DIE-BACK OF TAWA

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SYNOPSIS

Following reports of widespread tawa die-back in the Urewera country, four observation plots, two in logged and two in unlogged areas, were established. They were examined monthly for two years. It was noted that foliage, buds and young shoots were killed off in autumn and early winter; the dead leaves showed rupture of cells accompanied by a reddish to dark brown mottling. In late winter and spring, wilting of foliage and death of whole branches was observed. Early winter deaths were rarely found on foliage and shoots under a 0.8-1.0 canopy and the incidence of such deaths increased with decreasing canopy closure. Wilting of foliage did occur under a full canopy but the incidence was lower than under a lesser canopy closure. No micro-organisms pathogenic to tawa were found. Field observations and laboratory experiments strongly suggested that the damage in early winter was due to frost. The cause of the wilt is obscure. Most damage occurred in logged areas where the canopy was open; damage on a lesser scale was found in unlogged areas.

INTRODUCTION

In the course of the last decade, widespread die-back of tawa (*Beilschmiedia tawa*) was reported by Forest Service officers although none of the reports were published. In extreme cases, die-back resulted in death of the entire tree. The first specific mention of tawa die-back was in 1957 — in the Pelorous Bridge Reserve, Nelson. The damage was attributed to frost (Morgan, 1958, pers. comm.). Since then tawa die-back has been reported from the lower Waioeka catchment area (McQueen, 1967, pers. comm.) and from S.F. 58 Whirinaki and S.F. 89 Okui (Birt, 1967, pers. comm.). A survey made by A. Reiher and others in 1966-7 found dead tawa crowns in areas scattered throughout the Ikawhenua and Huiarau ranges.

Work on tawa die-back was begun by the writers in 1968. The main objects of the enquiry were to study the symptoms associated with the die-back and, if possible, to determine the cause.

MATERIAL AND METHODS

Four observation plots, two in logged and two in unlogged forest areas, were established. Details of the plots are given in Table 1 and Appendix 1. Ten trees were selected in each observation plot so as to include some marginal and some interior trees. Observations were confined to those parts of

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the trees which could be conveniently reached from the ground by a 1.8 m tall observer. On these, the branches and leading shoots which were already dead were marked with strips of calico and subsequent die-back was marked with coloured plastic tape which could be written on. Flushed and unflushed buds were marked with white plastic tape and damaged and undamaged leaves with "Quik-stik" labels. Observations were carried out once a month for two years from May 1968 to May 1970.

Canopy closure (the extent to which the sky was obscured by the canopy) was recorded on a ten point scale (0.0 = no canopy; 1.0 = full canopy) for the part of the tree or sapling which was under observation. Glasshouse-raised tawa seedlings were planted out in all four plots in February/March 1970 and in August 1970 under a canopy range of 0.1 to 1.0. Attempts to take ground minimum temperature readings had to be abandoned owing to interference with the thermometers by opossums and other animals. Weather records were obtained from Minginui climate station to serve as a general guide.

Samples of leaves, shoots, branches, stem, roots and soil were collected from the experimental areas for laboratory studies. Observations on the phenology of tawa were made.

FIELD OBSERVATIONS

Phenological Notes

September: On some of the plot trees, bud burst occurred in late September, but not on branches and seedlings under a dense canopy. No flowers were observed.

October: Early October showed more buds bursting and flushing; primordial leaves were present, about 7.5 mm long. Epicormic shoots appearing with shoot elongation taking place. By mid-October leaf development was proceeding rapidly. Flower buds on the point of bursting.

November: Buds still flushing; production of new leaves taking place, new leaves 7.5 to 50 mm long. Open and unopened flower buds were present. Shoots elongating fast.

December: Flushing of buds still continuing. New season's leaves range from 10 to 90 mm in length. Unripe fruits present, no flowers observed.

January: Production of new leaves continued. Length of leaves between 12.5 and 100 mm. Fruits ripening and flowers present.

February: Rate of leaf production dropped but new leaves still being produced. Ripe and unripe fruits present. Open flowers present.

March: Leaf production has almost ceased. Open and unopened flowers still to be found.

April: Production of leaves and shoot elongation has stopped. Epicormic shoots, however, continued elongation and leaf growth into late April. Open flowers present.

May: All buds dormant and no further leaf growth. Many immature leaves present.

TABLE 1: OBSERVATION PLOTS (ESTABLISHED MAY 1968)

Plot No.	*Locality*	*Area (m²)*	*Topography*	*Altitude (m)*	*Aspect*	*Forest* Type*	*Height Range of Study Trees (m)*	*Map Reference*	*Remarks*
1	Te Wai-iti	330	Wide valley gentle slope	460	W	N2	2-24	N44:41:44	Logged area with mainly tawa left
2	Waione	630	Slight escarpment gentle slope	430	S/SSE	L2	3-15	N44:04:37	Isolated virgin area mainly podocarps
3	Okui	670	Alluvial valley flat	300	Flat	N2	2-15	N44:23:55	Logged area with mainly tawa left
4	Okui	940	Narrow valley steep slope	370	NSW	N2	2.5-20	N44:23:55	Virgin area mainly tawa — some podocarps

*from: Nicholls, J. L., 1969: Ecological survey of New Zealand's indigenous forest. Type Map Series No. 2. Sheets N95 and N96.

June: All growing organs dormant. Live and dead flowers present.

July and August: No growth, flowers mostly dead.

Types of Injury

Two types of symptoms of injury which usually appeared in different seasons were observed. There was some overlap during August and September when both types of symptoms were observed.

1. Injury observed in Autumn and Winter (April-August)

The symptoms were variable and apparently depended upon the age of shoots and leaves affected. When late-flushed leaves were injured, they turned a bright orange and disruption of cells occurred. Older leaves of early summer or of the previous growing season often suffered damage to the veins and midrib which became outlined with a dark orange stain. Often only patches of the leaf blade died giving it a mottled appearance. Figure 1 shows these symptoms on leaves. Damaged epicormic shoots became flabby and turned black.

The greatest damage causing death of foliage and buds occurred in April, May and June. Time of the onset of severe injury varied from year to year. Observations showed that this depended on when the first frost occurred (Minginui records). However, most damage was observed in May in all

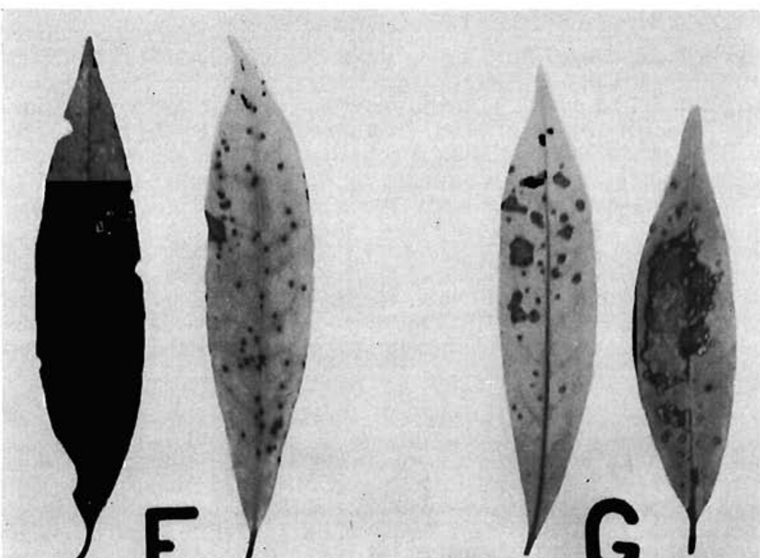

FIG. 1: *Symptoms of injury observed in autumn and early winter.*

years. This early winter damage was closely related to canopy closure. the worst injury occurred on exposed trees or on exposed parts of the tree canopy. The incidence of early winter injury declined as exposure lessened; when the canopy closure was 0.8 to 1.0 such injuries were very rare. Buds, late-flushed leaves, young shoots and epicormic shoots were the worst affected but older foliage also suffered if it was exposed. All trees in Plots 1, 3 and 4 suffered damage in early winter during the period they were under observation. Understorey shrubs in these plots showed typical frost injury: *Melicytus lanceolatus* in Plot 1, *Clematis* sp. and *Rubus* spp. in Plot 3, and *Coprosma* sp. in Plot 4. Plot 2, where tawa grew under a dense canopy, was an exception: 5 trees in this plot showed no damage in early winter and the other 5 showed very little damage. Seedlings planted in the plots showed a similar pattern of damage.

Field observations made in May 1970 on Plots 1 and 3 happened to coincide with heavy overnight frost. Healthy uninjured leaves and epicormic shoots were marked one evening and examined the following morning. Most were found to have been severely injured overnight. Ice crystals were present on the injured leaves. After three days, many injured leaves had the typical mottled appearance and one month later, leaves and shoots had died. All marked leaves that had escaped injury were found to be quite dry; presumably shelter from adjoining branches had prevented dew from gathering on them.

2. *Injury observed in Late Winter, Spring and Summer (August-February)*

In late winter and spring, whole branches with their buds and foliage were found to be dead. No visible injury such as rupture of cells occurred; the leaves wilted and eventually became dry. turning a bright red or reddish brown colour. This type of injury affected branches with healthy foliage as well as those bearing foliage and buds which were damaged in autumn and early winter.

Wilting leaves and shoots were first observed in August, large-scale deaths of branches, shoots and leaves occurred during September and October, and then the amount of damage declined. In 1968, no deaths were observed after mid-December but in 1969-70 such deaths continued to occur up to February 1970 (Table 2). This type of injury was not clearly related to canopy closure but it was greater on already injured or exposed trees.

3. *Other Observations*

Epicormic shoots were very susceptible to injury and most damage to these appeared between May and November. Epicormic shoot death was usually in stages, commencing in early winter with the tips dying back and suffering recurrent die-back after further periods of frost. Exposed shoots of the current season suffered most, the whole shoot being killed in the course of one winter.

TABLE 2: DEATH OF FOLIAGE AND BRANCHES ASSOCIATED WITH LATE WINTER INJURIES

Number of trees affected per month out of 10 trees per plot

Plot No.	*Plot Location*	*Year*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*
1	Te Wai-iti	1968-9	1	7	6	4	2	—	—
	(Logged)	1969-70	3	3	2	4	1	1	1
2	Waione	1968-9	2	2	—	—	—	—	—
	(Unlogged)	1969-70	3	4	1	4	—	—	—
3	Okui	1968-9	2	1	1	1	—	—	—
	(Logged)	1969-70	5	8	6	8	7	3	4
4	Okui	1968-9	4	6	—	—	—	—	—
	(Unlogged)	1969-70	1	10	8	4	1	1	8

Exposed seedlings were very vulnerable to damage, often being killed back to ground level or losing all their leaves. The epicormic shoots which appeared subsequently were killed off the following winter. After such repeated damage, the seedling lost its form and became a bushy shrub in appearance. Tawa has a great capacity for recovery from such damage and none of the trees in the observation plots were completely killed by the die-back they suffered. However, there were many dead trees, especially in the logged areas, which appeared to have succumbed because of the repeated die-back of shoots.

Differences in the amount of damage suffered by trees in the logged and unlogged areas are shown in Tables 2 and 3. Trees in Plots 1 and 3 (logged) suffered considerable damage to all parts of the tree canopy. Trees in Plot 4, an unlogged area, suffered far less; although there was injury to the upper crown, mid and lower parts of the trees showed little damage. Trees in Plot 2, with its dense canopy of podocarps (*Podocarpus totara* and *P. spicatus*) and rimu (*Dacrydium cupressinum*) and heavy undergrowth of coprosmas (*Coprosma rhamnoides*, *Coprosma* spp.), horopito (*Pseudowintera axillaris)* and other shrubs, suffered least of all.

LABORATORY STUDIES

Micro-organisms isolated from Dying Tawa

Isolations on various media were made from leaves with necrotic patches (124 isolates), scars and cankers on twigs and branches (256 isolates), wood (10 isolates) and soil and roots (26 isolates). Percentage frequency of the various species of fungi isolated is given in Table 4.

Bacteria were isolated from all types of material but no attempt was made to identify them. Most of the attempted isolations from wood did not yield any organisms. All species of fungi (except those from soil and roots) were tested for pathogenicity by (a) placing a small piece of mycelium on a small wound made in the stem of a tawa seedling and (b) by spraying a spore or mycelial suspension on the leaves. Bacteria

TABLE 3: DEGREE OF INJURY TO THE 10 PLOT TREES IN EACH PLOT — 1968-70

Plot No.	*Forest Type*	*Location*	*No. of Trees*	*Early Winter Injury*					*Late Winter Injury*					*Canopy Range*	*Remarks*
				None	*Trace*	*Light*	*Mod.*	*Severe*	*None*	*Trace*	*Light*	*Mod.*	*Severe*		
1	N2	Te Wai-iti	10	—	1	5	2	2	1	1	5	1	2	0.5-0.9	Logged
2	L2	Waione	10	5	5	—	—	—	5	3	2	—	—	0.8-1.0	Virgin—dense canopy
3	N2	Okui	10	—	2	3	2	3	—	1	5	1	3	0.4-0.9	Logged
4	N2	Okui	10	1	8	—	1	—	—	1	6	2	1	0.5-1.0	Virgin—dense canopy with clearings

TABLE 4: PERCENTAGE FREQUENCY OF SPECIES OF FUNGI ISOLATED FROM TAWA

	Leaf	*Twig*	*Wood*	*Roots and Soil*
Aureobasidium pullulans	30	20	—	—
Coniothyrium sp.	—	4	—	—
Diplodia pinea	—	5	—	—
Epicoccum nigrum	—	4	—	—
Fusarium spp.	—	7	—	23
Pestalotia spp.	53	39	6	4
Phoma sp.	16	—	—	—
Pythium sp.	—	—	—	61
Stemphylium sp.	—	7	—	—
Sterile mycelia	9	11	—	12
Others	2	3	—	—
None	—	—	94	—

were tested by spraying a suspension of cells on the leaves. These tests were done both in the glasshouse and in the field during 1969 using potted glasshouse-grown seedlings. Fungi isolated from soil and roots were tested by method (a) and by growing them on oats and placing the oat grains around the roots of potted seedlings. None of the organisms tested was pathogenic.

Leaves from dying branches were macerated and the filtered extract was sprayed on mechanically injured and uninjured leaves of potted seedlings. Branches with dying leaves were also tied above healthy foliage in the field. None of the treated leaves died or showed symptoms of damage different from those on the control plants.

Effect of Low Temperature on Tawa

Using a refrigerated water bath fitted with a pump, a methanol : water mixture at temperatures below freezing was circulated through insulated condensers. The temperature of the circulating fluid could be adjusted to give temperatures of —15° C, —10° C and —5° C inside the condenser tube. Tawa leaves, some wetted by spraying them with water and some dry, were inserted in the condensers and left for various periods. A 2-hour exposure to —15° C killed both dry and wet leaves but at higher (but still below 0° C) temperatures the wet leaves suffered considerably more damage than dry leaves. Exposure to —10° C for 3 hours killed the entire wet leaf blade. At —5° C for 3 hours only some parts of a wet leaf blade were killed giving it a mottled appearance; at this temperature dry leaf blades did not appear to be at all damaged. The symptoms of low temperature injury to leaves were very similar to those found in the field in early winter (*cf.* Figs. 1 and 2).

By circulating the methanol : water mixture through a copper tube wound round the stem of a tawa seedling, a 4 mm wide band round the stem could be frozen. It was found that keeping this portion of the stem at —10° C for 2 hours resulted in wilting of foliage above the frozen portion.

Whole potted seedlings of tawa were subjected to white frosts of different intensities for 4 hours in a growth room at the Climate Laboratory, DSIR, Palmerston North. The soil in the pots was kept above freezing point. All foliage on seedlings held at —6° C and —9.6° C was killed. The leaves of only one seedling out of five were killed when held at —3° C.

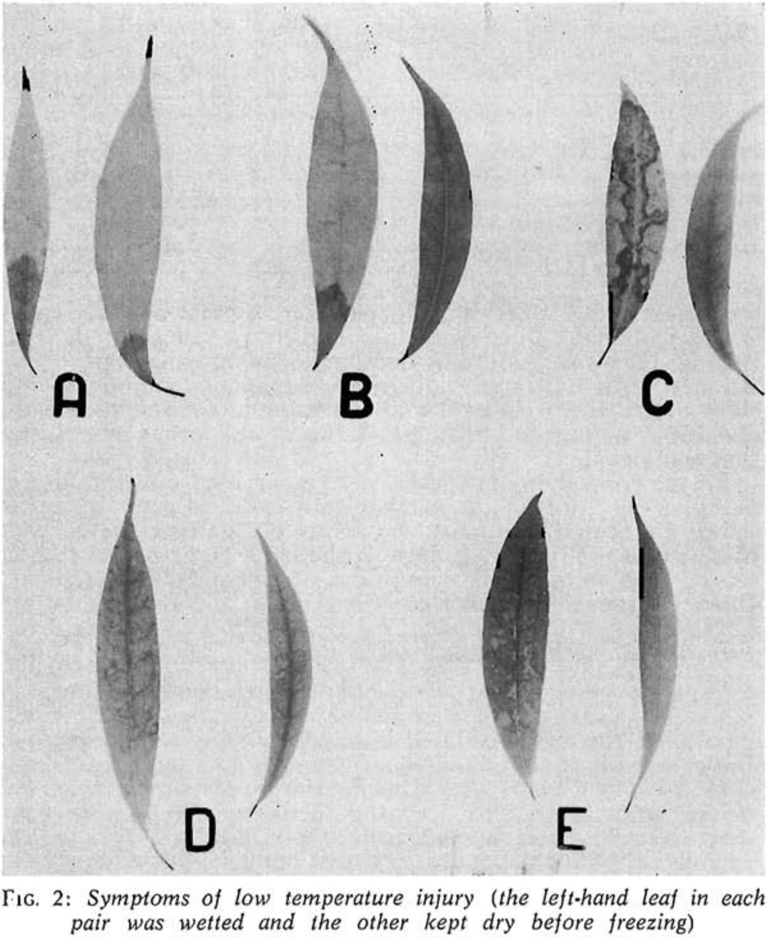

FIG. 2: *Symptoms of low temperature injury (the left-hand leaf in each pair was wetted and the other kept dry before freezing)*

A: —15° C for 2 hours. The lighter parts of both leaves are completely dead.

B: —10° C for 3 hours. The major portion of the wetted leaf has been killed. The dry leaf shows slight mottling, otherwise it is healthy.

C: —5° C for 3 hours. Wetted leaf shows extensive mottling, dry leaf healthy.

D: —5° C for 6 hours, slow freezing and thawing. Most of the wetted leaf is dead, dry leaf healthy.

E: —5° C for 3 hours, slow freezing and thawing. Wet leaf shows mottling, dry leaf healthy.

DISCUSSION

The laboratory investigations indicated that pathogenic fungi, bacteria or viruses were not likely to be responsible for the die-back of tawa. Of the many fungi isolated, *Diplodia pinea* is a well-known wound pathogen of conifers (Birch, 1936) and many fungi belonging to the genus *Pythium* are pathogenic (Peace, 1962). Although the pathogenicity tests indicated that these fungi did not cause damage to tawa, the possibility that under certain conditions they may contribute to tawa die-back cannot be discounted. There is also a possibility that a pathogen not detected by the methods used may exist.

Field observations and results of laboratory work on the effect of low temperature on tawa showed that the damage found in autumn and early winter was probably due to frost. It is possible that similar damage might result from exposure to cold, desiccating winds. Death of foliage preceded by wilting occurs well into summer months and the cause of this is obscure. It is possible that at least some of this damage is due to injury by frosts to cambium and vascular tissues of branches and that the symptoms of this damage do not become apparent until active growth is resumed in the spring, increasing demand for water which the damaged conducting tissues are unable to meet. It is interesting to note that in the normal summer of 1968-9 such deaths were found up to December while in the dry summer of 1969-70 they continued up to February.

It appears from our observations that die-back of tawa is much worse in logged areas, in natural clearings and on marginal trees. Other authors have noted that tawa is intolerant of exposure. Esler (1969) stated that "In the case of the death of tawa in semi-open stands, exposure in some form may be responsible . . ." and McKelvey (1963), discussing man-modified forest types in West Taupo indigenous forest, said: "The general disruption of the pre-existing forest structure has rendered many species vulnerable to exposure; the most conspicuous of these is tawa, which exhibits crown die-back and poor form". Forest Service officers have also made similar observations.

The results of our observations are not conclusive. Further study is required to elucidate the cause of the late winter, spring and summer deaths, and micrometeorological data are essential to evaluate the role of frost in die-back of tawa.

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APPENDIX 1

Plot	*Tree No.*	*Height (m)*	*Canopy Closure*	*Flora*
1 Te Wai-iti	1	2.1	0.8	*Aristotelia serrata:* dense regeneration
	2	2.1	0.8	*Melicytus lanceolatus*
	3	2.7	0.8	*Podocarpus spicatus*
	4	5.5	0.8	
	5	7.9	0.9	
	6	6.1	0.7	
	7	4.3	0.6	
	8	4.3	0.9	
	9	7.3	0.8	
	10	24.4	0.5	
2 Waione	1	7.3	0.9	*Coprosma* spp., *C. rhamnoides*
	2	7.9	0.9	*Pseudowintera axillaris*
	3	7.6	1.0	*Ixerba brexioides*
	4	6.1	0.9	*Pseudopanax crassifolium*
	5	9.1	0.9	*Podocarpus totara*
	6	3.1	1.0	*P. spicatus*
	7	3.7	1.0	*Dacrydium cupressinum*
	8	7.9	0.8	
	9	9.8	0.8	
	10	15.3	0.9	
3 Okui	1	9.2	0.6	*Aristotelia serrata*
	2	2.1	0.9	*Hoheria* sp.
	3	8.5	0.8	*Clematis* sp.
	4	11.6	0.8	*Rubus* sp.
	5	9.2	0.8	*Parsonia heterophylla*
	6	14.6	0.9	*Melicytus ramiflorus*
	7	8.5	0.7	*Carpodetus serratus*
	8	4.3	0.7	*Lophomyrtus obcordata*
	9	6.7	0.4	*Podocarpus totara*
	10	15.3	0.7	
4 Okui	1	5.5	0.9	*Dacrycarpus dacrydioides*
	2	19.8	0.5	*Olea* sp.
	3	9.1	0.9	*Coprosma* spp.
	4	16.4	0.9	
	5	10.4	1.0	
	6	7.9	0.8	
	7	16.8	0.9	
	8	7.9	0.9	
	9	4.9	0.9	
	10	2.4	1.0	