1-1-1965

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Grateful appreciation is expressed to Messrs. A. Lynam and G. Tate at Bridgetown and to C. Fontanini and W. Kamman at Manjimup for allowing these trials to be conducted in their orchards. Similar appreciation is expressed to Mr. McAlinden and the Committee controlling the Showgrounds orchard at Bridgetown. Acknowledgment is also made of the assistance given by all Departmental officers who have helped with this work.
APPLE DIEBACK IN WESTERN AUSTRALIA

OBSERVATIONS AND FIELD TRIALS

Dieback of apple trees has been a serious and persistent problem in Western Australian orchards for many years. Field observations and trials suggest that it can be greatly reduced or avoided by spray thinning to control cropping, summer irrigation, light pruning, and avoidance of root damage by cultivation.

GOOD growth and longevity of apple trees occur only in those countries of the world where a cool, moist summer is experienced. Such an environment is in direct contrast to the Mediterranean climate of the South-West of Western Australia where the apple industry is centred.

Although the average annual rainfall is 30 to 40 inches in this area only 15 per cent. of this is received during the apple growing season. Much of the rain at this time of year is lost by evaporation before it reaches the roots. Since the majority of orchards have received little or no irrigation in past years most trees have undergone a period of severe stress which has adversely affected tree health.

Under these conditions the apple industry developed over the past 60 years a system of husbandry which included scrupulously clean cultivation of the orchard in summer, detailed spur pruning and rigorous hand-thinning. This enabled fruit of marketable size to be produced but did not prevent overcropping and the occurrence of an extreme biennial bearing habit.

Apple tree dieback then became prevalent, affecting all varieties. The time of its first appearance depended on actual growing conditions in the individual orchard.

Appearance of Apple Tree Dieback

The first sign of dieback is leader stoppage with loss of vigour on the highest parts of the apple tree. This can occur in trees as young as eight years of age but may not develop until orchards have been in production for 10 years or more. Subsequently the leaders die from the tip downwards and develop a papery bark condition. Although moderate growth of new shoots arises from lower down on the limbs the overall fruiting area of the tree is reduced. In severe cases this dieback progresses downwards on the tree to within a few feet of the ground, leaving the dead limbs as a framework of dry, seasoned timber.

Wood-rotting fungi invade dieback-affected trees through the dead tips of leaders and large wounds on main limbs resulting from removal of stopped leaders. Once established these fungi bring about a gradual decay of the limbs which, in time, extends down to the butt.

This article was prepared by officers of the Horticulture, Plant Research and Biological Services Divisions of the Department of Agriculture who have been actively associated with a programme of investigations related to apple dieback. The officers are: F. Melville, Senior Adviser, and S. E. Hardisty, Adviser, Horticultural Division, N. J. Halse and J. C. Cripps, Research Officers, Plant Research Division, and R. F. Doepel, Plant Pathologist, Biological Services Division. These officers have been engaged in a range of investigations of the apple dieback problem following general directions set down in 1959 by Dr. T. C. Dunne, then Deputy Director of Agriculture, Mr. H. R. Powell, Chief of the Division of Horticulture, Mr. W. P. Cass Smith, Chief of the Biological Services Division (now retired), and Mr. G. H. Burvill, Chief of the Plant Research Division.
Field Observations

Observations on orchard practice and tree growth suggest that the onset of apple dieback is related primarily to the following factors:

Heavy Cropping

Research workers in England and Japan have demonstrated that heavy crops of fruit reduce root growth and also available food supplies within the tree. Locally, the interaction of dieback and overcropping had been observed and investigations have highlighted the reduction of top growth which can be brought about by overcropping. This overcropping is accentuated by the excessive development of fruit buds in West Australian orchards, probably due to high light intensities.

Local experiments have also shown that satisfactory shoot growth depends on the prevention of overcropping in any one year. Drastic chemical thinning in a year when overcropping would otherwise occur results in an increase in top growth the following year. Moderate crops can then be harvested each year without loss of tree vigour or total production.

The harmful biennial bearing habit, which is a feature of apple orchards in this State, is accentuated by thrips attack in "off-crop" seasons.

Drought

Loss of vigour in the top part of trees is very noticeable in any season following one in which a heavy crop was produced under drought conditions. If overcropping and drought are experienced over several seasons dieback symptoms become manifest and vigorous growth only appears from lower down the trees. A permanent restriction of sap flow due to gum plugging of conducting tissues within the tree has been attributed by Baker (1931) to the adverse effects of drought.

Drought drastically curtails root growth and the dry soil also prevents uptake of plant nutrients by the tree.

Leader stoppage remains despite the application of irrigation water but the overall increase in fruiting area on new wood augments cropping. In this way irrigation of apple orchards has been observed to mask some of the effects of dieback.
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Pruning

For many years detailed spur pruning, involving the removal of most of the current season's wood during each pruning operation, was the normal practice in apple orchards in Western Australia. The increased growth which follows light pruning (provided that the trees are not allowed to overcrop) indicates that much of the dieback has been related to spur pruning. Spur pruning, with cuts close to the main limbs, is considered to dry out the sap wood and so retard the upward movement of water. An overall reduction in sap flow is reflected in lack of vigour in the top sections of the apple tree. This explanation has been advanced by Baker (1931) who associated hard pruning with adverse effects on total tree growth. In his investigations both severe pruning wounds and drought were found to desiccate sap wood with a consequent permanent change into non-conducting heartwood.

Over the past five years apple growers have tended to adopt a lighter pruning method which has resulted in improved tree vigour.

Wood Rots

Much concern has been shown over the wood rots which become evident in dieback-affected apple trees throughout the State. The wood rotting fungi*, which are established in and spread from decaying logs and fire-damaged trees in the forest, are responsible for the typical symptoms of papery bark observed in the orchards. The ink-staining of apple limbs is considered to be due to dark coloured fungi which are growing in the sap exuded from large pruning wounds. Over a period of time the bark tissue beneath the ink-stain decays and exposes a wedge of dead wood down the limb. Overseas workers have related such damage to the prolonged action of fungi, yeast and bacteria in the exuded sap. The large pruning wounds had resulted either from removal of stopped leaders to promote growth in a vigorous lateral or as a consequence of the long established spur pruning system. The wood rotting fungi gain entry into the trees through these wounds and also by way of the dead tops of leaders.

*Coriolus spp. and Stereum spp.

Although the overall effect of wood rots on the trees is considerable, investigations have shown that they play a secondary role in the dieback problem. Drastic tree surgery has been adopted in some orchards in an effort to check these rots. However, a field trial at Manjimup has indicated that cutting back to unaffected wood lower down on the scaffold limbs does not prevent downward extension of the papery bark and may possibly accelerate the rate of dieback in the tree.

Wood-rotting fungi have been of no consequence where trees have remained in a vigorous condition.

Root Damage

Before the advent of irrigation the conservation of soil moisture was all-important for successful orchard establishment. The soils selected for planting were deep, heavy loams and were often located on steep slopes in deeply dissected country. Both sheet and gully erosion in these situations further aggravated the damage to apple roots made by cultivation equipment. In addition, the introduction of offset discs, before World War II, which were worked close to the butts of trees, resulted in the cutting of main roots close to the trunk and also severe scalloping of other roots. This was particularly a feature in the lighter orchard soils.

Additional damage has been caused, for many years, by the larvae of the curculio beetle which feeds principally on the bark tissue of the apple roots. The severe channelling of main roots attributed to this pest has been observed both in young and long-established orchards. In addition, the smaller lateral roots are often completely ring-barked.

Meadow or root lesion eelworms have also been found to be widespread in all apple growing areas in this State. These eelworms move freely in the soil and burrow into the feeder and smaller lateral roots. The resulting damage to the root tissues is further aggravated by rotting due to invasion by secondary fungi and bacteria.

In England Rogers and Vyvyan (1934) have demonstrated that a constant ratio exists between top growth and roots of apple trees. In heavy loams the roots were
found to support a tree framework of twice the actual root weight. When root growth is restricted or reduced by cultural operations or by the activities of pests it is considered that a correspondingly greater restriction of top growth could eventuate. The onset and development of dieback in local orchards is believed to be a consequence, in part, of such root damage.

**Dieback Trials in South-West Orchards**

A series of trials was initiated on several growers' properties at Bridgetown and Manjimup, in the 1960-61 season, in an endeavour to substantiate conclusions drawn from field observations regarding dieback of apple trees. Various cultural treatments were imposed on selected, un-replicated blocks of Granny Smith trees in these orchards. Although both light pruning and irrigation were to have been included as treatments of prime importance the growers had adopted these measures either shortly before or at the commencement of the trials.

**Experimental Details**

On each of five orchard sites a uniform block of apple trees was subdivided into six treatment plots, comprising six trees in a row with adjacent rows of buffer trees. Within each treatment area of 14 tree squares the soil management, soil fumigation and fertiliser treatments were applied and maintained as required. Tree girth increases and leader extension measurements were carried out during each season but crop records were only made in the 1962-63 and 1963-64 seasons on some sites.

**Plot Treatments**

**Soil Management**

The standard treatment was shallow cultivation following a winter cover crop, to obtain satisfactory weed control. In addition, weedicides were applied around the butts to obviate the need to work implements close to the trees.

A satisfactory non-cultivation treatment consisted of close and repeated mowing of the winter and spring cover crop in the orchard. Summer weed germination was greatly reduced and surface trash did not remain as a fire risk.

Surface mulching of the soil with a 6-inch layer of fresh jarrah* or karri† sawdust was adopted as an alternative soil management treatment. Greatly improved vigour and cropping was evident in trees given this mulch. Stopped leaders remained but were masked by the vigorous lateral growth. Similar outstanding increases have been observed in a number of orchards where sawdust mulch has been adopted as a general ground treatment. More recently, however, problems have arisen with the application and subsequent utilisation of fertilisers by the trees.

**Soil Fumigation**

The soil fumigant DBCP‡ was applied to three of the treatment plots in each trial, at the rate of 10 gallons per acre, for root-lesion eelworm control. The chemical was diluted with water and incorporated in the soil at a depth of 4 inches, using pressurised tractor-drawn equipment. Fumigation caused a marked reduction in eelworm numbers. Tree vigour could not be related to this treatment since both fumigated and non-fumigated plots showed similar growth responses.

**Fertilisers**

A low rate of 5 lb. orchard manure 3.5 per cent. N, 16.75 per cent. P₂O₅, and 5 per cent. K₂O per tree was applied to the control treatment plots. Two other plots received 10 lb. sulphate of ammonia per tree and others had 10 lb. sulphate of ammonia, 10 lb. superphosphate, and 5 lb. muriate of potash per tree. Spray applications of copper, zinc and manganese sulphates as 1 per cent. solutions were also made to the trees during the dormant period.

Trees to which heavy applications of nitrogenous fertilisers were made carried

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* Jarrah = Eucalyptus marginata.
† Karri = E. diversicolor.
‡ Dibromochloropropane as "Nemagon E.C." Naming of a particular brand of chemical does not imply preference over other brands of the same chemical.

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dark green leaves and fruit and tended to crop more heavily.

Chemical Thinning

The control plot received some hand thinning to prevent limb breakage. Chemical thinning sprays were applied to all other treatments. Trees in the non-spray-thinned treatment made less growth than those to which a thinning spray was applied.

Conclusions and Recommendations

The preliminary results obtained in the dieback trials at Bridgetown and Manjimup confirm the conclusions drawn from field observations regarding the cause of dieback.

It is considered that the adoption by growers of the measures outlined below will maintain the vigour of healthy apple trees for many years. In established orchards where leader stoppage is evident these changes in management may be expected to increase the fruiting wood over much of the tree framework. Older trees affected with dieback and wood-rots cannot be expected to recover but may continue profitable cropping for a longer period than would otherwise have been possible.

Suggested Orchard Practice

1. Use adequate irrigation wherever possible.
2. Prune lightly once the initial framework of branches has been formed on the tree. Avoid making large cuts on main limbs.
3. Prevent overcropping and biennial bearing by chemical thinning and also by controlling thrips plagues.
4. Where cultivation is practised do not cut deeper than the top 3 inches of soil, and never close to the tree trunk. Apply weedicide chemicals around the tree butts to control weeds. Close mowing of the winter cover crop is an alternative method of soil management.
5. Minimise root and above-ground damage from curculio beetle by adequate chemical control.
6. Supply moderate amounts of nitrogenous fertilisers before spring rains have finished or before applying irrigation water.

ACKNOWLEDGMENTS

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