime, and 1 gallon of water.

_Other Copper Sprays_

_Burgundy mixture_. Burgundy mixture or soda-Bordeaux has been used at times on citrus as a substitute for Bordeaux, when lime has been scarce. It is prepared similarly to Bordeaux, except that lime is replaced by soda. Either fresh washing-soda or soda ash may be used, equivalent amounts for 2 pounds of stone lime in Bordeaux mixture being 3 pounds of fresh washing-soda, or 1 pound 2 ounces of soda ash. See p. 217 for notes on the qualities of these substances and the deleterious effects of soda on the trees.

_Copper oxychloride_. This proprietary material has been used as a Bordeaux substitute. It has suffered by comparison owing to its much lower resistance to weathering after application and therefore a lowering of its efficacy as a fungicide, but recent formulations show a considerable improvement in this respect.

_Cuprous oxide mixture_. This mixture has been favoured in Queensland largely because it leaves less residue on the trees than Bordeaux mixture, thereby being less encouraging to scale insects, and it has not such a deleterious effect. Two solutions are prepared from the following ingredients:

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<th>B</th>
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<td>Copper sulphate</td>
<td>3 pounds</td>
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<tr>
<td>Molasses</td>
<td>3 pints</td>
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<tr>
<td>Water</td>
<td>12 pints</td>
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Solution A is made by dissolving the bluestone completely. The molasses is added and stirred well into the solution. Solution B is made by adding
fresh caustic soda to the amount of water. As heating occurs, allow to cool before use.

Next, solution B is added and stirred well into solution A. Stirring becomes difficult and should be continued until it becomes easier. The mixture is then allowed to age for at least a week, during which time the colour changes from green to yellow. Stir occasionally. After mixing,

the height of the mixture in the vessel is measured with a rod and the vessel is covered to reduce evaporation. Before use add water to replace that lost by evaporation.

For use on citrus, three gallons of the stock solution is diluted with water to make forty gallons.

**Honey formula.** This is used when the spray is to be combined with white spraying oil. Solution A is replaced by the following:

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<td>3 pounds</td>
<td></td>
</tr>
<tr>
<td>Honey (third grade)</td>
<td>½ pint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>14⅔ pints</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The honey formula, however, cannot be combined with BHC.

**Lime-sulphur**

Nowadays lime-sulphur is frequently purchased as a prepared stock solution. For use it is diluted with water, the proportions of gallons of lime-sulphur to gallons of water being briefly shown as 1 : 8, 1 : 50 and so on.

**Uses.** In general, lime-sulphur is not widely used on citrus, its chief uses being (a) in dormant spraying for white louse and as a check to
purple scale, and (b) of summer strength for citrus-bud mite, rust or silver mite, and white wax scale.

Precautions. In using lime-sulphur the following points should be kept in mind:

1. Strength. Whilst trees are dormant, lime-sulphur may be used at concentrations of 1:8 to 1:15, when it is applied to the trunk and main limbs. Provided the trees are quite dormant, some unavoidable drift of spray to the leaves will not cause injury. Once trees have resumed growth, much more diluted sprays must be used, namely 1:40.
2. Avoid hot weather and take into consideration hot weather to follow.
3. Trees to be sprayed should have ample soil moisture, as spraying trees when soil is dry will result in severe defoliation and fruit drop.
4. Lime-sulphur cannot be used with complete safety after Bordeaux mixture in the same growing season.
5. Red oil after lime-sulphur gives leaf injury.
6. White oil after lime-sulphur is generally safe. To obviate some leaf-fall, avoid hot weather and allow an interval of two to three weeks between sprays.

White Oil

White spraying oil, consisting of highly refined petroleum oil fractions in a miscible or emulsifiable form, is the standard insecticide for the control of scale pests when fumigation is not or cannot be used. It has superseded red spraying oil owing to its wider margin of safe usage.

Uses. White spraying oil is applied for the control of the following pests:

1. Red, purple, brown, soft brown, yellow, circular black, and Pulvinaria scales. The period ranges from December to February.
2. White wax and pink wax before the wax forms an effective cover on the young scales. Mid-December is frequently the best time, but a second spray may be required in mid-February. After this period the addition of soda is necessary (see Table XXVIII).
3. Citrus-bud mite and rust or silver mite, mid-December to mid-February applications, the latter being the most effective for these mites.

Precautions. The following precautionary measures should be taken when using white oil:

1. Strength. In humid regions the usual strength is one in forty gallons of water. Relative to the species of insects to be controlled and the severity of the infestation, one spray in midsummer may be sufficient, or it may be necessary to follow with another at an interval of four to eight weeks.

In the warmer summer of inland districts a spray of one in eighty followed by a second at the same strength after a two- to three-day interval offers a definite advantage over a single application of one in forty. Alternatively, white oil and fumigation may be used, either a spray of one in forty in January followed by fumigation, or fumigation in January followed by white oil one in forty in early March.

2. Spraying with white oil late in the season, after March, carries the risk of reducing the amount of blossom in the following spring.
3. White oil spraying, especially in inland districts, also tends adversely to affect fruit quality, and may be productive of some hard green fruit.

4. Bordeaux mixture or lime-sulphur after white oil may lead to a certain amount of blotching of the fruit, owing to the failure of the sprays to spread evenly over the oily surface. In the case of Bordeaux mixture this is overcome by the addition of oil, half a gallon to the hundred.

5. Resin soda following on white oil, even after an interval of three months, causes a fairly considerable leaf-fall. The reverse order is quite safe.

6. Heavy Bordeaux or other deposits on the leaves reduce the effectiveness of white oil as a scalicide, because they absorb some of the oil.

**Soda**

Soda is used for the destruction of white wax scale after the scales have migrated from the leaves to the twigs and have developed a white cap of wax, when white oil is no longer effective. The waxy covering of the scale is destroyed by the soda. It is also added to resin to make the resin soda used for the control of a number of scales, and is used in Burgundy mixture.

Either washing-soda or soda ash is satisfactory, but only the fresh, transparent crystals of washing-soda should be used in making up the spray, because when the soda becomes white and opaque through exposure to air its strength is increased, and if used to make up spray too great an amount may be taken.

Soda ash does not change in strength on exposure to air, and is used at the rate of three-eighths the amount of the washing-soda required.
Soda spraying is attended by more or less damage in the form of leaf-drop and fruit-burn, especially after Bordeaux mixtures.

**Nicotine Sulphate**

Nicotine sulphate is especially directed to the control of aphids and thrips, but is being superseded by synthetic organic insecticides. The strengths given in Table XXVIII refer to the amount to be used of the commercial preparation, which contains 40 per cent nicotine sulphate. This substance is a contact insecticide, and should always be used with a wetting agent, or spreader. It is most effective when used with an alkaline material such as soap, lime-sulphur, Bordeaux mixture, or white oil.

**Pyrethrum and Derris**

The active principle of pyrethrum, pyrethrin, is a contact insecticide; Rotenone, the active principle of derris, acts as both a contact insecticide and a stomach poison.

**Arsenic and Fluorine**

Arsenate of lead, although a highly toxic stomach poison, can be used at most to a very limited extent on citrus, because of its effect on the fruit—reducing the acid content and giving a very flat insipid flavour. The effect of a spray extends beyond the season of application. An arsenical insecticide, therefore, cannot be used as a general tree spray in citrus. Thus for an attack upon chewing insects, some other stomach poison, or a contact insecticide not having an objectionable physiological effect on the tree or the fruit, is necessary.

A stomach poison used to some extent is fluorine in the form of cryolite or as sodium fluosilicate (see under fruit fly and Fuller’s rose weevil in Table XXVIII). Cryolite powder is prepared from synthetic or naturally occurring cryolite, sodium fluoaluminante (Na₃AlF₆).

Cryolite should not be mixed with zinc-Bordeaux spray or nicotine. It may be mixed with white oil.

**Synthetic Organic Insecticides**

The development of new insecticides was accelerated by war-time research into substitutes for nicotine sulphate and pyrethrum, which were in short supply. The synthetic organic insecticides tested on citrus are of two main classes, the chlorinated hydrocarbons (DDT and BHC) and the organic phosphorus compounds (Parathion, E605, and HETP).

**DDT and BHC.** Dichlorodiphenyltrichloroethane (C₁₄H₉Cl₃), known as DDT, has been found to be toxic to an extremely wide range of insects. It has a lengthy residual action or persistence. It is of little value for scale or mite control, and the persistent residues adversely affect the natural predators of many other pests. It is used in low concentrations for bronze bug, fruit fly, and Fuller’s rose weevil.

BHC, or benzene hexachloride (C₆H₅Cl₆), is much more volatile than DDT, and consequently has a much shorter residual action, and does not kill out predators to the same extent. It is particularly effective for
soil applications and is indicated for the leaf-eating beetles (dicky rice weevil, Fuller’s rose weevil, and fruit-tree root weevil), which migrate from the soil, and for which spraying of the skirt of the tree and the soil is carried out.

It is expressly useful also for such classes of insects as aphid, bugs, and grasshopper (bronze orange-bug, spiny lemon-bug, green tree-hopper).

A deodorized form is available for spraying near picking-time.

Organic phosphorus compounds. Organic phosphates, such as Parathion ($C_{10}N_{14}NO_3$ PS), E605, and HETP, are effective against nearly all the insects and against mites as well. They give an immediate kill and do not possess the residual action of DDT and BHC. Parathion and E605 have a very short residual effect, HETP has none. Parathion in particular has been used widely in overseas countries and experimentally in Australia against red scale, and is toxic to aphids and other insects and mites. As it takes twenty to thirty days to disappear from plant tissue, three to four weeks after spraying should elapse before harvesting.

Organic phosphates are very toxic to man and must be handled with the utmost caution; special protective clothing should be used and other protective action taken. Even vapours in orchards on hot, calm days may cause sickness. Malathion, which is much less poisonous to man than Parathion, is a more promising insecticide.

Hydrocyanic Acid Gas

Fumigation with hydrocyanic acid gas is the alternative method of scale control to white oil sprays. It is the most effective single method of controlling red scale and is especially suitable for inland areas. Climatic conditions and the use of Bordeaux sprays militate against its use in coastal districts.

Preparation of grove. Fumigation should be done some three weeks after, or immediately before, an irrigation; recently irrigated ground produces undesirable high humidity under the tent. The ground should be made level, and have a fine surface and be free of weeds, to enable the flaps of the sheets to lie closely appressed to the soil surface, and so reduce leakage of the gas.

In the case of Valencian orange-trees, picking of the late-hanging fruit before fumigation assists control of scale. Because scale is hard to kill on mature fruit, late-hanging fruit is a source of infection to the new crop.

Some pruning of the trees will usually be required. Skirting the growth to a height of about twelve inches from the ground is necessary, since the gas is lighter than air, and dense growth at ground-level may not receive a dose that is lethal to the scale. Very densely foliaged trees may require to be thinned somewhat. The trees should be examined particularly at the top to prune away any limbs or dead wood that could damage the sheets.

Covering the trees. Fumigation sheets used for covering trees are octagonal, and made from closely woven heavy calico or heavy duck (ten- or twelve-ounce weight) or plastic, the essential features of the
sheets being heaviness and durability to withstand the usage, and a close weave so that they will be as gas-tight as possible. Sheets should be dry when used. The sizes required for different-sized trees are given in Table XXVI.

### TABLE XXVI
**FUMIGATION SHEET SIZES**

<table>
<thead>
<tr>
<th>Height (ft)</th>
<th>Diameter (ft)</th>
<th>Required size of sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
<td>25 x 25</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>30 x 30</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>35 x 35</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>40 x 40</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>45 x 45</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>50 x 50</td>
</tr>
</tbody>
</table>

The sheets are marked in feet from the centre to the edge, and before being marked they should be shrunk by damping.

The number of sheets required is as follows: twenty-five to thirty tents for a four-man gang; ten to twelve for a two-man gang.

A systematic plan for working through the orchard is needed, so that the sheets can be shifted with a minimum of effort and no trees are missed.

The sheet is pulled over the tree by means of ropes and poles, or by a mechanical tent-puller. Pulling is done in the same direction as the seams, to lessen the strain on the sheet. The overlap is folded back and flattened on the ground to reduce leakage of gas.

**Dosage**

The dosage required is obtained by employing the “over and around measurements” of the tree; the “over” measurement is from the ground on one side over the top of the tree to the ground on the other, and is obtained by adding the markings on the sheet; the “around” measurement is the circumference of the widest part of the tree, usually about four feet from the ground (see Table XXVII). The dosage figures given in the table may be read as the number of calcid briquettes, ounces of sodium cyanide, or units (14 cubic centimetres) of liquid HCN. If cyanogas is used the dosage figure should be doubled and the resultant dosage measured as ounces of cyanogas; if potassium cyanide is used, the figure should be increased by one-third. When using sodium cyanide the proportions of cyanide, sulphuric acid, and water should be 1 : 1 1/2 : 2.

Hydrocyanic acid gas is generated by one of two main methods: (i) liquid hydrocyanic acid, obtained in cylinders and introduced under the tent by machine; (ii) calcium cyanide. One commercial preparation of calcium cyanide is calcid briquette (88 per cent calcium cyanide). The number of briquettes required (see Table XXVIII) are fed into a
TABLE XXVII

DOSAGE CHART FOR FUMIGATION: "OVER AND AROUND" MEASUREMENTS*

Time of exposure 45 minutes.
Distance around the tree (in feet)

| Distance over the tree (in feet) | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
|----------------------------------|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 6                               | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 8                               | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 10                              | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 12                              | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 14                              | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 16                              | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 18                              | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 20                              | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 22                              | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 24                              | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 |
| 26                              | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 |
| 28                              | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 |
| 30                              | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 |
| 32                              | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 |
| 34                              | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 |
| 36                              | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 |
| 38                              | 38 | 40 | 42 | 44 | 46 | 48 |
| 40                              | 40 | 42 | 44 | 46 | 48 |

*Source: Fumigation for Control of Scale Insects of Citrus Trees, New South Wales Department of Agriculture Bulletin.
portable machine that grinds them and blows the fine powder under the
tent. A second commercial preparation is Cyanogas, a fine powder con-
taining about 45 per cent calcium cyanide, which is also introduced
under the tent by a suitable machine.
Calcium cyanide generates the gas on exposure to air, according to
the following reaction:

\[
\text{Ca(CN)}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{HCN} + \text{Ca(OH)}_2
\]

At high relative humidity of the atmosphere the gas is almost all
generated from briquettes within five minutes, and from Cyanogas over
a somewhat longer period.
The tents are usually allowed to remain on the trees for forty to forty-
five minutes before being pulled onto other trees.

 Conditions for fumigation. Fumigation is mainly carried out at night,
because trees can be treated then with comparative safety. The highly
poisonous gas is particularly injurious to trees during daylight while
photosynthesis is going on. At night, when this process ceases, hydrocyanic
acid gas can be used with comparative safety. Also, conditions of tempera-
ture, humidity, and calmness of the atmosphere are more suitable usually
than in the day.
Wind is prejudicial to a satisfactory kill of scales, and fumigation
should not be continued if the wind force is such as to cause flapping
of the tents.
Owing to the high solubility of the gas in water, moist surfaces such as
damp foliage or soil moisture under the tent reduce the dosage available
for killing the scales. Fumigation should be stopped if dew appears.

 Fumigation seasons. Fumigation should be carried out in January,
February, and March to control scale on developing fruit as well as on the
tree, but it may be extended right through the winter till full bloom in
the spring. Winter treatment is of value on heavily infested trees when
followed by a subsequent summer fumigation.

 Injury. Different species of citrus are susceptible to injury from liquid
hydrocyanic acid gas in the following decreasing order of susceptibility:
oranges, mandarins, grapefruit, lemons. On the other hand, lemons are
particularly susceptible to Cyanogas.
Injury takes the form of tip-burn, a blackening of the young tender
tips of the shoots, which is more or less inseparable from satisfactory
fumigation and is usually taken to indicate that the dosage has been
suitable for killing scale. Some fall of old leaves usually occurs also.
Leaf-fall may be excessive, especially if a sudden and marked drop
in temperature follows fumigation. The fallen leaves may be either
shrivelled and scorched if the fumigation injury was severe, or green and
apparently healthy if the injury was slight. The severe form of defoliation
is often accompanied by pitting and scorching of the fruit, and possibly
the death of some twigs. These latter should be pruned out and the tree
irrigated, since under immediate treatment fumigated trees show a very rapid and marked general improvement.

**Precautions.** The following precautions should be taken to avoid injury:

1. Conditions for fumigation must be satisfactory if a good kill of scales is to be obtained and tree injury avoided.

2. Fumigation with hydrocyanic acid gas cannot be carried out at high temperatures and high humidities without bringing about serious injury to the tree. It may be done at high temperatures and low humidities or vice versa. The temperatures and relative humidities that have been found safe for fumigation in northern Victoria are:

<table>
<thead>
<tr>
<th>Temperature range (°F)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80—90</td>
<td>Below 40</td>
</tr>
<tr>
<td>75—9</td>
<td>60</td>
</tr>
<tr>
<td>70—4</td>
<td>82</td>
</tr>
<tr>
<td>60—9</td>
<td>90</td>
</tr>
<tr>
<td>50—9</td>
<td>94</td>
</tr>
</tbody>
</table>

It is recommended, however, that fumigation should be discontinued above a relative humidity of 85 per cent unless performed under the direction of an experienced fumigator, who could estimate the tolerance of the particular trees being fumigated.

3. It should be remembered that trees in poor condition are very subject to injury.

4. Fumigation must not follow the application of Bordeaux spray or paste until at least six months have passed. Zinc acts as a safener, and fumigation can follow immediately after the use of zinc-Bordeaux spray or paste.

5. Hydrocyanic acid is a highly poisonous gas, and a first-aid kit should be kept for emergencies.

**SPECIFIC TREATMENTS FOR PESTS AND DISEASES**

Table XXVIII gives in concise form the treatments for various pests and diseases. The recommendations of the New South Wales Department of Agriculture,\(^{11}\) representing a summary of the control measures applicable to the largest citrus-growing State, form the bulk of the matter in the table. Owing to the important effect of local conditions on the occurrence of pests and diseases and the particular method of treatment, official recommendations\(^9,^{10}\) for certain regions may be found to differ in some instances from those set out in the table and should be adhered to.
### TABLE XXVIII
### TREATMENT OF SPECIFIC PESTS AND DISEASES

<table>
<thead>
<tr>
<th>Pest</th>
<th>Treatment</th>
<th>Time of treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APHIDS</strong>. Clusters of tiny black or green aphids appear on new shoots and blossoms in spring and again sometimes in autumn. Setting of Navel oranges affected adversely.</td>
<td>1. Nicotine sulphate 1 pint, soft soap 5 lb. (or white oil ½ gal.), water to make 100 gals.</td>
<td>Spring, Autumn if necessary. Spray early to prevent injury to young growth. As above.</td>
</tr>
<tr>
<td></td>
<td>2. DDT spray 0·05 per cent. May be combined with routine Bordeaux mixture used in spring for fungus control or in autumn for snail or brown-rot control.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. HEPT ½ pint per 100 gals water.</td>
<td>As above.</td>
</tr>
<tr>
<td><strong>ANTS</strong>. Some species nibble edges of leaves, others affect trees indirectly by encouraging scales, repelling parasites.</td>
<td>Spray trunk and ground beneath trees with Chlordane 1·0 per cent or Dieldrin 0·5 per cent.</td>
<td>When ants are found ascending trees in numbers.</td>
</tr>
<tr>
<td><strong>BLACK THRIPS</strong>. These cause superficial scarring of fruit surface. Main crop Valencia oranges are most liable to injury.</td>
<td>1. HEPT ½ pint per 100 gals water.</td>
<td>December to February.</td>
</tr>
<tr>
<td></td>
<td>2. DDT spray 0·1 per cent.</td>
<td>December to February.</td>
</tr>
<tr>
<td></td>
<td>3. Nicotine sulphate ½ pint, white oil 1 gal., water to make 40 gals.</td>
<td>December to February.</td>
</tr>
<tr>
<td></td>
<td>Spray may be included with routine white-oil sprays for the control of red scale.</td>
<td></td>
</tr>
<tr>
<td><strong>BRONZE CITRUS-BUG</strong>. The egg clusters occur on undersides of leaves. The young and mature bugs puncture shoots (causing wilting and die-back) and fruit-stalks, causing fall of newly set crop.</td>
<td>1. Soft soap 10 lb. to 40 gals water.</td>
<td>June to July. Undersides of leaves must be sprayed.</td>
</tr>
<tr>
<td></td>
<td>2. Resin-soda spray; resin 10 lb., commercial caustic soda 3 lb., fish oil 1½ lb., water 40 gals.</td>
<td>June to July. Do not spray at other periods of year during very hot weather.</td>
</tr>
<tr>
<td></td>
<td>3. DDT spray 0·1 per cent.</td>
<td>Spring and early summer.</td>
</tr>
<tr>
<td></td>
<td>4. BHC or Lindane 0·04 per cent.</td>
<td>Spring and early summer.</td>
</tr>
<tr>
<td>Insect/Problem</td>
<td>Description</td>
<td>Method 1</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>Jarring the branches of the tree.</strong></td>
<td>White oil 1 gal. in 40 gals water.</td>
<td>Early morning, while bugs are very sluggish. Collect and destroy.</td>
</tr>
<tr>
<td><strong>BROWN OR OLIVE SCALE.</strong> Mature scales have an H-shaped ridge.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CITRUS BUTTERFLIES.</strong> Irregular shaped pieces are eaten out of leaves on scattered shoots. The large greenish caterpillar has brown and white or black and yellow markings, and may protrude a red forked process from behind the head when disturbed.</td>
<td>1. DDT spray 0.05 per cent.</td>
<td>Summer and especially autumn.</td>
</tr>
<tr>
<td></td>
<td>2. Arsenate of lead powder 1/2 lb. to 50 gals water.</td>
<td>Summer and especially autumn.</td>
</tr>
<tr>
<td></td>
<td>Caterpillars may not be numerous enough to warrant spraying, and hand-picking will then be sufficient. Young or cut-back trees with abundant new growth are susceptible to attack, and may also be infested with aphids.</td>
<td></td>
</tr>
<tr>
<td><strong>CITRUS-BUD MITE (Fig. 73).</strong> Mainly on Navel orange and lemon. Leaves are distorted, often heart-shaped. Growth is reduced, often rosetted. Blossoms are deformed, also fruits, especially of lemon.</td>
<td>1. White oil 1 gal. in 40 gals water.</td>
<td>Mid-February. White oil routine spray at this period for red scale will control bud mite.</td>
</tr>
<tr>
<td></td>
<td>2. Lime-sulphur 1 gal. in 40 gals water.</td>
<td></td>
</tr>
<tr>
<td><strong>CIRCULAR BLACK SCALE.</strong></td>
<td>See red scale.</td>
<td></td>
</tr>
<tr>
<td><strong>DICKY RICE WEEVIL.</strong> Grubs feed on roots. Adults migrate to leaves, where they produce obvious ragged or tattered edges. Fruit rind is also eaten.</td>
<td>1. Band the tree-trunks with sticky tree-banding material before blossoming and after chipping and cultivation.</td>
<td>August to December.</td>
</tr>
<tr>
<td></td>
<td>2. DDT spray 0.1 per cent.</td>
<td></td>
</tr>
<tr>
<td><strong>ELEPHANT BEETLE.</strong> Larvae tunnel in wood of main roots. Exit holes usually found round the butt.</td>
<td>Bordeaux paste acts as a deterrent to egg-laying beetles. Maintain trees in a healthy condition and resoil where main roots are exposed.</td>
<td>Paint trunks end of September.</td>
</tr>
</tbody>
</table>
**TABLE XXVIII—continued.**

<table>
<thead>
<tr>
<th>Pest</th>
<th>Treatment</th>
<th>Time of treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRUIT FLY.</strong> Adult punctures fruit, laying cluster of eggs which usually fail to develop into maggots (except in grapefruit and well-matured citrus fruits generally). Puncture areas soften and are subject to green mould infection. Early colouring fruit are first attacked.</td>
<td>1. Apply foliage spray made of 2 oz. sodium fluorosilicate or 2 oz. tartar emetic, 2½ lb. sugar and 4 gals water. Apply in patches at rate of 6 fluid oz. per tree, avoiding fruit.</td>
<td>Valencia orange December onwards. Navel orange, grapefruit, and mandarin, March to May. Spray six weeks prior to colouring of fruit; spray every seven days.</td>
</tr>
<tr>
<td></td>
<td>2. Pick up and destroy fallen and infested fruit.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Harvesting of fruit is compulsory under the Plant Diseases Act, N.S.W., as shown in next column.</td>
<td></td>
</tr>
<tr>
<td><strong>FRUIT-TREE MOTH BORER.</strong> Larvae ringbark branches, covering injured area with mat of webbing and sawdust. Yellowing of foliage also indicates injury.</td>
<td>Remove webbed material to expose tunnel opening. Insert pliable wire to kill grub, or inject a few drops of kerosene into tunnel to cause caterpillar to crawl out. Tunnels should be plugged afterwards with grafting wax or putty.</td>
<td>Intermediate crop Seville oranges by 31st December, main crop Seville and mandarins by 3rd October in those areas included in the Schedule to the Act. Elsewhere in State, by 15th December.</td>
</tr>
<tr>
<td><strong>FRUIT-TREE ROOT WEEVIL.</strong> Grubs feed on roots, greatly reducing vigour of top. Adults migrate to leaves but cause little damage. Also see p. 82.</td>
<td>1. Apply tangle-foot to trunks, forming band about 2 ins wide and about ½ in. thick, as high above ground as possible. Collect and destroy beetles at regular intervals, and freshen bands when required. Where trunks are exposed to the sun place banding material on grease-proof paper tied round the trunk. Cut down weed by which the beetles may reach the trees. Prune lower limbs back to 6 ins from ground.</td>
<td>Early August onwards, when webbing and frass observed on trees. Young plantings, especially near bushland, may be infested for the first four or five years.</td>
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<td></td>
<td>2. DDT spray, 0·1 per cent. Also spray ground and trash beneath trees.</td>
<td>Begin before early spring when weevils ascend tree-trunks, and maintain bands in an effective condition.</td>
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<td>3. Hand-picking.</td>
<td>When weevils first appear (often indicated by leaf-margin damage).</td>
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<td>As soon as possible.</td>
</tr>
<tr>
<td><strong>FULLER'S ROSE WEEVIL.</strong> Larvae feed on the roots. Adults migrate to the leaves where their feeding habits produce a typical neatly scalloped margin.</td>
<td>1. DDT spray 0.05 per cent.</td>
<td>January to February. Spray as soon as first weevils appear.</td>
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<td>2. Cryolite 1½ lb. to 50 gals water. If not included with routine oil spray, white oil ½ gal. to 100 gals water should be added as a spreader. See Fluorine, p. 218.</td>
<td>As above.</td>
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<tr>
<td><strong>GALL WASP.</strong> Large galls are formed on stems and petioles. Cut off and burn galls. The damage is particularly injurious to nursery stock, for the main stems are attacked.</td>
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<td>Autumn or winter. Complete by end of August.</td>
</tr>
<tr>
<td><strong>GREEN TREE-HOPPER</strong> (Fig. 75). Large deep scars develop on fruit from the damage caused by hoppers feeding on young fruit rind. DDT spray 0.05 per cent.</td>
<td><strong>PINK WAX SCALE.</strong> Conical pink scales occur on mid-ribs mainly of mandarin. Treat same as white wax scale.</td>
<td>Spring. DDT spray applied at this time for the control of Dicky rice weevil also controls tree-hoppers. See “Treatment” column.</td>
</tr>
<tr>
<td>Infestation is secondary; trees showing gumming are frequently infested during late summer. Keep trees in good health. When skeletonizing or pruning, take precautions to prevent dieback (Chapter 13). Skeletonized or pruned trees should be sprayed as soon as possible with lime-sulphur 3 gals to 40 gals water. Pruning stubs should be painted with bitumen paint.</td>
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<tr>
<td><strong>PULVINARIA SCALE.</strong></td>
<td><strong>PURPLE SCALE.</strong> Occurs in shady parts of tree. The purple mussel-shaped scales usually cause noticeable yellowing of leaves. Also called Grass-sud scale. Treat same as red scale, but also, to check scales, apply in midwinter the following: lime-sulphur 3 gals, water to make 40 gals.</td>
<td>See “Treatment” column.</td>
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<td>See red scale.</td>
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<tr>
<td>Pest</td>
<td>Treatment</td>
<td>Time of treatment</td>
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<tr>
<td><strong>RED SCALE</strong> <em>(Fig. 74)</em></td>
<td>1. Hydrocyanic acid gas (see p. 219).</td>
<td>January to April or July to August.</td>
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<td>2. White oil, 1 gal. in 40 gals water.</td>
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<td>3. Severe infestations may require two treatments: spray (2), followed by</td>
<td>Mid-December to March.</td>
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<td>fumigation or two sprays, the initial spray in mid-December and the</td>
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<td>second treatment in mid-February. Two half-strength sprays, 1 in 80, with</td>
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<td>an interval of two to three days, offer definite advantages over a single</td>
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<td>spray of 1 in 40.</td>
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<tr>
<td><strong>RUST OR SILVER MITE</strong></td>
<td>1. Lime-sulphur, 1 gal. in 40 gals water.</td>
<td>Early December. Control measures should be undertaken when fruit is ( \frac{1}{2} \text{in.} ) to ( 1 \text{in.} ) diameter, especially if mites were in evidence during the previous season.</td>
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<td></td>
<td>2. White oil, 1 gal. in 40 gals water.</td>
<td>Mid-December and mid-February (see under red scale). If only one oil spray is contemplated, the mid-February application is likely to be the more satisfactory.</td>
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<tr>
<td><strong>RUTHERGLEN BUG</strong></td>
<td>1. DDT spray 0·1 per cent.</td>
<td>Spring.</td>
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<td>2. Early cultivation, no later than August, is essential to destroy weeds</td>
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<td>in which the bugs develop.</td>
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<tr>
<td><strong>SOFT BROWN SCALE</strong></td>
<td>Treat same as red scale.</td>
<td>Control measures should be applied during the early stages of development of the</td>
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<td></td>
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<td>pest.</td>
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**SPINY LEMON BUG.** This green bug with prominent shoulder spines sucks the juice, causing fall of young fruit and drying out of larger fruit. It favours lemons and mandarins.

1. DDT spray 0.1 per cent or BHC 0.04 per cent or Parathion 0.025 per cent. May be combined with a routine white oil or Bordeaux mixture.
2. Hand-picking. Bugs and egg-masses should be destroyed when seen.

February to March.

See “Treatment” column.

**WHITE FLY.**

**WHITE WAX SCALE** (Fig. 72). The young scales at first line the main veins and mid-rib, when they can be readily controlled with white oil. As they develop they migrate to the shoots, develop a white cap of wax and eventually grow the permanent white waxy covering of the mature scale. Later, masses of salmon-coloured eggs develop beneath the scale.

1. White oil 1 gal. in 40 gals water, plus ¾ pint nicotine sulphate.
2. Lime-sulphur 1 part in 40 parts water, plus lime-casein spreader ½ lb. to 40 gals water.
3. Washing-soda 10 lb. or soda ash 3½ lb. to 40 gals water. The soda may be combined with oil sprays being used for other scales.
4. Washing-soda 15 lb. or soda ash 5½ lb. to 40 gals water.

Spring on signs of infestation.

Mid-December when larvae are on the leaves.

Mid-December. See precautions under lime-sulphur.

“White cap” stage, about mid-February. See precautions under soda.

In later stages of scale (March). See precautions under soda.

May to August.

June to July. See precautions under lime-sulphur, p. 215.

**WHITE LOUSE SCALE** (Fig. 71). These tiny elongated scales cluster mainly on trunks of dense trees, often meriting the alternate name of snow scale. They may spread through the branches and on to the fruit. This scale causes great loss of vigour and splitting of the bark.

1. Fumigation with hydrocyanic gas (see p. 219).
2. Lime-sulphur 3 gals in 40 gals water, plus lime-casein spreader ½ lb. to 40 gals water. The trunk and main limbs should be thoroughly sprayed from the inside of the tree, taking care to avoid spraying the fruit. A complete spraying of Navel orange trees may be necessary if bud mite is also present. Also see p. 137.

June to July. See precautions under soda.

**YELLOW MONOLEPTA BEETLE.** This beetle feeds on blossoms and young foliage.

1. DDT spray 0.05 per cent.
2. Pyrethrum powder 1 lb., plus kaolin or talc 2 lb. Also make a light application of dust to beetles that have fallen to the ground.

Spring and autumn, when beetles first appear on the trees.

Spring to late autumn.
<table>
<thead>
<tr>
<th>Pest or disease</th>
<th>Treatment</th>
<th>Time of treatment</th>
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<tbody>
<tr>
<td><strong>RABBITS, HARES.</strong></td>
<td>See p. 122.</td>
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<tr>
<td><strong>SNAILS.</strong> These eat a lace-like pattern on leaves mainly round the lower part of the tree. They also eat away large pieces of fruit rind and flesh. Colouring fruit attracts them. They occur mainly in damp locations or periods.</td>
<td>1. Poison baits, calcium arsenate 11b., bran 16 lb., water 2 gals. Make a crumbly mash and spread where snails congregate. The calcium arsenate bait must not be spread over the trees, otherwise fruit and leaves may fall. 2. Bordeaux mixture 2-2-80, plus white oil, 1 in 80, has a repellent and residual action. 3. Khaki Campbell or Indian Runner ducks, two per acre.</td>
<td>Spring and autumn. Apply late in afternoon or at night. Spring and autumn. Late summer, before hatching of new brood of snails.</td>
</tr>
<tr>
<td><strong>ANTHRACNOSE.</strong> On lemons causes small dark-brown spots or single large lesion. On oranges, especially maturing Washington Navel, the spots occur mostly at the stem and if the inoculum is spread over the fruit from affected wood tear-drop markings develop. Disease develops on weakened trees.</td>
<td>1. Bordeaux mixture 3-3-50⁻¹. 2. Remove dead wood and paint wounds with Bordeaux paste. Pick up fallen fruit.</td>
<td>Late autumn (mid-April) or early spring (mid-September). See “Treatment” column.</td>
</tr>
<tr>
<td><strong>ARMILLARIA ROOT-ROT.</strong> Top growth shows yellowing and vein chlorosis (Fig. 48). Also see p. 82.</td>
<td>Expose the crown and larger main roots, cut away diseased parts. Care in clearing new land reduces infection (see p. 95).</td>
<td>When symptoms are noticed.</td>
</tr>
<tr>
<td><strong>BLACK PIT AND LEAF BLAST OF LEMONS.</strong> Mainly in southern districts. Infection occurs through rind wounds and results in sharply demarked grey to black sunken areas. Infection of leaves and twigs results in blackening or blast. Occurs mostly in late winter to early spring.</td>
<td>Bordeaux mixture 6-6-100⁻¹.</td>
<td>Autumn. Also spring for severe infection.</td>
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</table>
**BLACK SPOT** (Fig. 92). Infection takes place in spring although symptoms do not appear till the following spring. First symptoms are minute rust-red depressions on the rind; becoming small round brown sunken spots surrounded by a narrow ring of green skin. With higher temperatures and maturing of the rind larger sunken brown spots may develop rapidly. Fruit falls readily at this stage.

1. Bordeaux mixture 1-1½-80-½,
or
2. Bordeaux mixture 2-2-80-½.

These sprays should be followed by a two-spray oil programme for scale control, never by soda sprays. Oil spray may be satisfactorily combined with the second Bordeaux spray.


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**BROWN ROT AND LEAF BLIGHT** due to Phytophthora spores splashed from soil, specially when flooded. Brown rot is a soft pliable rot with characteristic odour.

Bordeaux mixture 3-3-80-½.

Unless the infection has been particularly severe, it is sufficient to spray to a height of 4 or 5 feet only. The soil under the trees should also be sprayed. Low-hanging branches should be pruned back to prevent contact with the soil.

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**BROWN SPOT OF MANDARIN** (Fig. 93). Young fruit showing small black spotting is very liable to fall. As the fruit grows spots enlarge and become brown. Infection of the leaves and shoots causes defoliation and die-back, affecting vigorous growth particularly.

Severe pruning or heading is to be avoided. Diseased twigs should be cut out and the trees opened up sufficiently to permit free circulation of air and rapid drying out of moisture. The thinning out of crowded limbs and inside growth is advantageous.

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**COLLAR-ROT, GUMMOSIS** (Fig. 39). See pp. 35, 78.

Cut away diseased parts carefully. Paint the wounds with Bordeaux paste or Stockholm tar.

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**LEMON DIE-BACK**. In the common form caused by Sclerotinia the shoots take on light grey fibrous appearance. White fungal outgrowths occur which become hard black granules, the sclerotia or resting bodies of the causal organism.

Remove and destroy affected shoots, to dispose of the sclerotia, cutting well back into healthy wood. Control weeds, which harbour organism.

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**LEMON SCAB** (Fig. 76). On leaves infection produces swellings on lower surface corresponding with pits on the upper surface. On rind infection produces marked swellings with air without scab-like incrustation.

Bordeaux mixture 6-4-80-½.

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**WHENEVER OBSERVED**.
**TABLE XXVIII—continued.**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Treatment</th>
<th>Time of treatment</th>
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<tr>
<td><strong>MELANOSE.</strong> On leaves scattered gum spots are raised and rough to the touch giving “sandpaper” effect. On fruit the raised dark-brown gum spots may be small and scattered or arranged into tear-drop markings or involve areas of the skin, giving “pancake” effect. Infection extends into the wood and may choke off moisture supply, causing sudden wilting and collapse of branches, which die back. Also causes a gummosis and collar-rot of the trunk, and fruit stem-end rot (see p. 264).</td>
<td>1. Bordeaux mixture 3-3-80-½. 2. The three-spray programme for black spot will give satisfactory control of melanose in the Valencia orange. 3. See p. 136 for other sprays for Washington Navel orange.</td>
<td>Immediately after all the blossoms have shed their petals and again in late January, where autumn rains regularly induce a late infection of nearly mature fruit.</td>
</tr>
<tr>
<td><strong>ROOT-ROT.</strong> General yellowing of foliage, especially after excess soil moisture. Vein chlorosis may appear (Fig. 48).</td>
<td>Improve drainage.</td>
<td>In March, before autumn rain.</td>
</tr>
<tr>
<td><strong>SEPTORIA SPOT</strong> (Fig. 77). Sunken dark-brown spots occur singly or coalescent into large areas or streaks on the skin. Infection occurs after first autumn rains and spotting starts to show up in winter after cold spell or frost. Fruits fall readily. Severe on navel oranges.</td>
<td>1. Bordeaux mixture 2½-2½-100-½. 2. Zinc-Bordeaux mixture made from zinc sulphate 5 lb., bluestone 1 lb., lime 4 lb., water 100 gals, plus ½ gal. white oil, where it is desired to combine Septoria spot spray with zinc spray for mottle-leaf. 3. Copper oxychloride 1 lb., water 100 gals, plus ½ gal. white oil.</td>
<td>In March, before autumn rain.</td>
</tr>
<tr>
<td><strong>SOOTY BLotch AND FLY SPECK.</strong> A smoky appearance on the rind which can be rubbed off. Dense accumulation of the organism forms black specks which are difficult to remove.</td>
<td>1. Lime-sulphur 1 in 40, or 2. Bordeaux mixture 2-2-80-½. 3. The black spot spray programme for Valencia oranges will control sooty blotch without a further autumn spray.</td>
<td>Early May.</td>
</tr>
<tr>
<td><strong>SOOTY MOuLD OR FUMAGINE.</strong> A dense sooty deposit on the fruit and leaves formed by the organism which grows on the excretion of scales.</td>
<td>Control the insects, which provide the food of sooty mould, especially brown, soft brown, and white wax scales.</td>
<td>Early May.</td>
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FROST

Unlike pests and diseases, which offer a continual threat to the life and health of citrus-trees, frost is of importance to Australian citrus-growing only in occasional years and in certain locations. Citrus-growing was tried in a number of districts that proved too frosty, and was discontinued. No present districts employ regular heating to control frost, as is done extensively in some areas overseas. Many districts are entirely free of damaging frosts, and the remainder generally speaking are frost-labile only in certain defined "frost pockets".

By frost is meant temperatures below the freezing point of water, 32°F. In meteorological records made in the standard meteorological screen 36°F. is taken as indicating a light frost at ground-level, and 32°F. as a heavy frost at ground-level.

Fig. 78. Frost damage to branch of an orange-tree.

Fig. 79. Frost damage to orange fruit.

(Photo: A. E. Vincent.)
Extent of Injury

The amount of frost that will cause damage depends a great deal on the stage reached by the tree. Blossom and young fruit will only stand one or two degrees of frost for half an hour. A light frost such as this may cause evident damage to lemons and other citrus whilst in active growth; and a frost that would not damage trees in more southerly areas is liable to damage those in the warm Queensland districts. In more southerly areas, as temperatures decline from autumn to winter all new growth ceases and hardens off and the trees reach an inactive or dormant stage as far as vegetative growth is concerned, although fruit hanging on the tree continues to increase in size.

Orange-trees thus conditioned by southern winter temperatures will stand five to ten degrees of frost without damage, provided that the low temperatures are of short duration. Despite the previous conditioning to low temperature, longer and heavier frosts may cause extensive killing of the shoots, the bark of older limbs, and the tissue of maturing fruits. Frosted fruit dries out, becomes light, puffy, often bitter; crystals of the bitter glucoside, hesperidin, appear in the flesh of oranges (Figs 78, 79).

In southern districts the chief danger is therefore from (i) frosts which occur in early winter before the growth has thoroughly hardened off, or in early spring when in response to rising temperatures the tree is showing signs of growth, and (ii) more severe and lengthy frosts than those referred to when they occur during the completely dormant period. Young trees after planting in their first or second year of growth, that is, until properly established, are more susceptible than older, well-established and healthy trees. Such trees also are more resistant than trees in impaired health.

Trifoliata rootstock is not only more cold-resistant than other stocks, but seems to impart cold-resistance to the scion over and above what might be expected from a root system unimpaired by Phytophthora root-rot.

Susceptibility of Species

The frost susceptibility of citrus species is of the following order: citron and lime are the most susceptible, followed by lemon and grapefruit, then mandarin and orange, except that Satsuma and Meyer are more frost-resistant than other mandarins and lemons respectively. They are hybrids. Cumquat and trifoliata are the most resistant species.

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<th>JAN.</th>
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Fig. 80. Months of greatest frost risk.
(Data from Foley.)
The relative susceptibility of the lemon is of interest, because it succeeds well where the heat index is lower than that required for oranges. Oranges are less susceptible to frost, but require a higher heat index than lemons.

Months of Greatest Frost Risk

The months of greatest risk from frost are tabulated for the different States in Fig. 80, these being extracted from Foley.¹

Frost Formation

The following account of frost formation under Australian conditions is also taken from Foley.¹

The fall in temperature to below freezing point results from two major processes in nature:

1. The transportation over the country of a mass of cold air which itself may be at a temperature near or below freezing point.
2. Radiation of heat from the ground and a consequent chilling of the air in contact with the ground.

Both processes usually contribute to the occurrence of frost and the degree to which the second is effective is, especially in spring and autumn, largely dependent on the characteristics of the first.

Radiation . . . in the case of the great majority of frosts (probably all in Australia), it is only a shallow layer of air near the ground that is subject to the chilling which is necessary before frost forms.

During the day, the ground receives heat radiated by the sun . . . and the air in contact with it is warmed by conduction. This air expands and is displaced upward by denser and colder air from the surroundings. Heat is distributed through considerable depths of the atmosphere by resulting turbulence. The lower strata, however, receive the greatest increments and the temperature falls off with height at an average rate of approximately 1 °F, per 300 feet. During a clear night, the ground continues to radiate heat to space, and becomes progressively colder. Air in contact with the ground is chilled and, being thus denser than the overlying strata, remains inert, especially if the surface is level. As a result, instead of a progressive fall in temperature with height, we find a marked increase in temperature through a shallow layer, above which there is a decrease similar to that existing during the day.

This condition is known as an “inversion of temperature”.

The most common form of frost may thus be regarded as a radiation phenomenon, and its occurrence is largely determined by conditions which permit a free radiation of heat to and from the earth’s surface. [Nature or meteorological conditions set the stage for the occurrence of a frost.] Almost every passing low pressure system in temperate latitudes is characterized by a frontal line, along which there is a more or less sharply defined boundary between air masses of tropical and of polar or sub-polar origin. Between a depression [or “low”] and . . . a following
anticline [or "high"] a broad stream of relatively cold air flows over the country. The early stages of inflow are often marked by strong winds with cloud and showers, but in later stages the rapid movement of the stream subsides and the cloud dissipates. At night the air may be still and the sky quite clear. In the lee of mountains these conditions may be experienced much sooner, after a cold change, than in open country. . . .

A clear sky permits radiation to pass freely to and from the ground with very little absorption. . . . If the sky is clouded the exchange of radiant energy between the ground and outer space may be entirely cut off. In such circumstances there is an exchange of heat between the ground and the moist air or cloud layer and the loss of heat by the ground is greatly reduced.

The moisture content of the air plays another part in regulating a fall of temperature during the night. If the moisture content is high, the dew point will be reached when the temperature has fallen a relatively small amount. Condensation may take place in the form of dew or fog, and a further drop in temperature will be retarded by the liberation of latent heat. If the moisture content and dew point are low, the fall in temperature may, on the other hand, be considerable and may even go well below the freezing point of water.

A necessary condition for the chilling of the ground layer of the atmosphere as a result of radiation is that there should be little or no mixing of the strata by wind. There is usually some slight movement of air even on the coldest of nights, perhaps due to air drainage down a slope or other causes, but a light wind of perhaps three miles per hour may be sufficient to mix the dense freezingly cold air at the bottom of an inversion layer with the warmer air above and thus remove the danger of frost.

The conditions under which frosts are to be expected, in season, are thus seen to be the phase of the movement of pressure systems when a depression ["low"] has passed and an anticyclone ["high"] is approaching or moving over the locality. In this phase the air is cold, its moisture content is relatively low, and skies are clear or clearing. Frosts may be expected immediately the wind drops. Usually the barometer is high and rising. . . .

Practical Measures Against Frost

Regarding the frost question broadly, there are some nine measures that may be adopted, namely (i) heat conservation, (ii) heating, (iii) frost fans, (iv) improvement of health of trees, (v) treatment of frosted trees, (vi) covering of young trees, (vii) selection of site, (viii) planting, and (ix) separation of frosted fruits.

Heat conservation. As frost is a radiation phenomenon, heat conservation practices are of considerable importance. They have the object of retaining the heat absorbed in the soil during the day in order that the temperature of the air at soil level ("grass temperature") may not fall to the extent of a heavy frost. Such practices depend on the fact that soil in a moist consolidated state radiates less heat than open (recently
cultivated) and dry soil. Sands radiate more freely than heavier soils. A stand of green crop is disadvantageous, for the top of it becomes the "grass temperature" (that is, the lowest temperature during the "inversion" period); a high green crop thus carries the "grass temperature" as high as the foliage of the trees and is especially dangerous among young trees.

To decrease radiation, therefore, in susceptible areas any green crop should be dissected down or be ploughed under well before the susceptible period, and the soil be allowed to consolidate. When furrow irrigation is to be used, the furrows should also be put down so that it will not be necessary to disturb the compactness of the soil during the susceptible period. Irrigation may be used if available and when necessary to ensure that the condition of a moist and compact soil obtains.

Soil cultivation during frosty periods is dangerous. Cover crops may have to be mown and allowed to lie so as to avoid cultivation.

*Heating.* This is based on the setting up of convection currents from burners in the orchard; cool air is drawn in from the ground and, on being heated by the burners, rises, spreads out, loses its heat, and returns towards the ground. This process will continue at least as long as the burners are alight. A requirement for successful heating is that the inversion layer should be shallow, the "ceiling" being only some thirty-five to forty feet from ground-level.

The equipment consists of an alarm thermometer that rings at say 34°F to arouse the grower, who then starts to light up the oil burners in an order determined by local experience or on the evidence of strategically placed thermometers, starting with the most susceptible spots in the orchard.

*Frost fans.* The efficiency of frost fans depends on the creation of turbulence in the immediate atmosphere of the grove, that is, the mixing of the higher warmer air with the lower colder air.

A good deal of experimental work on frost fans has been done at Griffith Research Station. A commercial frost fan has only recently appeared on the market in Australia. Mounted on a high steel tower, it depends on the principle of drawing upper warmer air through a duct by the fan-motor unit, which then directs the air over the orchard as it slowly rotates horizontally through a full circle, creating turbulence. The motor is ten horsepower and is thermostatically controlled. One machine is claimed to protect three to four acres of citrus orchard.

*Improvement of health of trees.* This practical measure against frost applies to root and soil conditions. Trees in impaired health or condition are more susceptible than healthy trees. Susceptibility is especially noticeable when root injury is occurring, such as from Phytophthora, Armillaria, root-weevil, dry soil, or toxic substances in the soil.

*Treatment of frosted trees.* Trees in which shoots or heavier wood have been killed should not be pruned straight away, for it is difficult to judge the extent of the damage. "Undamaged" wood may form shoots that only die later in the season; some damaged wood forms satisfactory shoots. It is essential to delay pruning until the development of new
growth clearly defines the extent of the damage and indicates what wood may be cut away with safety (Figs 81, 82). Up to a year’s delay may be necessary. (Incidentally, a similar attitude to pruning is best adopted when trees have been damaged by fire.) The pruning should not be done when there is any danger of frost.

Covering of young trees. Owing to the greater susceptibility of young trees before they are well established, they should be wrapped when young with straw, cornstalks, hessian, or paper. Of these, complete covering with straw is desirable. The covering should be removed when danger of frost is over. See also p. 122 and Figs 41, 42.

![Fig. 81. Frosted orange-trees before pruning.](image1)

![Fig. 82. Frosted orange-trees after pruning to new growth.](image2)

*(Photos: A. E. Vincent.)*
Selection of site. Freedom from frost has been included as one of the qualifications in selecting a site for a grove. Foley\textsuperscript{1} states:

It is a well known fact that air chilled by nocturnal radiation of heat from the ground tends to gravitate to the lowest parts of a field or valley, and that frosts are more severe in the bottom of a valley or depression (frost pocket) than on a slope.

A knowledge of the mechanism of “air drainage” is useful in laying out an orchard or in planting crops susceptible to frost damage. On a clear sunny day, radiant heat absorbed by the ground warms up the air in contact therewith by conduction, and heat is carried upward by turbulence until the overlying strata are warmed to a considerable height. This is true for the hillside upon which the sun’s rays fall, as well as for the floor of the valley or depression. The amount of heat received on a hillside depends on its steepness, length and the aspect of its slope. The maximum intensity of radiation is received at an angle perpendicular to the rays of the sun. A southerly aspect is colder than a northerly (in the southern hemisphere). A steep slope to the south may remain in shadow all day.

During the night heat is lost from the ground by radiation and the adjacent stratum of air is chilled and becomes denser than the warmer air above. In the lowest levels of a depression or valley, a cold layer forms and becomes stable, while on the slopes the chilled air drains into the “pool” and is replaced by warmer “free” air from over the valley. It is found that severe frosting often occurs on the lower slopes of a valley, while the upper slopes are entirely untouched. A point where a valley debouches on to a plain or where two valleys meet is particularly subject to heavy frost since chilled air tends to accumulate at such a place. . . in Mallee country . . . frosts are most severe near areas covered by belts of Mallee scrub.

Planting. This should be carried out when frosts are over, or if frosts are still possible the trees should be wrapped.

Separation of frosted fruits. The death of tissue in a part of the fruit when it is frosted causes drying out, and affected fruits fall from the trees. Frosted fruits gathered with sound fruit are difficult to separate. The principle of a machine for separating frosted and sound fruit consists of a constant flow of water in a trough, with an adjustable baffle. Oranges of a given size drop into the stream from a given height. The heavier sound oranges pass under the baffle, whilst the lighter frosted fruit rise before the baffle and are diverted to the discard.
CHAPTER 13

PRUNING AND RENOVATION PRACTICES

The secateurs and pruning saw are used relatively little on citrus-trees. The uses of pruning described so far have included: (a) promotion of budwood; (b) cutting out sporting limbs; (c) at transplanting, reduction of the transpiring surface and establishment of a head to the tree; (d) assistance in forming the framework, removal of suckers and water-sprouts, removal of unduly vigorous shoots and preservation of the symmetry of the tree; (e) skirting of trees in connection with the control of pests and diseases such as brown rot and root-weevil, and for fumigation; (f) cutting out dead wood; and (g) removal of frost-injured growth.

Other uses are thinning the canopy of growth, principally in the lemon and mandarin, renovation pruning, top-working, and inarching.

THINNING THE CANOPY

Thinning out of shoots in the leaf canopy of oranges and grapefruit is seldom practised. Lately, however, Cahill² as a result of investigations in Western Australia has made a definite recommendation that all bearing citrus-trees should receive an annual light to moderate pruning of the canopy. This general recommendation is not made in other States.

On the other hand, it is agreed on all sides that lemons and mandarins should be thinned out from time to time (see p. 120).

RENOVATION PRUNING

A long-recognized treatment for the renovation of trees that have gone out of condition and the restoration of them to a state of satisfactory growth and production is hard pruning. It is the nature of this pruning that has undergone a considerable change in recent years. In such works as those of Quinn⁸ the method of renovation used at that time is clearly shown and may be described as a heavy thinning out of the canopy. This type of pruning required a considerable amount of attention to fine cutting. Two newer methods are skeletonizing and pollarding.

Skeletonizing

During the 1930s the method of hard pruning, known as skeletonizing, was evolved at Gosford, and has now been used in other districts. The result largely of the work of Mr Roy Wood, a former Fruit Inspector of the New South Wales Department of Agriculture, this consists of
cutting off all the leafy canopy, leaving the framework limbs or "skeleton" exposed. A reduction in work is effected, because comparatively few large cuts are required; these are done with long-handled secateurs. The method, therefore, has the great advantage of rapidity of operation, and large areas of trees on the east coast, as well as elsewhere, have been rejuvenated by this means. Skeleton pruning, however, has not proved a satisfactory treatment for orange-trees in deep alluvial soils. It is not recommended for mandarins, in which the young vigorous growth will be blighted by brown spot. Oranges and lemons respond well to skeletonizing.

In the Gosford-Sydney region the method has been incorporated in the general system of management of orange-trees by some growers. A proportion of the grove is done each year. If the trees subsequently show decline, the process can be repeated. The advantages of rejuvenation in this region, if after-care is faithfully carried out, are a great reduction in melanose- and black-spot-affected fruit, increased size of fruit, and improved cropping. Skeletonizing throws the trees out of production for two seasons.

**Prior Treatment of Debilitated Trees**

Before resorting to the skeletonizing of trees that have lost vigour, the cause of the condition should be closely investigated. Sometimes the trees can be improved considerably by less drastic measures. In any case, trees to be skeletonized in the spring should receive a good nitrogenous dressing in the previous autumn. Those in poor condition should not be skeletonized until the causes leading to debilitation are brought under control and the condition of the trees improves; the response will then be very satisfactory and the effects more lasting and pronounced.

Improvement in the growth of a tree can be expected only if the underlying causes of debilitation are found and the appropriate treatment is given. While unsatisfactory soil conditions such as bad drainage and root-rot prevail, or when there are unrelated spells of drought, or if erosion has denuded or impoverished the soil, trees cannot be expected to improve. Action must be taken to overcome these fundamental defects first. According to the type of defect, it will be necessary to supply under-drainage or supplementary irrigation or to resoil.

When soil conditions are basically sound, alterations in practice can bring about remarkable improvement. Excessive cultivation (which keeps the surface roots cut) or insufficient or untimely weed control are practices that quickly cause trees to deteriorate.

Lack of fertilizer is another common cause of unthrifty condition of trees. This aspect must be examined rather broadly, for major elements, trace elements, or organic matter in the soil, or a combination of them, may be involved. The introduction of fowls into the orchard on the correct principles, and some expenditure on fertilizers, often makes a very great difference to the health of trees within a year. Animal manures at the rate of three to five tons per acre are also beneficial if weeds are effectively controlled.
Skeletonizing should not be done until all danger of frosts is over. Trees pruned in early spring make the most rapid response. August and September are the best months on the east coast, although the work may be done until the end of October in most districts, and as late as December in localities where there is no shortage of summer moisture or risk of high temperatures following the operation, and no risk of winter frosts.

*Fig. 83.* Skeletonizing. Pruning effected, branches are allowed to drop their leaves before being hauled away.

**Method**

The pruning given may be described generally as severe. The first step is to select the principal limbs, ensuring that they are well spaced. Remove any crossing or crowding limbs, and remove vertical limbs rather than spreading limbs. The next step is to remove all the side growth from the limbs, including dead wood, and head back the limbs themselves, giving a desirable reduction in tree height. Long-handled secateurs expedite the job.

The prunings may be heaped beneath the tree (Fig. 83), because the shade from them suppresses weed-growth and the falling of the leaves returns nutrients to the soil. When the leaves have fallen the bare limbs are carried away.

**After-treatment**

Immediately after pruning the tree skeletons should be sprayed with lime-sulphur (1 to 10 or 15) if necessary to effect a clean-up of white
louse, moss, lichen, etc., or limewash to prevent sunburn. Young shoots will break in abundance all along the upper surface of the limbs in the course of a few weeks. These growths should not be thinned out, but should be sprayed with Bordeaux mixture to control melanose. Growth of the shoots may be blighted severely by melanose unless this precaution is taken, and one of the advantages of skeletonizing—that of cleaning out melanose—will be lost. If the shoots are thinned out the remainder do not grow as well, apparently because of the demand for carbohydrates by the large frame and root system of the trees.

As the shoots grow, some become more vigorous than others. It is largely the vigorous shoots that will form the new canopy, and in the early years the weaker shoots will blossom and bear fruit. They finally crowd one another and die out, thus effecting a natural thinning of the shoots. In the third or fourth spring the centres may be cleaned out of weak growth.

Excessive thinning and pruning of heavy shoots has a weakening effect on the tree.

Normal pest and disease spray programmes should be resumed from the second spring when the trees start to blossom again.

Weeds that grow under the trees until the shady canopy is re-established require suppression.

**Cropping**

The crop that would have formed on the spring growth had it not been removed is of course lost. Growth produced usually blossoms in the succeeding spring and may give a light crop. Normal blossoming should occur by the second spring.

One advantage accruing from skeletonizing is the improved external qualities of the fruit as regards size and freedom from disease markings. Owing to the fungicidal treatments given in the after-treatment and the cleaning out of the centre of the tree later, the crops of fruit obtained should be free of melanose. The invigoration of the growth also produces fruit less liable to black spot, which is much more prevalent on the fruit of old debilitated trees.

**Pollarding**

This is a still more severe method of renovation pruning, being used mainly in South Australia. The main limbs are cut back uniformly some five to six feet from the ground and all remaining shoots and foliage are removed. They are given a coat of limewash to prevent sunscald.

For mandarins a method of heavy pruning by pollarding and skirting has been reported to be very successful for improving fruit size and the regularity of bearing of tall growing Dancy mandarins in South Australia. The tops of trees are cut down to about nine feet and skirted up to four feet from the ground. Such invigoration treatment would not be safe for brown-spot-susceptible varieties in eastern coastal areas.

**Hedging**

When trees grow over-large for their planting distance, the spread makes inter-row operations difficult and the shade reduces production
around the skirt, normally a highly productive part of the tree, where the crop is easily sprayed and picked.

A method suggested to deal with such cases is hedging. The growth on rows of trees in one direction is cut back to form a wall and becomes hedge-like, requiring the cessation of inter-row operations in a cross direction.

REWORcING

When a grower possesses trees of a commercially undesirable strain, variety, or species, he may replace them with a desired type of citrus either by digging out and replanting young trees, or in many cases by reworking the old trees.

Precautions

Among the precautions to be observed are the following:

1. The trees to be reworked should be sound, otherwise it is better to dig them out and start with new trees.

2. The variety to be worked onto the old stump should be satisfactory in combination with it. Reworking has been carried out mostly in the older districts where varieties that have been planted in the past are today no longer profitable. A considerable range of combinations of varieties and species has come under notice. Incompatible combinations recorded have been lemon on Siletta orange, Seville orange on Valencia orange, and sweet orange on Wheeny grapefruit, in all of which the resulting growth was very poor.

Trees infected with virus may be top-worked, provided that combinations which manifest serious virus symptoms are avoided (see p. 31). Orange-trees affected with quick decline in early stages have been successfully worked to lemons, which are not affected. No orange leaves should be allowed to grow in the combination, or the quick decline will develop. Stem-pitted grapefruit-trees on Rough lemon may be top-worked to lemon and orange varieties.

3. The care necessary in the selection of scion wood, as discussed in Chapter 3, should also be observed in selecting the scions for top-working.

4. The trees to be worked should be in good condition, and it may be desirable to improve the nutrition and vigour by manuring in the previous season, that is, the spring or even as late as the autumn before the reworking is to be done.

A special case is that of Emperor mandarins, in which it has been found that the very vigorous shoots produced after cutting back the tree severely are very subject to brown spot and may prevent satisfactory working. In that case resort may be had to side-grafting.

Methods

Essentially the operation of reworking consists of cutting back trees to the desired height in spring and then (a) grafting the stump immediately, or (b) budding the new growth that arises from the stump, this being done preferably in the following autumn or alternatively in the succeeding spring.1,4
PRUNING AND RENOVATION PRACTICES

Cutting back the Trees

To prepare trees for grafting, first select from three to five well-spaced limbs and saw them back to near their junction with the trunk. These cuts will usually be about three feet from the ground. In the case of large trees more limbs may be retained and cut back. Make the saw-cut square across the limbs and pare the wound smoothly. If possible retain a circle of the lower limbs with all their foliage, to act as nurse limbs until the development of the grafts or buds partially restores the canopy of foliage to the stump.

For budding in the autumn, cutting back should be done in September. Later cutting will not allow time for the shoots to develop well rounded and mature wood by the autumn, and budding would have to be delayed till the following spring. Cutting back for grafting may be delayed slightly (late spring and early summer), and should be followed immediately by the use of whitewash on the exposed limbs and trunk to prevent sunscald.

In inland areas, cutting back for grafting should be done as soon as possible after the danger from frost is over (latter end of September). Delay results in insufficient growth to form a protection to the stump before the advent of hot weather.

Grafting the Stump

Grafting should only be attempted in springtime, and is done immediately on cutting back the tree. The bark graft is commonly used on the ends of the cut limbs, and side grafts may be inserted along the limbs. The method for bark grafting consists of paring the wound smooth; for each scion that is to be inserted two longitudinal cuts, the width of the scion apart, are made one and a half to two inches down the limb. The number of scions depends upon the diameter of the limb.

Then make a long flat sloping cut on one side of the scion, insert it between the bark and the wood of the stump, and push the cut surface almost completely out of sight. When firmly in position secure with two half-inch panel pins driven carefully through the bark of the stock, the scion, and into the wood of the stock. Then cut off the scion with secateurs so that only two or three buds remain. When the stubbed limb is fitted with the required number of grafts, the whole of the cut surface should be covered with a grafting mastic or wax to exclude air and moisture. Further protection, and assurance to success, will be obtained by tying heavy paper round the grafted limb, allowing the paper to extend about two inches beyond the limb, and then filling the space available with fine soil to the height of the graft. Sand should not be used because it reflects too much heat.

No further attention is necessary until it is apparent that many new shoots are breaking on the sawn limbs. They should be rubbed off as frequently as they appear, if the grafts are also shooting.

If the grafts have failed, allow the shoots to grow without thinning until they will withstand wind damage. Then select up to three well-spaced shoots along the limb for budding, and remove the remainder.
Budding

A tree to be reworked by budding is cut back in the early spring, in a similar manner to that for grafting, and the shoots are allowed to grow until the autumn, by which time desirably placed shoots should be of sufficient size and well rounded and mature for budding.

Fig. 84. Reworking. Two years’ growth of Valencia grafts on Emperor mandarin. Nurse limbs have been removed.

(Agricultural Gazette of N.S.W.)

Each shoot near the base is budded with the T or shield bud, as described in Chapter 4. The tie on each budded shoot must be cut before it starts to constrict growth, say in about three weeks, and the buds should be examined for the success or otherwise of the operation. Shoots in which buds have failed may be rebudded forthwith. The buds will lie dormant until the spring, when they will be stimulated into growth by cutting back the shoots to within three or four inches of the bud. The new growth from the bud may be tied to this stub to prevent dislodgment by wind or by accident. When this danger is past the stubs are cut off.

When budding is delayed until the following spring the work should be examined two to three weeks after the operation and, where the buds have taken, the shoots should be cut back almost to the bud as just mentioned. It is risky to cut back under three weeks from budding. Failures must be patched with new buds very soon to secure uniform growth.
Fig. 85. Inarching.

After-care

When the shoots from the grafts or buds have established a fair canopy—usually by the end of the first season—all growth except that arising from grafts or buds must be cut away. Further cutting away may be
needed for a time to dispose of any growth of the old variety. The nurse limbs, however, may be reduced gradually until they are completely cut out by about two years after the grafting was done (Fig. 84).

INARCHING

Inarching is a minor practice which has for its object the provision of a new root or a supplementary root system to an existing tree whose root system is unsatisfactory or has become extensively damaged.

The method consists of planting seedlings beside the tree to be inarched and grafting the top of each into the trunk or into convenient limbs of the tree, using a type of approach graft. The graft may be secured with a panel pin and covered with mastic. Shoots on the inarched seedlings are suppressed in order that the union between the root and the tree-top to which it is connected will be effective and the whole be interdependent (Fig. 85).

The operation is done in the spring, consisting as it does of the operations of planting and grafting. It has been used to help support the top of a tree whose root system has been affected by white ants or root-rot. In the latter case the root-rot-resistant trifoliata seedlings have been used. Although the roots may have grown reasonably well, the general experience is that inarching has not been a success as far as supporting a tree with a new rootstock is concerned. Inarching is rarely able to renew the vigour of mature trees, but is more successful with young trees.
CHAPTER 14
CROPPING AND WASTAGE

Bearing habits of the commercial species were discussed in Chapter 8. The present chapter deals with various stages in the development of the crop from the formation of blossom buds to picking maturity, and concludes with an account of the losses and wastage to which the fruit is subject during development on the tree and after ripening. A knowledge of these aspects is essential to an appreciation of the care required in harvesting and preparation for market, which are the subjects of the next chapter.

Blossom-bud Formation

West and Barnard investigated the process of blossom-bud formation, which they describe as follows:\textsuperscript{12}

The 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 are triangular in shape and rather fleshy, the first or outermost being invariably situated opposite the thorn. An accessory bud is formed in the axil of the second 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, namely the primary and the accessory. Each bud usually possesses four to five scales, and above these, upon the axis, approximately six rudimentary leaves 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 primordia, and are formed as a continuation of the same spiral sequence. The first sepal, which is usually the sixth or seventh 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 second, third and fourth sepals in a very close spiral sequence makes it possible to distinguish the rudimentary blossom at this stage. 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. 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 buds were nearing maturity no difference was observed between the development of the Navel and that of the Valencia.

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.

![Fig. 86. Types of spring shoots: (A) flowers but no leaves; (B) flowers and a few small leaves; (C) several flowers and several large leaves; (D) leaves and a solitary terminal flower; (E) vegetative shoot.](Australian Journal of Agricultural Research.)

**fruitfulness of shoots**

At flowering it will be observed that some of the blossoming shoots are leafless and others leafy. The leafless shoots have a poor ability to set fruit. At Mildura, Sauer⁹ found that the spring flush shoots of Washington Navel and Valencia orange-trees could be classified as illustrated and described in Fig. 86.

The setting of fruit increased consistently with increasing vigour of the shoots in both varieties, as shown in Table XXIX. The higher the ratio
of leaf area to number of flowers, the greater the chances of setting and maturing fruit.

TABLE XXIX
FRUITFULNESS OF ORANGE SHOOTS

<table>
<thead>
<tr>
<th>Type of shoots (Fig. 86)</th>
<th>Washington Navel</th>
<th>Valencia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total shoots</td>
<td>Fruit set</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>B</td>
<td>49.0</td>
<td>1.7</td>
</tr>
<tr>
<td>C</td>
<td>20.1</td>
<td>3.8</td>
</tr>
<tr>
<td>D</td>
<td>18.8</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>12.2</td>
<td>27.5</td>
</tr>
</tbody>
</table>

As far as the greatest production of fruit was concerned on these trees, type C was the most productive in Washington Navel and type A in Valencia. In Washington Navel this was owing to a combination of a high setting ability and a reasonable percentage of the total shoots. In Valencia it appears to be due to the preponderance of type A growth, notwithstanding that the percentage of fruit set was the lowest of all classes.

December Drop

The fruit set in Table XXIX expresses the fruit carried per shoot. Of the total number of blossoms, a set of approximately one per cent is usually sufficient to produce a commercial crop. Excessive flowers and young fruits are shed off the tree at two main stages. The first shedding occurs shortly after blossoming, and in the normal course of events leaves considerable numbers of young fruits. The prospects of a good crop are determined mainly by the second drop, which from the time of its usual occurrence is called the December drop, although it may extend into January. It is somewhat variable in the time at which it occurs and it may be either protracted and gradual, or short and sudden in incidence.

Growth conditions prevailing since the start of spring growth undoubtedly have a great influence on the extent of the drops. A satisfactory supply of moisture and nutrients minimizes the drop and assures a crop. Among the nutrients, nitrogen is generally a pre-eminent requirement owing to the demand on this element made by the tree for all new growth since winter, whilst in certain areas other elements are also very important; copper deficiency results characteristically in heavy blossoming and poor setting, and when deficiencies of zinc and magnesium have existed for some time the set is likely to be affected. Washington Navel oranges seem to be especially sensitive to the occurrence of water deficit before the December drop, and when a drought, even of short duration, occurs, it is likely to bring about a considerable drop. This variety is especially liable to set poorly after an attack of black citrus aphid.
It is evident from what has been said about the fruitfulness of shoots that vigour of growth is positively correlated with fruit setting, and reasonably vigorous growth of the tree and the retention of old leaves are required for satisfactory setting. Shoot vigour and leaf retention reflect adequate moisture and nutrition. When trees are making poor growth and showing a heavy leaf-fall with every new flush of growth it is not uncommon for the December drop to entirely remove the prospective crop.

Ill-considered practices are frequently the cause of interference with the moisture and nutrient supply and consequently of excessive fruit drop. Allowing undue competition from weeds, turning in weed or cover crop too late and without adding nitrogen to counteract nitrogen deficiency during decomposition, ploughing that cuts surface roots, insufficient fertilizer, or too late an application of fertilizer are examples of such practices.

Natural causes often play a major part. Drought, wet conditions that encourage the invasion of the roots by Phytophthora, and high winds and sharp heat-wave conditions, which cause excessive transpiration, are contributing causes or may be the prime cause for excessive December dropping.

Whilst the December drop is a natural phenomenon, fruit may be caused to drop at subsequent periods in its development by the action of diseases such as black spot or the attacks of insect pests such as fruit-fly.

**GROWTH OF THE FRUIT**

Records were made of the growth of Washington Navel and Valencia oranges on the Murrumbidgee areas as long ago as 1928. Outside fruit growing among the surface leaves, and inside fruit growing within the canopy of foliage, were similar in general development. Navel oranges came to the end of their main period of growth in May, although they continued to grow more slowly until picked in July. Valencia oranges slowed down about the same time after a main period of growth similar to that of the Navel oranges. They grew slowly through the winter months and started to grow more rapidly in spring to early summer, from late July to early August (Fig. 87).

Weekly measurements in 1929 showed that growth was checked temporarily from time to time by moisture shortages during the autumn, and that it suffered a prolonged check during the dry cold winter of that year. Fruit growth responded to irrigation in several instances.

Short temporary checks did not seem to affect the attainment of good size by Washington Navels at picking time, and the prolonged winter check to Valencia did not affect the size at picking of this variety. The fact that the fruit grew rapidly in the spring is evidence that it is able to respond at that time to good growing conditions.

Recently, growth of Valencia oranges has been studied at Merbein (Fig. 88). The growth curve shows the same general features as mentioned above. Growth showed response repeatedly to irrigation and rain.
Fig. 87. Growth of Washington Navel and Valencia oranges relative to temperature trends and water supply. Monthly rainfalls are shown within hatched areas, irrigation by arrows, and estimated soil moisture condition as heavy line.

(Agricultural Gazette of N.S.W.)
The correlation of growth rate with moisture conditions suggests that a weekly measurement of twenty marked fruit with the calipers shown in Fig. 89 would afford a good indication as to frequency of irrigation. Measurements should be made early in the morning before the fruits are exposed to direct sunlight.

An interesting feature of numerous growth curves available for Valencia oranges is that the fruit has grown differently in the different seasons, yet has attained satisfactory size at picking.

![Graph showing growth of Valencia orange](image)

*Fig. 88. Growth of Valencia orange. (Citrus News.)*

**Obtaining Good Size**

Hand thinning of fruits as annually practised in deciduous fruits to impart size and quality by a definite picking date is generally unnecessary in citrus, owing to the less definite nature of the picking date and the ability of the fruit to hang on the tree and to continue to grow, given good conditions, after it has reached harvesting maturity.

When the obtaining of satisfactory size is a problem it is usually tackled by improvement of the tree by way of attention to moisture supply, fertilization, and in some cases pruning—subjects already dealt with.
For mandarins regular pruning is desirable, aided by hand thinning in certain varieties such as Glen Retreat, to obtain superior size and quality. The thinning is done in January.

**Obtaining Quality**

The qualities sought in the fruit necessarily vary with the variety. The term quality embraces both the external appearance, such as colour, fineness, and freedom from blemish of the skin, and the internal qualities of thin skin, juicy flesh, good flavour, freedom from obvious rag or fibrousness of the juice sacs, and the condition of the central axis.

When concern is felt about fruit quality a review of cultural factors is called for. Many aspects of culture affecting quality have been referred to—for example, the influence of rootstock and bud selection. Examples were also given in Chapter 9 of the effects on quality of excess nitrogen and potash, bringing about coarseness in fruit, and of copper deficiency, resulting in small hard fruit subject to splitting. Balance of the main fertilizing elements—nitrogen, phosphorus, and potash—is doubtless also of importance, with emphasis of late on phosphorus. Quality is

![Diagram of fruit measuring instrument](Citrus News.)
notably affected by climatic and weather conditions; the external qualities of abrasion marks, insect and fungal blemish, and the rind condition generally are especially affected by prevailing weather conditions. These are treated in more detail towards the end of the present chapter.

**Control of Pre-harvest Drop**

The final definite drop to which citrus fruits are subject occurs shortly before or as the fruit is reaching maturity, and is known as the pre-harvest drop. The drop is accentuated by wet weather. Trees suffering from malnutrition, such as nitrogen deficiency or an excess of salt, also drop their fruits more severely than trees in good health. The drop is due to the maturation of the abscission layer between the button (or persistent calyx) and the fruit.

Certain varieties such as Washington Navel orange and Marsh grapefruit are particularly subject to this drop. Considerable losses occurred prior to the discovery that it may be controlled by sprays of the sodium salts of 2,4-D (2,4-dichlorphenoxyacetic acid) and 2,4,5- TA (2,4,5-trichlorphenoxyacetic acid). These substances delay the development of the abscission layer. The discovery was also of considerable theoretical importance, because pre-harvest-drop sprays of the naphthaleneacetic acid type, which were effective on deciduous trees, were of no use for citrus.

Spraying during the most dormant period of the trees is advisable, because the spray causes distortion of growth that has not hardened off. These sprays cannot be used during the season when there is soft new growth on the trees. The possibility of insufficient hardened growth is the reason for lower strengths used in coastal climates in some instances.

In inland areas the spray is used at twenty parts per million, usually with a pint of white spraying oil added as a spreader and sticker, but in the milder climates of coastal districts as low as eleven parts per million are used.

The best time to spray for Washington Navel oranges and Marsh grapefruit is just before the drop is expected, usually May in middle latitude districts. The effect of the spray lasts several months. McAlpin and Merrett found that a spray applied in late May to early June was still reducing the normal pre-harvest drop of Marsh grapefruit as late as December. These first spectacular results with grapefruit are shown in Fig. 90.

Trees should be sprayed thoroughly, paying attention to wetting of the fruit-stalk. After spray equipment has been used for hormone sprays it should be well flushed out with clean water.

**Ripening**

Ripening is not necessarily marked by the onset of any very sharp change in external appearance or internal qualities corresponding with those that occur in deciduous fruits. Taking citrus fruits as a whole an increase in juice content is probably the closest approach to such a change.

Ripening is marked by gradual changes: increase in juice content,
decrease in acid, increase in total soluble solids (mostly sugar in non-acid species), development of colour, development of full and characteristic flavour.

*Loss of acidity.* Citric acid \((C_6H_8O_7\cdot H_2O)\) is the chief cause of acidity. Investigations overseas\(^2\) suggest that the actual amount of citric acid in fruit from the unripe to the ripe stages may be constant, and that the increase in size and juiciness of the fruit is responsible for the diminution in the percentage of acid.

*Increase in sugar.* The sugars of the fruit consist of sucrose and hexose; the increase in sugars during ripening is largely due to increases in the

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*Fig. 90.* Control of pre-harvest drop of Marsh grapefruit (one week’s fruit fall from trees). *Upper figure,* not sprayed; *lower figure,* sprayed with 2,4-D at twenty-two parts per million.

*(Journal, Department of Agriculture, Vic.)*
sucrose, whilst the hexose may be more or less constant or may increase only slightly as the fruit ripens. Ripening is thus marked by condensation of sugars; the reverse process, inversion, starts to take place when the fruit is removed from the tree and, after a long period of storage, sucrose may be entirely converted to hexose.

 Sugars are highest on the sunny side of the tree, and in exterior compared with interior fruit. In the fruit the sugar content of the juice is higher towards the stylar than towards the stalk end.

 The proportion of sugars in the total soluble solids varies with the species. In oranges sugars approximate to 8 to 9 per cent of the 11 to 12 per cent total soluble solids. In lemons sugars comprise only 2 to 3 per cent of the 8 to 10 per cent total soluble solids, the balance being mainly citric acid.²

 In ripe fruit the proportion of sucrose to hexose is about equal in the orange, twice as much in the mandarin, and half as much in the grapefruit.

 Change of colour. The green fruit contains both the green pigments, chlorophyll \(a\) and \(b\), and the yellow pigments, carotene \((C_{40}H_{56})\) and xanthophyll \((C_{40}H_{56}O_2)\). During ripening the chlorophyll breaks down, enabling the yellow pigments to give the yellow to orange colour to the ripening fruits; the carotenoid pigments increase still further during ripening. In limes, lemons, and grapefruit part of the carotene disappears simultaneously with the chlorophyll.

 The colour of citrus juices is mainly produced by carotene and xanthophyll. The ratio of these two carotenoids determines the colour of the juice, which becomes a deeper orange with increased xanthophyll content. Pink colour is due to an anthocyanin pigment in solution.

 Loss of green colour and development of yellow and orange colours of the skin are not necessarily a ripening change, but rather an effect of a period of low temperature. In middle latitude districts with a cool winter the change from green to orange occurs before full palatability is reached, whilst in the low latitude of the north Queensland districts the change has not occurred by the time the fruit is palatable. In more tropical areas the green colour does not change fully to yellow or orange; this is adequately shown in the beautiful coloured illustrations of Fruit Growing in the Dutch East Indies. Colour changes, of course, form a useful guide to the approach of the palatable stage for any given district.

 Depth of colour also seems to be related to the temperatures of the winter. Inland districts, with their sharper winter, yield fruits that tend to develop a deeper colour in oranges and a finer yellow in grapefruit than coastal-grown fruit.

 The reverse change of orange to green occurs after the fruit has gone through a period of high temperature.

 Flavour. Flavour seems to be due to the presence of oil globules in the juice in very small amounts. They comprise a mixture of substances. Determinations have shown that at maturity the amount is only four parts per million of the fruit weight.² The occurrence of bitterness in orange juice was mentioned in Chapter 3.
Maturity Defined by Regulations

The gradual nature of the change in content of juice, acid and soluble solids, and the irrelevance of skin colour changes to palatability, leave no alternative but the adoption of palatability (development of full flavour) and some standard of chemical composition as the legal standards of maturity. In Australia a certain content of acid and juice forms the basis of the chemical standard; investigations that served as the analytical basis for the adoption of standards in New South Wales were reported as early as 1933. The present standards of juice and acid contents are summarized in Table XXX.

### TABLE XXX

**STATE AND EXPORT REQUIREMENTS FOR CITRUS MATURITY**

<table>
<thead>
<tr>
<th>Class of citrus fruit</th>
<th>N.S.W.</th>
<th>Qld</th>
<th>Vic.</th>
<th>S.A.</th>
<th>W.A.</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navel oranges</td>
<td>33</td>
<td>35</td>
<td>30</td>
<td>33</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Other sweet oranges</td>
<td>33</td>
<td>35</td>
<td>30</td>
<td>33</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Grapefruits</td>
<td>33</td>
<td>30</td>
<td>30</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Lemons</td>
<td>25</td>
<td>30</td>
<td>30</td>
<td>..</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Mandarins</td>
<td>20</td>
<td>35</td>
<td>20</td>
<td>..</td>
<td>..</td>
<td>30</td>
</tr>
</tbody>
</table>

### Maximum Acidity

(Number c.c.s. N/10 caustic soda to neutralize acidity in 10 c.c.s. juice)

<table>
<thead>
<tr>
<th>Class of citrus fruit</th>
<th>N.S.W.</th>
<th>Qld</th>
<th>Vic.</th>
<th>S.A.</th>
<th>W.A.</th>
<th>Europe Elsewhere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navel oranges</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Other sweet oranges</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>Europe and New Zealand 30 Elsewhere 26</td>
</tr>
<tr>
<td>Grapefruits</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
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</tr>
<tr>
<td>Lemons</td>
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</tr>
<tr>
<td>Mandarins</td>
<td>..</td>
<td>20</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>
Either the palatability test or the acid test alone may be misleading, for oranges on trifoliata in the main regions often develop good palatability before they are able to pass the acid test. On the other hand, northern fruit is able to pass the acid test often before it has developed good palatability. In some citrus-producing countries total soluble solids are taken into consideration and maturity is defined as a certain ratio of acid to total soluble solids. The Australian maturity test is simpler.

**Fig. 91.** Equipment for citrus-maturity testing.

(Government Printer, N.S.W.)

**Maturity Tests**

Equipment (graduated in cubic centimetres) is as follows:

- 50 c.c. burette and stand.
- 10 c.c. pipette.
- 300 or 500 c.c. Erlenmeyer flask.
- 100 c.c. measuring cylinder.
- 500 c.c. beaker.
- Glass stirring rod.
- Conical glass lemon-squeezer.
- Wire-mesh strainer of not less than thirty meshes to the linear inch.
- Solution of deci-normal sodium hydroxide in stoppered bottle (also called 0·1 N or N/10th caustic soda, NaOH).
- Phenolphthalein indicator (one per cent alcoholic solution) in dropper bottle.
- Suitable balance.
The glassware should be kept clean by washing it in distilled water or rainwater. If it becomes "greasy" it may be cleaned by rinsing with a warm mixture of potassium bichromate and sulphuric acid. If the burette tap sticks or drips from the side, apply a light smear of Vaseline to the bearing surface, taking care not to block the hole in the tap. Care with the 0·1 N sodium hydroxide solution is necessary; do not replace unused sodium hydroxide solution in the stock bottle; keep the stock bottle tightly stoppered; have solutions made up to exactly 0·1 N by a qualified analytical chemist; obtain new stocks before the start of each Navel and each Valencia season.

*Juice test.* Select and weigh five fruit typical of the fruit to be picked or that has been picked. If a range of sizes is available, select five fruits representing the large sizes, and five the small sizes. Cut the fruits across and extract the juice on the conical glass lemon-squeezer, using hand pressure only. Filter the juice into the beaker through a strainer of thirty meshes to the linear inch. Weigh the juice and express as a percentage.

*Acidity test.* After mixing the juice with the glass rod in the beaker, draw up the juice into the pipette over the mark. Lower the juice-level to the mark by slowly rotating the pipette until the bottom of the meniscus is exactly on the mark. Run the juice into the bottom of the Erlenmeyer flask. Allow time to drain, but do not blow out the pipette, which is designed to deliver the exact quantity under these conditions. Dilute the juice with approximately 100 cubic centimetres of distilled water from the measuring cylinder. Add 5 drops of indicator.

Fill the burette over the zero mark with 0·1 N sodium hydroxide. Allow the soda to run out until the tip of the burette below the tap is filled and free of air bubbles. Run the solution through the burette until the bottom of the meniscus is exactly on the zero mark. Then place the flask containing the juice under the burette and titrate with constant stirring, until a tinge of pink occurs. Stir the liquid and then add more solution, drop by drop, until, using a white background, a faint but permanent pink colour is obtained. Read the burette and record the reading. Add another drop of solution as a check; this should merely intensify the colour if the first reading is correct.

Rinse the glassware with distilled water or rainwater before proceeding with the next sample. Blow the rinsing water from the pipette.

Have a good light for reading the burette and use a white background to detect the colour change when titrating. In borderline tests take additional samples and carry out duplicate tests. If necessary, check intermediate-size fruits.

*Other Regulations Affecting Harvesting*

Time of harvest in some instances may be limited by other regulations. Thus, under the Plant Diseases Act of New South Wales it is required that main-crop Seville oranges and mandarins and intermediate-crop Seville oranges shall be harvested by certain dates as a fruit-fly control measure. For details see Table XXVIII, under Fruit-fly.
Hastening Maturity

In reality there are no practices that hasten the maturity of fruit, as normally obtained under good cultural and management conditions. However, it has been found that a spray of arsenate of lead (four pounds of powder to a hundred gallons of water) depresses the acid content of oranges, thus enabling fruit to pass the acidity test some two to three weeks earlier than unsprayed fruit. The flavour, however, is usually quite inferior to normally ripened fruit, and arsenate-sprayed fruit is not marketable until it is able to pass the acid and full orange flavour tests for maturity.

Phosphorus, similar chemically in many respects to arsenic, has also been used for the same purpose, in the form of superphosphate sprays (fifty pounds of superphosphate to a hundred gallons of water). Soil applications of superphosphate in the amounts normally used have not been found to depress the acidity of the fruit in Australia, although in South Africa this effect has long been observed.

Delay in Harvesting

There are no methods of delaying maturity, but the delay of harvesting after maturity is discussed on p. 269.

LOSS AND WASTAGE OF FRUIT

At this stage it is convenient to consider losses to which a crop is subject, as well as to consider the losses and wastage in fruit after harvesting. Some of the losses occur in the orchard, some develop whilst harvesting and handling, whilst other losses, generally referred to as wastage, take place after the fruit is marketed or if it has been stored.

In the Orchard

Marks and rubs. Marks and abrasions of a non-parasitic nature include rubbing of the skin of the fruit from contact with adjacent leaves or shoots, the ground, or in certain varieties thorns. Silver scurf of lemons is an injury due to rubbing of the skin. Considerable and extensive marking of the skin will occur when protection from wind is inadequate (Chapters 5 and 6). Ground rubs can be eliminated by skirting the trees. Other markings of a non-parasitic nature include hail marks (seldom in the main citrus districts), gumming and splitting of the fruit from exanthema, and injury spots from fumigation or sprays.

Weather losses. Fruit losses can occur as a result of prevailing rainfall conditions, drought (causing fruit drop), excessively rainy periods (causing water spot and fruit drop), or irregular wet and dry spells (causing splitting).

Water spot. This is due to injection of the skin with water during wet periods. Washington Navel oranges and some mandarin varieties are especially subject to the trouble in wet winters. Oil spraying increases susceptibility.
Pest and disease blemishes. Many pests and diseases are responsible for the loss of otherwise good fruit. Those attacking the fruit are listed conveniently in Chapter 12.

Spray residues. Bordeaux mixture is the main offender as the cause of spray residue spotting.

During Harvesting and Handling

Punctures and abrasions. Throughout the various stages in harvesting and preparation for market, great care should be exercised to avoid breaks in the skin and crushing. Any fruit with obvious breaks will be discarded. The most minute punctures and abrasions are important because they afford the means of entry for green and blue moulds.

Oil spot, or oleocellosis. If fruit is harvested while wet or even while damp from rain or dew, the oil cells are likely to be ruptured. The escape of the oil causes shrunklen brown spots to appear in about three days. Fruit should be quite dry when it is being picked.

After Picking

The loss or wastage\(^4,5\) to which fruit is subject after picking and packing may be grouped as follows: (a) fungal wastage including spots resulting from latent infections, rots resulting from the same cause, and surface infections; (b) wilting and loss of flavour; (c) physiological rind blemishes that develop during storage. A number of the disorders are shown in Figs 92-7.

Fig. 92. Black spot.  Fig. 93. Mandarin brown spot.  (Photos: C.S.I.R.O.)

Fungal Wastage

Fungal wastage consists of spots and rots resulting from latent infections, and recent surface infection.

Spots From Latent Infections

Spots resulting from latent infections are black spot and Septoria spot (Figs 92 and 77).
Black spot and Septoria spot arise from infection in the orchard, where suitable control measures should be taken (see Table XXVIII). The former spot develops more rapidly, and the latter less rapidly, and eventually ceases with the increasing temperatures of the spring and early summer months.

**Rots from Latent Infections**

Rots resulting from latent infections are stem-end rot, button rot, and centre-rot.

**Stem-end rot.** The causal organism, *Phomopsis citri*, occurs in the tree, causing melanose, wilting of shoots, and other effects. Infection extends into the button, but not into the fruit on the tree. Fruit harvested from infected trees carries the infection in the button. Injury to the attachment of the button or maturation of the abscission layer between the button and the fruit enables the organism to grow into the fruit. It forms a buff-to brown-coloured pliable or leathery rot. Stem-end rot is second in importance to green mould as a cause of wastage. A weaker-growing organism, *Diplodia natalensis*, which also causes stem-end rot, is found to only a minor extent.

First necessity is the control of the infection in the grove (see Table XXVIII). Pulling, which detaches the button, may result in less stem-end rot than clipping, but the wound renders the fruit very susceptible to green-mould attack. Prevention of the ageing of the button tissue by the hormone 2,4-D has been very successful with lemons. Borax treatment and diphenyl wraps give a measure of control of this organism. Stem-end rot is often accentuated by late harvesting and high storage temperatures.

**Button spot** (Fig. 95). This is a brown, pliable, leathery rot occupying a small area round the button. Several organisms, *Alternaria* spp.,

*Fig. 94. Alternaria centre rot.*

*Fig. 95. Button spot.*

*(Photos: C.S.I.R.O.)*
Colletotrichum gloeosporioides, and Fusarium spp., have been found in these lesions.

Centre-rot (Fig. 94). This occurs when further penetration sometimes takes place along the central pith, when Alternaria spp. predominate, giving the characteristic Alternaria centre-rot.

Surface Infection

Surface infection comes from organisms that cause brown rot and green mould and blue mould rots. For brown rot see Table XXVIII.

Green mould rot. This is caused by Penicillium digitatum and appears first as a soft water-soaked area in the rind. It enlarges rapidly, and a white mycelium appears on the surface, followed by the development of olive-green powdery spore masses, which form a dust-cloud when disturbed.

Blue mould rot. This is caused by P. italicum and develops similarly to green mould rot, but much less rapidly, and the white mycelium forms only a narrow band round the blue spore masses. It is not unusual for blue mould to develop first and be subsequently obscured by the more rapidly growing green mould.

The penicillium spores lodge on the surface of the fruit and later infect wounds. They are essentially wound parasites, hence the necessity for avoiding wounds at all stages of handling. They easily invade rind spots. Sound and unwounded fruits are much more resistant to Penicillium, but they succumb when they reach advanced ripeness, and when exposed to contact infection from infected fruit.

In humid districts green mould is extremely prevalent, and the number of spores on the skin may be in excess of 50,000 per orange. Reduction of the sources of infection is the most obvious method of control, and the importance of hygienic methods both in the grove and in the packing-shed cannot be over-emphasized. Washing to decontaminate the fruit and fungicidal treatments to give it a protective coating are advisable in humid districts.

Since green mould is the chief cause of wastage, the fungicidal treatments given during handling are designed principally for the control of this organism. Borax, sodium orthophenylphenate, and diphenyl wraps are the chief measures used in Australia. As stated above, the first and the last-mentioned methods also give control of the second most important cause of wastage, stem-end rot.

Wilting and Loss of Flavour

After the fruit is picked from the tree the moisture lost as a result of its normal life processes is not replaced, and this loss soon becomes manifest in the development of a wilted, unattractive appearance. Fruits eventually develop discoloured desiccation blemishes on the rind. Fruit that has escaped fungal wastage may become over-mature in storage and develop stale and off flavours that render it inferior.
Physiological Rind Disorders

Storage spot. This consists of discoloured areas of the skin, more or less shrunken and more or less irregular in outline. They are dry, firm, and amber to brown in colour. Storage spot may be divided into button storage spot, referring to markings round the button, and lateral storage spot, referring to all other lesions of the type. Button storage spots are often infected with fungi, and are liable to subsequent rotting. for the button end is the least resistant part of the fruit. Very dark spots are usually not found round the button. Button spots usually contain fungi, for example, Alternaria spp., Colletotrichum gleosporoides, and Fusarium spp.

Lateral spots (Fig. 96) are much less frequently infected although they may contain organisms, for example, Colletotrichum gleosporoides, Alternaria spp., Macrosorum spp., and Septoria spp.

Storage spot occurs commonly on oranges and grapefruit stored at relatively low temperature (37°F to 45°F). Sweating the fruit for several days at 70°F or a few hours at 100°F gives some reduction of storage spot.

Storage at lower temperatures gives other rind disorders, namely scald, gooseflesh, crinkled collapse, skin bleach, and glazed scab.

Scald (Fig. 97). A type of low-temperature disorder, developing in the low range of storage temperature, 34°F to 37°F. It commonly takes the form of a light-brown superficial discolouration, covering most of the fruit.

Gooseflesh. This is more prevalent at 32°F to 34°F. The oil vesicles stand out, the tissue between them being pale and depressed. Gooseflesh is often accompanied by an oily, disagreeable flavour and aroma, and the affected area may be rapidly invaded by mould on removal from storage.
Crinkled collapse. A common disorder of cool-stored mandarins. The oil glands darken and stand out prominently, while the outer rind assumes a pale, irregular crinkly appearance. Finally the skin darkens and the whole fruit collapses.

Skin bleach. This condition may be very serious in cool-stored fruit. It starts as a creamy, opaque discoloration of a considerable area of the rind. The oil vesicles are darker than the surrounding tissue and stand out prominently. The affected area is rather soft, and is readily invaded by organisms.

Glazed scab. This is a dirty cream-coloured scab, with a hard and enamel-like surface. This disorder appears to be purely functional in origin.
CHAPTER 15

HARVESTING AND PREPARATION FOR MARKET

HARVESTING POLICY

Fruit from a given locality ripens at a certain time; thus northern fruit is early, southern fruit is late. Every grower should be aware of just what part or parts of the citrus market his fruit will be capable of supplying and in which his fruit will compete for the best prices. He can then produce and harvest fruit to suit most exactly and economically the requirements of the market at those times. This aspect of the subject may be called harvesting policy, and is discussed before entering upon the technical details of handling the crop.

Fresh-fruit Market—Local and Interstate

Lemons. Up to the present the best plan for harvesting lemons for the fresh-fruit market has been to pick coloured fruit as it reaches commercial size and to maintain a constant supply to the market whilst prices are profitable. Large coarse lemons are not wanted on the fresh-fruit market. When there is a heavy winter crop arrangements will be necessary to dispose of some for juice, for the prices on the fresh-fruit market do not hold.

Keeping the fruit picked also encourages intermediate and summer crops, which are the more profitable. Recent investigations (see p. 284) have placed the curing of lemons on a sound basis, and the amount of this type of fruit could be judiciously increased.

Oranges and mandarins. Early varieties are carefully watched in order to obtainpickings of early coloured fruit as soon as they will pass the maturity test. This practice is especially important in early districts. Such fruit is often artificially coloured; coloured fruit, however, should be of good palatability, otherwise the early orange market will be affected very adversely for several weeks. Marketing as soon as possible also enables avoidance of much fungal spot of the fruit in humid districts.

Washington Navel oranges to be held on the tree should receive a pre-harvest stop-drop spray, otherwise they may drop badly after rain.

With the late variety of orange, Valencia, the period of holding fruit on the tree may be as long as five months after maturity. This practice enables clearance of all the Navel and mid-season oranges, and mid-season and late mandarins. To profit fully from the late hanging of Valencias, proper spraying for pest and disease control is essential.

Grapefruit. Whilst Marsh and Wheeny grapefruit ripen in the winter
better prices obtained in warmer weather, and prevention of fruit-fall by a stop-drop spray is advisable, to take advantage of the summer prices.

Fresh-fruit Export

The regulations made under the Commerce Act of the Commonwealth lay down certain provisions to be complied with in the exportation of fresh fruit. Intending exporters should get in touch with the local fruit officer or inspector to ascertain the current requirements.

Cool storage. Only a small amount of citrus fruit is cool-stored for the local market. Cool storage is required for citrus exports to European markets and is advisable for fruit intended for Eastern markets; exports to New Zealand are usually carried in unrefrigerated space. The small use of cool storage is due to development of other methods of handling the fruit, as will be discussed presently, and to the fact that the possibilities of cool storage for lengthening the life of the fruit are not great; also, the risk of serious wastage in the past has been high. Special harvesting and preparatory treatment is indispensable to successful cool storage.

Fruit for Factories

A certain amount of citrus fruit is required for factory purposes—juice, jam, or marmalade (mainly Seville oranges), canning (mainly grapefruit), peel and pectin (lemons). Harvesting of fruit for factory purposes is arranged, under prior contracts, to conform with the requirements of the processor.

Late Harvesting

The ability of citrus fruits to hold on the tree after they have reached the palatable stage is one of the most remarkable characteristics of the species, which is turned to advantage in the industry. Use is made of this character to spread the harvest, enabling the grower to wait until fruit from earlier districts is disposed of, or to harvest fruit from time to time according to the state of the markets.

Depending on the variety, the fruit on the tree continues for some time to increase in size and sugar content, to decrease in acidity, and frequently to improve in colour. In the interests of maintaining consumption at a high level throughout the citrus season, only fruit from the stage of legal maturity to prime condition should be marketed.

After a certain time, deleterious changes begin to occur. The skin may become coarser, particularly in lemons. After reaching full palatability the flavour deteriorates gradually. Mandarins have only a short period in first-class condition, after which the skin becomes puffy and the flesh loses its juiciness.

In late-held Valencia oranges the changes are marked. If held on the tree into the summer, the rind tends to re-green, and as it is held longer the juice tends to decrease, and the individual juice sacs, notably at the stalk end, to separate, giving the effect known as granulation or riciness. The effect of rootstock on these fruit qualities has been noted on p. 40. The practice adopted to delay granulation as long as possible is to keep the
soil rather dry. After the fruit is picked ample irrigation may be given. Another effect of late hanging in the Valencia orange is the development of alternate cropping.

Whilst held on the tree the fruit withdraws organic and mineral substances. One effect should be referred to here: this is the build-up of magnesium in the seed during and after ripening, which depletes the leaves, aggravates any tendency to yellow-leaf development, and necessitates magnesium fertilizing.

Changes occurring whilst fruit is held on the tree after commercial maturity are fundamentally retrograde as far as the potential life of the fruit is concerned. The life of Washington Navel oranges from the Mildura district is reported to be about three months. When the oranges are picked in July they will last three months in store at 45°F., picked in August they last two months, picked in September they last one month. In October they have reached the lack-of-palatability stage on the tree. Of course, this loss of potential life by holding the fruit on the tree is of no consequence in the case of fruit that is harvested for consumption within two or three weeks. Late hanging of the fruit cannot be carried out unduly without encountering pest and disease effects, such as carry-over of red scale, greater susceptibility to fruit-fly, or rapid development of black spot. Hence citrus fruits held on the tree may reach the end of their commercial life either from loss of palatability by becoming flat or stale in flavour, or by disease development or pest attack. In inland districts disease much less frequently terminates their life than on the coast, where moulds, stem-end rot, brown rot, black spot, and fruit-fly are prevalent and are the more usual cause of terminating the life of the fruit.

**HARVESTING PROCEDURES**

In Chapter 14 sections were given to maturity requirements and the causes of loss during handling and processing, to indicate the precautions which should be taken in practices connected with the time and methods of harvesting. Careful handling is of great importance. Fruit should be dry at the time of picking. All handling of the fruit should be done so as to avoid punctures and other damage such as bruising or crushing, which make abrasions on the skin and allow the entrance of the green-mould fungus. Clippers and gloves are sometimes used when extra care is desired to avoid making wounds. Fingernails should be kept short.

Mature fruit can be picked by an upward twist of the stalk or cut by special clippers. Double clipping—one cut to remove the fruit from the tree and a second cut to sever the stalk at the junction with the button—ensures that there will be no projecting stalk to cause punctures. Clipping results in less subsequent wastage than pulling, unless the fruit is given a fungicidal treatment.

For harvesting, ladders, picking bags, and field-boxes are essential (see Fig. 98). The harvested fruit is placed in the picking bag without allowing it to drop onto other fruit, and the operator must see that bags of fruit are not subject to bruising or crushing against the ladder. When the bag is full, the fruits are allowed to roll out in a steady stream into
the field-box. All fruit should be below the top of the box to prevent crushing when full boxes are stacked on one another. Leave the case on the shady side of the tree.

Field-boxes should be smooth internally and have no projecting nails or splinters, etc. To avoid the entrance of grit as they are distributed, they may be stood on bags or on pieces of timber three inches by two inches in dimension spread out by the trees. Wood-wool in the bottom of the case also saves grit punctures.

Fig. 98. Harvesting oranges.

(Photo: Land.)

After loading on the truck, attention is necessary to the point that transport and unloading does not cause damage en route to the packing shed.

Experiments¹ have shown that careful handling has approximately halved green-mould wastage compared with the usual type of commercial handling. The pickers used gloves, carefully clipped the fruits from the trees and transferred them from the picking bags to the field-cases, which
were smooth and clean and had wood-wool on the bottom. They avoided over-filling the cases, which were carefully handled during transport to the packing house. In the comparative treatment no gloves were used, the oranges were pulled from the trees, and the field-cases were often rough and dirty.

**Hygiene**

Attention to hygiene in various directions to reduce the spore-load on the fruit is necessary, especially in humid districts. These methods include clean-up measures in the orchards prior to picking, the use of clean picking bags and field-boxes, and regular clean-up and sterilization of all equipment used in the packing shed.

**THE PACKING SHED**

The essential features of a packing house are as follows:

1. Sufficient space must be left near the inwards door to stack the fruit from the orchard. If sweating is to be done the space allowed will be larger than if immediate packing is to be carried out.

2. Case-making and case-storage space must be provided. Cases may be purchased ready-made or be made up during slack periods and stacked away, usually with the paper label pasted on. Considerable space may therefore be required. The main case-storage area may be separate from the shed, provided there is reasonable day-to-day storage space in the shed itself. The cases are fed by means of gravity conveyors or hardwood skids to within reaching distance of the packers at the packing bench.

3. A central position is needed for the sorting, grading, sizing, and packing unit.

4. When some preservation treatment is to be given to the fruit, such as washing, waxing, etc., the equipment is set up in front of the previously mentioned unit.

5. A case-closing unit is necessary. This includes the lidding press, labelling (if not already carried out), and the stamping of size and variety of fruit and name of consignee on the case.

6. Sufficient space must be left near the outwards door to stack the closed cases.

7. In certain districts a colouring chamber is conveniently situated for gassing the fruit prior to stage 3.

8. For lemons, storage space annexed to the shed or near by is desirable for economical handling.

The shed should be constructed so as to be cool and airy, the walls about ten to twelve feet high, with high windows in order that stacks of fruit will not obscure the light. Artificial light over the packing unit may be required, and fluorescent lights deserve consideration.

Small houses are frequently more or less oblong in plan. A generalized plan is shown in Fig. 99.

The size of shed depends on the crop to be handled. The sorting, grading, and sizing machine, which should be of a size suitable for the crop to be
handled, forms the central feature of any shed. This equipment together with the spaces for stacking near the inwards and outwards doors are the chief factors determining the size of the house. Size should always err on the generous side, for cramped working conditions are prejudicial to the requisite care in the handling of the fruit.

Arrangements should be such as to allow for the most efficient movement of the fruit and ready progress from one stage to the next. Opportunity should be taken to effect a reduction of manhandling by the use of roller conveyors, conveyor belts, or hardwood skids.

![Diagram of packing shed design](image)

Fig. 99. Packing shed design (not to scale).

(Department of Agriculture, N.S.W.)

**Treatment of Fruit at the Shed**

On unloading, the field-cases are stacked to head height, keeping different pickings, varieties, etc., in stacks separated by spaces.

Treatment of the fruit may consist of few or many steps. The procedure is usually one of three series. Colouring or sweating, if required, may precede any of them. The three procedures are:

1. Sorting, grading, sizing, and packing. This is the minimum procedure and is suitable for good lines of clean fruit.

2. Sorting, washing, or brushing, waxing, grading, sizing, and packing. The object of this series of treatments is to give an improved appearance to the fruit, by the cleaning and polishing treatments.

3. Sorting, washing, disinfection in a fungicidal bath, waxing, grading, sizing, and packing. The object of this—the complete series of treatments—
is to control wastage, as well as improving appearance, by the addition of fungicidal treatments to procedure 2. The main fungicidal methods are the borax "Keepswell" process, the phenate process, and the use of diphenyl wraps.

Sweating

The keeping quality of the fruit will be adversely affected if it is handled in a turgid condition, and a period is allowed for slight wilting. This procedure is sweating. But it has not always been proved in experiments that sweating has a markedly beneficial effect on keeping quality, possibly because a desirable loss in turgidity has either been exceeded or not reached. It seems desirable that the wilting should be equivalent to a one per cent loss in weight (of turgid fruit), and with experience can be judged on the feel of the fruit after standing some time in the stack. The sweating period varies from one or two days to as long as ten days.

The shrinkage of the fruit that takes place enables tight packs to be made, which will withstand transport better. Loose packs, resulting from shrinkage of the fruit in the case, are regarded very unfavourably by the trade.

Colouring

The use of artificial colouring treatment is confined usually in mid-latitude and southern areas to the early fruit of Navel oranges and the late-hanging fruit of Valencia oranges that have undergone re-greening on the tree. In northern districts, where more green colour is retained on the fruit at maturity, a greater range of varieties is subjected to colouring.

Only mature fruit should be treated. Fruit that is artificially coloured but has not developed satisfactory flavour only engenders buyer-resistance, which lasts for some time. In the colouring process, immature fruit is slow to colour, does not develop the best colour, and is highly susceptible to burn from the gas used.

The fruit is treated in the field-boxes.

Gas-tight chambers are necessary for the colouring process. There are no set dimensions for the rooms, and various designs are in use. Moderate-sized chambers approximately six feet cubed are better than one large one. When loading the fruit into the chamber the cases are stacked with a small space between them in order to allow free circulation of the colouring gas.

Either ethylene or acetylene is used.

Ethylene, \( \text{C}_2\text{H}_4 \), is obtainable in cylinders, and by the use of special gauges the correct charge can be introduced into the chamber. For oranges, ethylene is used at the rate of one in five thousand parts at a temperature approximating to 75°F. and a humidity of eighty-five to ninety-five per cent, whilst for lemons the rate is one part in twenty thousand.

Acetylene, \( \text{C}_2\text{H}_2 \), is generated by the use of calcium carbide and water, and is commonly used in northern areas. The required amount of carbide is measured out into a suitable container, and a second vessel containing
water is arranged so as to permit the water to drip slowly on to the carbide, thus releasing gas over a period of time. The reaction is as follows:

\[ \text{CaC}_2 + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{C}_2\text{H}_2 \]

calcium carbide water slaked lime acetylene

The quantity required varies somewhat with the variety. Navel oranges are easily damaged by acetylene, and one to one and a half ounces of carbide will produce a sufficient concentration of gas for each charge in a chamber of two hundred cubic feet capacity. Grapefruit require four to six ounces and lemons twelve to sixteen ounces.\(^6\)

With acetylene, no regular system of recharging is followed. Sometimes the chambers are sealed and charged with gas for four hours, opened and allowed to air for two hours. In other cases they are charged only once in twenty-four hours, the gas being held overnight for ten to twelve hours and the room aired for twelve to fourteen hours. From eight to twelve chargings may be necessary to develop full colour in the fruit.

Temperature influences the rate of colouring, the best range being 65°F. to 75°F., although higher temperatures are not usually detrimental.

Ventilation, preferably forced ventilation, is important. Colouring exposes fruit to conditions that predispose it to the development later of mould and, if present, brown rot.

**Sorting**

Sorting is the first step when the fruit starts on the packing line. As the fruit rolls forward on rotating rollers, blemished fruit is directed towards the discard or cull bin and the remaining fruit towards the packing line for the appropriate grade. Special watch should be kept for fruit with breaks in the skin.

**Fruit-cleaning**

*Brushing.* Light deposits of surface dusts and any other material may be removed by passing the fruit over rotating brushes.

*Wet brushing.* A stiffer type of brush together with a battery of water jets will be required if scale has to be removed.

*Detergent bath.* Heavier accumulations of dust together with fumagine and other superficial fungal developments require washing, especially in wet seasons that encourage the growth of fungi. Fruit passes over the rollers into the bath, where it is submerged and moved forward by rotating paddles.

Considerable work has been done on the washing medium. The proprietary detergents available are mainly based on sodium metasilicate and soap powder, and may include the addition of a synthetic detergent. A proprietary substance (M.1 or M.3) is used at the rate of 0.2 to 0.4 per cent.

The temperature of the bath is 100°F. (90°F. for early picked Navel oranges and lemons), the heat being maintained by heated coils, and the period of immersion is thirty seconds. This period is extended to two minutes when the fungicidal treatment, sodium orthophenylphenate, is combined with the detergent.
Alkaline baths increase wilting or shrivel during the distribution period. A recent development overseas is the replacement of alkaline baths by a soap foam, which is applied at the same time as brushing. A bath becomes charged with spores of green and blue mould as well as dirt and requires changing periodically.

Rinsing. Rinsing away of the alkaline wash is done by a battery of hot-water jets directed on the fruit as it moves over the brushes. The water is held at a temperature of 100°F. The fruit then moves over rotating towels or spin rollers to effect as complete a drying as practicable, in order that dilution of the next tank will not take place.

Fungicidal Treatments

Borax tank. For boraxing, the fruit passes from the cleaning tank and rinsing into a second tank where it is again kept submerged and moved along by rotating paddles. This tank contains five per cent borax held at a temperature of 110°F. The period of immersion is thirty seconds. Alternatively, the bath may contain four per cent borax and one to two per cent boric acid. The purpose of the bath is to provide a fungistatic for green and blue mould control. It also gives some control of stem-end rot. Excess concentrations of borax increase wilting during the distribution period. This effect is alleviated to some extent by the use of the borax and boric acid mixture.

Fruit containing borax is totally prohibited in the United Kingdom, but no prohibition applies to local sales. The borax bath leaves a slight white deposit on the surface of the fruit, which is objectionable from the sales point of view, and is obscured by the subsequent waxing process.

Borax—Wax emulsion tank. In this method the fruit passes from the cleansing bath and rinsing into a tank containing the following mixture:

- Proprietary wax emulsion (Brytene) \ldots 1 volume
- Water, containing borax four per cent and boric acid two per cent \ldots 4 volumes

The concentration in the final mixture is borax 3·2 per cent and boric acid 1·6 per cent.

Sodium phenate tank. Sodium orthophenylphenate is a very promising alternative fungicide to borax, giving better control of green mould. Long and Roberts\textsuperscript{4} at Gosford Citrus Wastage Research Laboratory showed that it is necessary to carefully watch the alkalinity of the tank to avoid injury of the fruit. Injury takes the form of scald spots on the skin, especially of early picked fruit. A pH value less than 11·7 increases the risk of injury, whilst values between 11·7 and 12·0 have proved satisfactory. Hexamine at one per cent had been added as a safener, previous to this discovery.

Sodium orthophenylphenate is used in the first or cleaning tank. It is used at two per cent at a temperature of 90°F. The period of immersion should be two minutes but no longer.

The solution is made up of twenty pounds of commercial sodium
orthophenylphenate, containing 73 per cent of the pure salt, and one pound of fresh caustic soda per hundred gallons of water. Tests of the pH of the solution should be made daily. When the pH has fallen below 11-7 about one pound of caustic soda is required per hundred gallons of solution.

The tank requires topping up with full-strength solution at a rate of approximately thirty gallons per thousand cases of fruit treated, and needs draining, cleaning, and refilling after dipping about six thousand cases of fruit per hundred gallons of capacity. The waste solution is useful for hygienic washing and spraying of field-boxes and the shed and its equipment. Care must be exercised in handling phenate and soda owing to their caustic action.

Phenate dipping is followed by rinsing.

*Other Fungicidal Treatments*

Other fungicidal treatments for the control of wastage may be mentioned here, for the sake of completeness although, as will be pointed out in each case, they are not applied at the same stage in the sequence of processing as fungicidal baths.

*Diphenyl wraps.* These have given very satisfactory control of wastage, especially for export fruit or during long storage. As well as providing effective fungicidal action against green mould and stem-end rot, the wraps prevent shrivel and so the case appears as tightly packed after some two to three months' storage as when first packed.

The wraps should contain thirty to forty milligrammes of diphenyl per hundred square inches (ten-inch by ten-inch wrap) for effective wastage control.

The wraps impart a slight taint to the fruit. It is mainly absorbed in the rind, and quickly disappears when the fruit is unwrapped and exposed to the air.

*Nitrogen trichloride or Decco gas.* This is used to gas railway trucks or rooms packed with cases of fruit, but is not available commercially in Australia. It gives good control of green mould but not of stem-end rot, and moreover it accelerates the rusting of iron fittings.

*Waxing*

Waxing is intended to improve the appearance of the fruit, giving it a clean, highly polished, attractive appearance. It also prevents wilting, but has no fungicidal action. When the borax treatment is used waxing obscures the slight deposit of borax. Various methods have been employed for applying a waxy coating to the fruit, including hot fog, cold slab, and dipping in emulsion. The latter is used in Australia. The main constituents of the proprietary emulsion used are paraffin and carnauba wax.

*Drying*

Dipping in the wax emulsion tank is followed by drying. Hot-air draught dryers are held at a temperature of 120°F. The fruit takes about two and a half minutes to pass through the dryers and be completely dried. Thorough drying is essential.
Grading

State regulations provide for the sale of fruit in grades. Growers should ascertain the exact specifications. Briefly it may be said that special, standard, and plain grades provide that the fruit offered for sale shall be mature, juicy, typical of the variety, sound and of reasonably even colour. Minimum sizes are also prescribed (two inches for oranges and grapefruit in New South Wales). In special grade, the fruit may have skin blemish to the extent of 2½ per cent of the surface of each fruit; in standard grade to the extent of 10 per cent; and in plain grade to the extent of 25 per cent. Factory grade, which must be sold to a factory, is fruit that does not comply with the requirement of the grades mentioned.

Fruit for export must conform with Commonwealth regulations.

The sorting of the fruit to the appropriate grade is carried out after processing and before it passes to the sizing machine.

Sizing

The sizing machine (Fig. 100) depends on conveying fruit on an endless rubber belt past a long rubber roller of stepped decreases in diameter; the smallest opening between belt and roller occurs first, allowing the smallest fruit to pass off the belt; successive sizes pass off at successively wider openings between belt and roller. The fruit is received in bins. The rotary bin has the advantage that there is less possibility of damage to the fruit, and the fruit is held up to a height convenient for the packer.

The branding of individual fruits carried out in some central sheds is done mechanically just as the fruit enters the sizing machine.

Packing

One object of the packing method is to place or fit fruit firmly into a container so as to ensure the least possible damage during transport and distribution. The container should be as economical as is consistent with the object of holding the fruit without damage; the container is sold with the fruit, and in most circumstances is non-returnable. A second object is the use of a standard or regular system of packing.

Containers. These objects will not be achieved unless the container is suitable. Fibreboard cartons, mesh bags, and other novel containers have been used at times and have received a certain amount of publicity, but the standard container is the wooden case.

The size of the bushel cases permitted under certain Acts is shown in Table XXXI.

<table>
<thead>
<tr>
<th>Type of case</th>
<th>Length</th>
<th>Width</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard case...</td>
<td>18 ins</td>
<td>11½ ins</td>
<td>10½ ins</td>
</tr>
<tr>
<td>Australian dump</td>
<td>18 ins</td>
<td>8½ ins</td>
<td>14½ ins</td>
</tr>
</tbody>
</table>
Fig. 100. Sizing machines, with canvas, spring boards (above), and rotary bins (below).

(Photos: Lightning Implements Pty Ltd.)
Thickness of the timbers used in construction of the case is important. Timber thickness for the standard case as specified for export may be summarized as shown in Table XXXII.

**TABLE XXXII**

TIMBER THICKNESSES IN STANDARD CASES

<table>
<thead>
<tr>
<th>Part of case</th>
<th>Soft wood not less than</th>
<th>Hard wood not less than</th>
</tr>
</thead>
<tbody>
<tr>
<td>End</td>
<td>$\frac{1}{6}$ to $\frac{1}{4}$ inch</td>
<td>$\frac{1}{4}$ to $\frac{1}{2}$ inch</td>
</tr>
<tr>
<td>Sides</td>
<td>$\frac{1}{9}$ inch, one or two pieces</td>
<td>$\frac{1}{4}$ inch, one piece; $\frac{1}{6}$ inch, two pieces</td>
</tr>
<tr>
<td>Top and bottom</td>
<td>$\frac{1}{9}$ inch, two pieces, or if united with cleat, two, three, or four pieces, not less than $\frac{1}{4}$ inch, or more than $\frac{1}{8}$ inch thick</td>
<td>$\frac{1}{9}$ inch, one, two, or three pieces, or if united with cleat, two, three, or four pieces, not less than $\frac{1}{4}$ inch, or more than $\frac{1}{8}$ inch thick.</td>
</tr>
</tbody>
</table>

The case should be put together in a workmanlike manner, especially as regards freedom from projecting nails and correct spacing of the pieces of timber so that they will not mark the fruit. Suitable nails are one and a half inch, 12-gauge. When the case is packed and wired and stacked on its side, the dimensions of the timbers are such that the weight of the fruit is borne largely on the end pieces—the strongest timbers.

*Standardization.* The second object of packing is to use the standard or regular system of packing, which gives attractive uniform packs.

Standardization is the key-note of packing. The size of the cases is prescribed by law. The size of fruit in each bin has been carefully regulated by the sizing machine. Packs have been worked out for the different sizes, giving a certain number or count of fruit in the case. The counts must be marked on the label. Buyers expect these standard counts, and regard counts that do not conform with them as foreign counts and evidence of faulty sizing and packing. The fruit in a case that has a foreign count may be quite uniformly sized and well packed, but the size and the count are not those accepted as standard in the trade.

*Standard packs.* Table XXXIV gives particulars of standard packs in the standard bushel case for oranges ranging in size from 2$\frac{1}{4}$ inches to 3$\frac{1}{2}$ inches and for lemons ranging from 2 inches to 2$\frac{1}{4}$ inches. Similar packs for the Australian dump case are shown in Tables XXXV-XXXVII. Packed cases of lemons are shown in Fig. 102. The information provided in the columns in Tables XXXIV-XXXVII may be explained as follows:

The term “size” is the diameter from cheek to cheek. Although the machine may have been set to deliver the correct size, starting with 2$\frac{1}{2}$ inches, into the bins, the fruit in the bins should be checked with rings and a trial pack made to see that it will fill the case correctly,
using the pack indicated for the size. The effect on count of the larger and smaller fruit in the bin of a given size is shown in the case of 2½-, 2½-, 2½- and 3-inch fruit, by the terms N and F, which are explained in the tables.

The term "pack" refers to the number of fruit in two adjacent rows across the case and is illustrated in Fig. 101. It is decided by the first and second rows placed in the bottom of the box.

The term "row count" refers to the number of fruits that are fitted into the length of the case in two adjacent rows. Row count is decided by the number of rows of fruit fitted into the bottom of the case and is illustrated in Fig. 101.

The term "layers", sometimes also called tiers, refers to the number of layers required to fill the case.

The term "count" refers to the number of fruit in the case.

**Wrapping.** Much of the crop is sold as unwrapped fruit although a proportion has always been sold wrapped in thin sulphite paper. Diphenyl wraps have been referred to as a marked advance for wastage control. Wrapping is compulsory for all oranges packed for export.

![Fig. 101. "Pack" and "row count".

(Deartment of Agriculture, N.S.W.)](image-url)
The sizes of the wraps required for different-sized fruit are shown in Table XXXIII.

<table>
<thead>
<tr>
<th>Size of fruit</th>
<th>Size of paper</th>
<th>Number of cases per (\text{ream of paper})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2½ to 2¾</td>
<td>9 x 9</td>
<td>18 or 19</td>
</tr>
<tr>
<td>2½ to 3</td>
<td>10 x 10</td>
<td>17 or 18</td>
</tr>
<tr>
<td>3 to 3½</td>
<td>11 x 11</td>
<td>16 or 17</td>
</tr>
<tr>
<td>Over 3¼</td>
<td>12 x 12</td>
<td>15 or 16</td>
</tr>
</tbody>
</table>

*Lining paper.* This is seldom used for citrus packing, except for mandarins on occasion.

*Method of packing.* The method shown is space packing, that is, after the first row is placed in the box each orange, etc., is placed not opposite another but in the space between, until the bottom layer is completed according to the proper count. Correct pack and row count in the bottom layer are fundamental to obtaining a standard count in the packed box.

*Fig. 102.* Packed boxes of counts shown.

*(Department of Agriculture, N.S.W.)*
The second layer is started, and continued, in the spaces of the first layer. Subsequent odd-numbered layers will be similar to the bottom layer, and even-numbered layers to the second layer.

The fruit is brought up so that it is well above the top of the sides in the form of a crown (see Fig. 103) in the standard case.

![Fig. 103. Side view of packed case before lidding showing crown pack used in the standard box.](image)

![Fig. 104. Lidded and wired box (same case as in Fig. 103), showing equal distribution of crown between top and bottom boards.](image)

(Released by the Department of Agriculture, N.S.W.)

**Closing the case.** After packing, each case is stamped with the count and set on the conveyor to the case-closing unit, where the lid is nailed down. Various types of presses are available to suit the shed capacity.

When the standard case is closed the crown formed in packing will be distributed equally between the top and the bottom of the case (see Fig. 104), giving the necessary bulge required by the trade. The lid and the bottom, being of lighter timbers, take the bulge; the sides, being of slightly heavier timber, resist bulging and remain flat. The Australian dump case is packed without this noticeable bulge.

At this stage the case is turned on its side for all subsequent handling and stacking, in order that the weight will be taken on the end boards, via the flat sides. Individual cases, of course, may be set down on their end but never on the bulge.

Wiring is the next operation. It not only protects the contents against pilfering, but secures the end boards against splitting. The wires must be carefully placed as close to the end boards as possible, just inside the cleats of the top and bottom (Fig. 104).

**Labelling.** Regulations make minimum provision for labelling—that the package should be legibly marked on one end, in letters not less than three-quarters of an inch high with the name and address of the packer and the name of the variety, grade, and count or size of the fruit contained. For the printed paper label that is pasted on the end of the case, the letters may be not less than a quarter of an inch high.

The colour-printed label, of attractive design, clearly publicizing the contents of the case, is a telling factor in the presentation of fruit.
Lemons may be stored in orchard sheds at ordinary temperatures for a period of five to six months if the correct treatment is given. Highly satisfactory methods are now available as the result of investigations at the Gosford Citrus Wastage Research Laboratory, although storage must be entertained with due regard to the market. The main crop of lemons ripens during the winter months when demand and return are lowest, and it would be necessary to store winter lemons until January or February for the best prices.

### TABLE XXXIV
PACKING CHARTS FOR THE STANDARD CASE

N = Neat; F = Full.

**Oranges**

<table>
<thead>
<tr>
<th>Size</th>
<th>Pack</th>
<th>Row count</th>
<th>Layers</th>
<th>Total count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3-3</td>
<td>7-7</td>
<td>6</td>
<td>252</td>
</tr>
<tr>
<td>2F</td>
<td>3-3</td>
<td>7-6</td>
<td>6</td>
<td>234</td>
</tr>
<tr>
<td>2</td>
<td>3-3</td>
<td>6-6</td>
<td>6</td>
<td>216</td>
</tr>
<tr>
<td>2F</td>
<td>3-3</td>
<td>6-5</td>
<td>6</td>
<td>198</td>
</tr>
<tr>
<td>2N</td>
<td>3-3</td>
<td>5-5</td>
<td>6</td>
<td>180</td>
</tr>
<tr>
<td>2F</td>
<td>3-2</td>
<td>7-7</td>
<td>5</td>
<td>175</td>
</tr>
<tr>
<td>2W</td>
<td>3-2</td>
<td>7-6</td>
<td>5</td>
<td>163</td>
</tr>
<tr>
<td>2N</td>
<td>3-2</td>
<td>6-6</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>2F</td>
<td>3-2</td>
<td>6-5</td>
<td>5</td>
<td>138</td>
</tr>
<tr>
<td>2W</td>
<td>3-2</td>
<td>5-5</td>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>3</td>
<td>3-2</td>
<td>4-4</td>
<td>5</td>
<td>113</td>
</tr>
<tr>
<td>3F</td>
<td>2-2</td>
<td>6-6</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>2-2</td>
<td>6-5</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>3W</td>
<td>2-2</td>
<td>5-5</td>
<td>4</td>
<td>80</td>
</tr>
</tbody>
</table>

**Lemons**

<table>
<thead>
<tr>
<th>Size</th>
<th>Pack</th>
<th>Row count</th>
<th>Layers</th>
<th>Total count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3-3</td>
<td>8-7</td>
<td>6</td>
<td>270</td>
</tr>
<tr>
<td>2F</td>
<td>3-3</td>
<td>7-7</td>
<td>6</td>
<td>252</td>
</tr>
<tr>
<td>2</td>
<td>3-3</td>
<td>7-6</td>
<td>6</td>
<td>234</td>
</tr>
<tr>
<td>2F</td>
<td>3-3</td>
<td>6-6</td>
<td>6</td>
<td>216</td>
</tr>
<tr>
<td>2W</td>
<td>3-3</td>
<td>6-5</td>
<td>6</td>
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<tr>
<td>2N</td>
<td>3-3</td>
<td>5-5</td>
<td>6</td>
<td>180</td>
</tr>
<tr>
<td>2F</td>
<td>3-3</td>
<td>5-4</td>
<td>6</td>
<td>162</td>
</tr>
<tr>
<td>2W</td>
<td>3-2</td>
<td>6-6</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>2N</td>
<td>3-2</td>
<td>6-5</td>
<td>5</td>
<td>138</td>
</tr>
<tr>
<td>2F</td>
<td>3-2</td>
<td>5-5</td>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>3-2</td>
<td>5-4</td>
<td>5</td>
<td>113</td>
</tr>
</tbody>
</table>
The best time to harvest the fruit is when it is at the light-green to silver stage. Greener fruits are subject to excessive shrivelling in store.

The fruit should be at least 2½ inches in diameter. Fruits of sufficient size are more readily available at the light-green to silver stage than when greener. The lemons must be carefully clipped from the tree and handled very carefully to avoid injury that would allow the entrance of the green-mould organism. Fruit should be taken only from vigorous, healthy trees. Freedom of the tree from melanose is especially important in order to avoid stem-end rot of the fruit.

After harvesting, the fruit should be dipped immediately in a solution of 2,4-D, five-hundred parts per million, and sodium salicylanilide 0·25 per cent. The 2,4-D has the effect of keeping the buttons green. As a result, breakdown of tissue does not occur during storage at the abscission layer where the button joins the fruit, and the melanose organism does not invade the fruit and cause stem-end rot. The sodium salicylanilide is for the control of green mould, and it aids in the control of stem-end rot.

Alternative treatments aim at greater field control of the melanose (or stem-end rot) organism in the orchard. They are: (a) the routine Bordeaux spray at half-petal fall; (b) Bordeaux spray between February and April, additional to the half-petal-fall Bordeaux spray. The harvested fruit is dipped in 2,4-D as in the first-mentioned method.

**TABLE XXXV**

**PACKING CHART FOR THE AUSTRALIAN DUMP CASE**

| N = Neat; F = Full. |

| Oranges |

<table>
<thead>
<tr>
<th>Size</th>
<th>Pack</th>
<th>Row count</th>
<th>Layers</th>
<th>Total count</th>
</tr>
</thead>
<tbody>
<tr>
<td>ins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2N</td>
<td>3-2</td>
<td>7-7</td>
<td>9</td>
<td>315</td>
</tr>
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<td>7-6</td>
<td>9</td>
<td>293</td>
</tr>
<tr>
<td>2</td>
<td>3-2</td>
<td>6-6</td>
<td>9</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>3-2</td>
<td>6-5</td>
<td>9</td>
<td>248</td>
</tr>
<tr>
<td>2</td>
<td>3-2</td>
<td>5-5</td>
<td>9</td>
<td>225</td>
</tr>
<tr>
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<td>3-2</td>
<td>7-7</td>
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</tr>
<tr>
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<td>3-2</td>
<td>7-6</td>
<td>7</td>
<td>182</td>
</tr>
<tr>
<td>2</td>
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<td>2-1</td>
<td>4-3</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>2-1</td>
<td>4-3</td>
<td>5</td>
<td>53</td>
</tr>
</tbody>
</table>
The lemons are stored loose in paper-lined field-boxes in a ventilated, cool shed. They should be examined from time to time, and infected fruit should be discarded to prevent the contact spread of infection.

**Oranges, Mandarins, and Grapefruit**

These fruits have not the storage capabilities of the lemon, even through the use of cool storage. Suitable fruit of the Washington Navel may be kept a maximum of three months in store without excessive wastage, the Valencia slightly longer, although it is very subject to storage spot. Common oranges and mandarins have a shorter life than Washington Navel. Of the mandarins, Ellendale has better keeping qualities than Emperor. Grapefruit is very susceptible to storage spot and also has a very limited life.

Cool storage may be used for special purposes. For the destruction of fruit-fly in fruit from infected districts cool storage at 31°F. for a period of two weeks is required by the New Zealand market. The treatment may adversely affect the fruit.
The usual storage conditions given to fruit are as follows:

Temperature. Oranges 40°F. to 45°F.; for late pickings, which are more subject to fungal wastage, a temperature of 40°F. is preferable. Mandarins 45°F., grapefruit 50°F. It is of interest in passing, that storage temperatures for the different fruits range in a similar order to their growth-temperature preferences.

Humidity. Eighty-five to 90 per cent.

**TABLE XXXVII**

**PACKING CHART FOR THE AUSTRALIAN DUMP CASE**

<table>
<thead>
<tr>
<th>Size</th>
<th>Pack</th>
<th>Row count</th>
<th>Layers</th>
<th>Total count</th>
</tr>
</thead>
<tbody>
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<td>5-5</td>
<td>6</td>
<td>120</td>
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<td>6</td>
<td>108</td>
</tr>
<tr>
<td>3/4 in</td>
<td>2-2</td>
<td>4-4</td>
<td>6</td>
<td>96</td>
</tr>
<tr>
<td>3/4 in</td>
<td>2-2</td>
<td>4-3</td>
<td>6</td>
<td>84</td>
</tr>
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<td>5-4</td>
<td>5</td>
<td>68</td>
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<tr>
<td>3/4 in</td>
<td>2-1</td>
<td>4-4</td>
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<td>60</td>
</tr>
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<td>3/4 in</td>
<td>2-1</td>
<td>4-3</td>
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<td>53</td>
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<tr>
<td>4 in</td>
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<td>3-3</td>
<td>5</td>
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<tr>
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<td>2-1</td>
<td>2-2</td>
<td>5</td>
<td>30</td>
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</tbody>
</table>

**Mandarins†**

<table>
<thead>
<tr>
<th>Size</th>
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<th>Layers</th>
<th>Total count</th>
</tr>
</thead>
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<td>10</td>
<td>455</td>
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<td>6-6</td>
<td>10</td>
<td>420</td>
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<td>6-5</td>
<td>9</td>
<td>385</td>
</tr>
<tr>
<td>2 1/8 in</td>
<td>3-3</td>
<td>5-5</td>
<td>9</td>
<td>330</td>
</tr>
<tr>
<td>2 1/8 in</td>
<td>3-3</td>
<td>5-5</td>
<td>8</td>
<td>297</td>
</tr>
<tr>
<td>2 1/8 in</td>
<td>3-2</td>
<td>6-5</td>
<td>8</td>
<td>270</td>
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</tr>
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<td>6-5</td>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>3 1/2 in</td>
<td>2-2</td>
<td>6-5</td>
<td>5</td>
<td>140</td>
</tr>
</tbody>
</table>

* In all counts the grapefruit is packed on the cheek with the stylar end facing the sides of the case. The large-size grapefruit are very difficult to pack to a satisfactory height unless the following rule is observed: The 4-inch and 4½-inch are packed together as 53 count, the 4-inch and 4½-inch as 45 count, the 4½-inch and 4¾-inch as 38 count, and the 4½-inch, 4¾-inch and 5-inch as 30 count.

† For this mandarin packing-chart the straight method of diagonal packing is adopted, with the stylar ends of the fruit facing the sides of the case.
Ventilation. The ventilation of the fruit in the store is also important. The fruit is set on dunnage in stacks not more than two cases wide with spaces between the stacks, which facilitates the circulation of air within the cases and thus the maintenance of the desired temperature and humidity.

The danger of tainting other produce by the volatile products of citrus fruits in cool store should be borne in mind. Butter and other produce liable to absorb taint must be stored so that they will not be affected by the citrus volatiles.

As the respiration rate of citrus fruits is low and is not subject to appreciable reduction by cool storage, the function of cool storage is to provide conditions that postpone the three causes of wastage—namely, fungal wastage, shrivel, and loss of flavour—and physiological storage disorders, which have been discussed in the previous chapter.

Citrus fruits for storage must have reached harvest maturity and have developed pronounced flavour for the variety before they are picked. Although the fruit slowly loses acidity in store, it does not improve in flavour.

Early harvested fruit is more subject to storage spot, less subject to fungal rots, and generally speaking has a greater potential storage life. Early picks may end up rather flavourless.

Late-harvested fruit although less subject to storage spot is more subject to fungal decay, and has not much storage life left before loss of palatability occurs.

There is a great difference in the life of fruit grown under different conditions, fruit grown in humid climates usually having a lower keeping quality than that grown in arid climates.

Environmental conditions occurring during the growth of the fruit affect its storage life. For example, it has been found in Mildura that oil-sprayed fruit is more susceptible to wastage than fumigated fruit; that fruits from trees receiving a complete fertilizer are slightly less susceptible to decay than those receiving only nitrogen and phosphorus; that fruit from Rough lemon rootstock is more susceptible to decay than that on sweet orange and sour rootstocks; fruit from near the ground is slightly more susceptible to wastage than that from the top of the tree.

CITRUS BY-PRODUCTS

The technology of citrus by-products is discussed in a recent book by Braverman entitled Citrus Products. The anticipated third volume of The Citrus Industry, to be published by the University of California, will also include technological methods.
APPENDIX

KEYS TO GENERA AND SPECIES*

CITRUS AND THEIR NEAREST RELATIVES

The common edible citrus fruits are embraced in about ten species in the family Rutaceae, which contains some 1600 species. They are included in a compact group or sub-tribe, Citrinae, of the tribe Citreae, sub-family Aurantioideae, one of the seven sub-families of the family Rutaceae. The sub-tribe Citrinae is divided as follows:

<table>
<thead>
<tr>
<th>Group A. Primitive citrus</th>
<th>Group B. Near-citrus</th>
<th>Group C. True citrus</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Limnocitrus</td>
<td></td>
<td>11. Clymenia</td>
</tr>
<tr>
<td>5. Hesperethusa</td>
<td></td>
<td>12. Microcitrus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13. Citrus</td>
</tr>
</tbody>
</table>

The 13 genera of the Citrinae (the Citrus Fruit Trees), which include 65 species, differ strikingly from the other members of the orange sub-family in having pulp-vesicles, very peculiar structures that arise from the locule walls (especially the dorsal wall) and grow into the locular cavity, developing into sacs filled with numerous large, very thin-walled cells full of a watery juice. No such structures are found in any other plants of the family Rutaceae or in related families, and no close homologies are known among any of the higher plants. Other genera of the sub-family Aurantioideae have secretory glands on the locule walls, from which arises the mucilaginous gum that fills the locular cavity of the ripe fruit in most of the genera.

These organs are found only in the sub-tribe Citrinae and in full perfection only in the genus *Citrus*; nor are they known to occur in any other of the half million or so species of higher plants now recognized by taxonomic botanists.

**Group A. The Primitive Citrus Fruit Trees.** This group includes the five genera of the sub-tribe Citrinae: *Severinia*, *Pleiospermium*, *Burkillanthus*, *Limnocitrus*, and *Hesperethusa*, which show the most primitive pulp-vesicles, lacking the stalks of the pulp-vesicles of group C (the Træe Citrus Fruit Trees) and the definite conical shape with broad sunken bases of those of group B (the Near-citrus Fruit Trees).

*Hesperethusa*, like *Citropsis*, can be grafted on *Citrus*, and vice versa.

**Group B. The Near-citrus Fruit Trees.** This group includes two genera, *Citropsis* and *Atalantia*, that show well-developed pulp-vesicles having broad sessile bases and conical sides that taper regularly to the acute apices.† These pulp-vesicles are arranged more or less radially with the bases at the periphery of the fruit locules attached to the dorsal walls of the locules and embedded in the inner layer of the rind. The conical pulp-vesicles usually point toward the centre of the fruit unless deflected by the seeds, which (if present) are attached at the inner angle of each locule.

* After Walter J. Swingle, "The Botany of Citrus . . .", *The Citrus Industry* (see general reference 1 in the bibliography, infra).

† Some of the species of *Atalantia*, such as *A. ceylanica*, have fruits with very few pulp-vesicles, apparently because the seeds have become very large and fill the locules of the fruit almost completely, leaving little room for pulp-vesicles. These species constitute the sub-genus *Russet*. Another species, *A. guillauminii*, which has much resemblance to *A. ceylanica*, seems to have no pulp-vesicles; it has perhaps lost them by retrograde evolution.

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Both *Citropsis* and *Atalantia* are obviously related to the True Citrus Fruit Trees of group C, and some three species of *Citropsis* and two of three species of *Atalantia* (all that have been tested) can be grafted on *Citrus*, and vice versa.

**Group C. The True Citrus Fruit Trees.** This group includes six genera, *Fortunella*, *Eremocitrus*, *Poncirus*, * Clymenia*, *Microcitrus*, and *Citrus*, all marked by having orange- or lemon-like fruits with highly specialized, slender-stalked, usually more or less fusiform pulp-vesicles filling all the space in the segments of the fruit not occupied by the seeds, and also by having at least four times as many stamens as petals. All the genera have persistent one-foliate or simple leaves, except the monotypic genus *Poncirus*, which has three-foliate, deciduous leaves.

**Origin.** The region occupied by the six genera comprising the True Citrus Fruit Trees is a long, barrel-shaped area about 9000 kilometres (5590 miles) long and 3200 kilometres (1990 miles) wide in the centre, tapering to about 2600 kilometres (1615 miles) at the ends. This barrel-shaped area has its long axis slanting from the north-west (north-eastern British India to north-central China) to the south-east (east-central Australia to New Caledonia). At its broadest part the area extends from Java to the eastern shores of the Philippine Islands. If, as some experts believe, *Citrus* is native to southern Japan, there would be an extension of the northern corner of this area to include *Citrus tachibana*. *Citrus* is native to the whole of the area except in the southernmost corner (north-eastern Australia), where it is replaced by *Microcitrus* and *Eremocitrus*, and in the extreme northernmost corner (northern China), where it is replaced by *Poncirus*. *Fortunella* occurs in south-eastern China, where *Citrus* is probably also native, and *Clymenia* occurs in the Bismarck Archipelago (the extreme easternmost part of the area), where one species of *Citrus* is probably also native.

The six genera of group C are all obviously closely related and all (except the new and little-studied genus *Clymenia*) have been grafted on one another and hybridized with one another.

**KEY TO GENERA OF THE TRUE CITRUS FRUIT TREES**

Stamens four (or sometimes more) times as many as the petals; fruits filled with slender-stalked, fusiform pulp-vesicles acute at apex (subsessile in *Clymenia*, rounded at apex in *Eremocitrus* and most species of *Microcitrus*)—

Leaves deciduous, three-foliate; flowers produced from scaly buds on last year's twigs .................................................. *Poncirus*

Leaves persistent, one-foliate; flowers produced on new growth in spring—

Leaves very thick, grey-green, with palisade tissue and stomata on both faces; stamens with free filaments; ovaries with three to five locules, each with two ovules ................................................................. *Eremocitrus*

Leaves thin or only moderately thick, with palisade tissue and stomata on the lower side only; ovaries with many ovules in each locule, or if with only two in each locule, then with the filaments cohering in bundles—

Pulp-vesicles subsessile, sub-globose, usually narrowed toward the base but without a slender stalk, attached in large numbers to the side walls as well as to the dorsal walls of the locules; stamens very numerous (ten to twenty times as many as the petals); stamens with filaments free ................................................................. *Clymenia*

Pulp-vesicles usually elongate, sometimes sub-globose (*Microcitrus*), but always slender-stalked, attached to the dorsal walls, usually few or none attached to the side walls of the segments; stamens four to eight times as many as the petals—

Leaves dimorphic, very small on the young seedlings; stamens with filaments free; ovaries with four to eight locules, many ovules in each locule; stamens four (or five?) times as many as the petals .................................................. *Microcitrus*

Leaves not dimorphic; staminal filaments cohering in bundles—

Ovaries with three to seven locules, two ovules in each locule ................................................................. *Fortunella*

Ovaries with eight to eighteen (usually ten to fourteen) locules, four to twelve ovules in each locule; stamens four to eight times as many as the petals .................................................. *Citrus*
APPENDIX

SPECIES OF THE TRUE CITRUS FRUIT TREES

Fortunella margarita (Lour.) Swing. Oval cumquat
F. japonica (Thunb.) Swing. Round cumquat
F. polyantha (Ridl.) Tan. Malayan cumquat
F. hindsii (Champ.) Swing. Hongkong wild cumquat
Eremocitrus gleuca (Lindl.) Swing. Australian desert lime
Poncirus trifoliata (Linn.) Raf. Trifoliolate orange
Clymenia polyantha (Tan.) Swing. Clymenia
Microcitrus australasica (F. Muell.) Swing. Australian finger lime
M. australis (Planch.) Swing. Australian round lime
M. garrowayi (F. M. Bail.) Swing. Garroway's Australian wild lime
M. inodora (F. M. Bail.) Swing. Large-leaf Australian wild lime
M. maireana (Domin.) Swing. Maiden's Australian wild lime
M. warburgiana (F. M. Bail.) Tan. New Guinea wild lime
Citrus medica Linn. Citron
C. medica var. sarcodactydis (Noot.) Swing. Fingered lime
C. medica var. ethrog Engl. Etrog citron
C. limon (Linn.) Burm. Lemon
C. aurantifolia (Christm.) Swing. Lime
C. aurantium Linn. Sour, Seville, or bigarade orange
C. sinensis (Linn.) Osbeck Sweet orange
C. reticulata Blanco Mandarin
C. reticulata var. austera Swing. Sour mandarin
C. grandis (Linn.) Osbeck Pummelo
C. paradisi Macf. Grapefruit
C. indica Tan. Indian wild orange
C. tachibana (Mak.) Tan. Tachibana orange
C. ichangensis Swing. Ichang papeda
C. latipes (Swing.) Tan. Khasi papeda
C. micrantha Wester Binsung
C. celebica Koord. Celebes papeda
C. macroptera Montr. Melanesian papeda
C. hystrix DC. Mauritius papeda

KEY TO THE SPECIES OF Citrus

Pulp-vesicles nearly free from oil droplets and never containing acrid oil; petioles with narrow wings or wingless, or, if broadly winged, subcordate and never three-quarters as broad as the leaf blades; flowers large and fragrant (usually 2.5 to 4.5 centimetres in diameter); stamens cohering in bundles (sub-genus Eucitrus)—

Segments of the fruit few (six to eight); fruits flattened, yellow when ripe, juice bitter, making fruit almost inedible; petioles short, with very narrow wings; flowers small (about 1.2 to 1.4 centimetres in diameter) ..................................................... Tachibana orange, C. tachibana Segments of the fruit numerous (nine to fourteen, rarely fifteen to eighteen); pulp acid, sweet, or slightly bitter; flowers large (usually 2.5 to 4.5 centimetres in diameter)—

Petioles wingless, joined directly to the leaf blade or imperfectly articulated with it; flowers of two sorts, perfect or often male with abortive ovaries; fruits large, with very thick peel ............................... Citron, C. medica Petioles winged, clearly articulated with the blade—

Stamens usually more than four times the number of petals, flowers of two sorts, perfect or often male with abortive ovaries; petioles with very narrow wings ............................... Lemon, C. limon Stamens usually four times the number of petals; flowers usually perfect; petioles with narrow or broad wings—

Fruits with loose peel, easily detached from the segments—

Seeds small, not noticeably flattened, embryo green ............................... Mandarin, C. reticulata
Seeds large, roundish, flattened, about quarter to one-third as thick as long; petioles very short, one-tenth to one-fifteenth as long as the leaf blade, very narrowly winged; leaves caudate

\[ \text{Indian wild orange, } C. \text{ indica} \]

Fruits with adherent peel; seeds not green within—
Fruits large or very large (usually 10 to 15 centimetres in diameter)—

- Fruits very large (usually 11 to 17 centimetres in diameter); pulp vesicles large, usually easily separable; petioles broadly winged, subcordate; seeds large, usually flat and yellowish, rough, usually with only a single embryo

\[ \text{Pummelo, } C. \text{ grandis} \]

- Fruits large (9 to 13 centimetres in diameter); pulp-vesicles rather large, coherent; petioles rather broadly winged but not subcordate; seeds rather smooth, white, polyembryonic

\[ \text{Grapefruit, } C. \text{ paradisi} \]

Fruits medium-sized or small (usually 5 to 10 centimetres in diameter); pulp-vesicles mutually coherent; petioles with medium-sized or narrow wings, not subcordate—

- Fruits small (usually 4 to 6 centimetres in diameter), ovoid; pulp greenish, usually very acid; peel yellowish green; seeds small, smooth, with brownish-red chalazal caps

\[ \text{Lime, } C. \text{ aurantifolia} \]

- Fruits medium-sized (usually 5 to 9 centimetres in diameter), sub-globose; peel bright orange or scarlet-orange—
- Peel orange-coloured, smooth; pulp sweet, petioles narrowly winged

\[ \text{Sweet orange, } C. \text{ sinensis} \]

- Peel brilliant scarlet-orange, rough; pulp very sour, more or less bitter; petioles rather broadly winged

\[ \text{Sour or Seville orange, } C. \text{ aurantium} \]

Pulp-vesicles containing numerous droplets of acrid oil; petals long and very broadly winged, but not cordate, often nearly as broad as the leaf blades; stamens usually free (sub-genus Papeda)—

- Flowers large (1.5 to 3 centimetres in diameter); stamens cohering in groups (section Papedo-citrus)—
  - Leaves acuminate or caudate; seeds few, large, short, thick, angled

\[ C. \text{ ichangensis} \]

- Leaves somewhat blunt, not caudate; seeds many, medium-sized, thin, not angled

\[ C. \text{ latipes} \]

Flowers small or medium-sized (1 to 2 centimetres in diameter); stamens all free (section Eupapeda)—

- Flowers very small (1.2 to 1.3 centimetres in diameter or less); fruits with few segments (six to nine)

\[ C. \text{ micrantha} \]

- Flowers medium-sized (1.3 to 2 centimetres in diameter); fruits with ten to twenty segments—
  - Fruits with fifteen to twenty segments
  
\[ C. \text{ celebica} \]

- Fruits with ten to fourteen segments—
  - Winged petioles with sub-entire margins; fruits globose, smooth

\[ C. \text{ macroptera} \]

- Winged petioles with crenulate or toothed margins; fruits bumpy, bluntly pointed at one or both ends

\[ C. \text{ hystrix} \]
BIBLIOGRAPHY

GENERAL REFERENCES

Overseas

Australian

SELECTED REFERENCES

Chapter 1

Chapter 2


Chapter 3


BIBLIOGRAPHY


Chapter 4


Chapter 5

3. Fraser, L. See references 6, 7, 8 under Chapter 3 heading in this bibliography.

Chapter 6

2. Kook Spray Irrigation, Murrumbidgee Agricultural Service Bulletin No. 4, no date.

Chapter 7


Chapter 8

1. BENTON, R. J. See references 7, 8 under heading "General" in this bibliography.

Chapter 9

4. BRERETON, W. L. (later BENTON, R. J.), and STOKES, W. B., "Citrus Manural Trials", Agricultural Gazette of New South Wales, 1925, pp. 513-17; 1932, pp. 889-92.

Chapter 10

BIBLIOGRAPHY


Chapter 11


Chapter 12

3. Hely, P. C. (later J. G. Gellatley), and Kiely, T. B., Pest and Disease Bulletin, 1945 to date (monthly).
10. State Department of Agriculture: Pest, Disease and Spraying leaflets.

Chapter 13

Chapter 14

Chapter 15
BIBLIOGRAPHY


10. WHITTAKER, E. C., Packing Charts. Department of Agriculture, New South Wales, no date.
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