Response to Mr Batini's comments on Davison (2018) Australas Plant Pathol 47:245-257.

Dear Sir,

Thank you for the opportunity to respond to the issues raised by Mr Batini in relation to Davison (2018). I can understand reaction of many Western Australian foresters on learning that the unpublished results of Dr F Podger did not support his conclusion that *Phytophthora cinnamomi* killed jarrah (*Eucalyptus marginata*) trees. The purpose of this communication is to further clarify issues raised by Mr Batini in relation to the history of the jarrah dieback investigations.

Mr Batini wonders why marri (*Corymbia calophylla*) and bullich (*E. megacarpa*) did not opportunistically invade sites where jarrah trees died. In the historical record there are records of marri regenerating freely on these sites (Hamilton 1951; Wallace and Hatch 1953); this would have been of concern to foresters because marri is a less valuable timber species than jarrah. I have found no mention of bullich invading sites where jarrah had died in the historic literature.

Mr Batini raises the question of why there were no records of jarrah deaths near Jarrahdale between 1904 and 1932 when heavy rainfall (> 90th percentile) was recorded on eight occasions. In Davison (2018), Table 2 records when and where deaths occurred, in order to determine whether there was an association with specific weather conditions. This is not a complete record, for example Hamilton (1951) states:

'.. Some years ago, forestry officers noticed that there were areas in the northern part of the Jarrah Forest Region, where there seemed to be an abnormal number of dead Jarrah trees.

Later it was realised that the areas were becoming larger, more numerous, and the phenomenon began to assume economic proportions. ..'

As Hamilton (1951) does not provide specific dates and locations, his observations cannot be included in Table 2. In relation specifically to Jarrahdale, Stoate and Bednall (undated) state:

'.. Sufficiently widespread water logging in weak drainage areas north of Jarrahdale led to conversion then of the native forest to fine plantations. ..'

As no dates are provided, this too cannot be included in Table 2. Crown deterioration (Fig. 1 in Davison 2018) is a symptom that could be caused by water deficits within the tree, resulting from reduced sapwood conduction on sites that had become wetter than when jarrah established. Wallace and Hatch (1953) mention that the poor condition of jarrah crowns:

'.. has been taking place slowly over many years, and may be associated with the heavy canopy removal and site exposure following logging operations of 40-50 years ago ..'

Their report specifically mentions their concern that crown deterioration was an early stage of dying jarrah patches on poorer quality sites. Again, as there are no specific dates or locations, this data cannot be included in Table 2. The impression given in these historical, unpublished reports is that the deaths were not new; it was their scale that was of concern, and that led to the initiation of a joint research programme by the Western Australian Forests Department and the Forestry and Timber Bureau in 1947.

As mentioned by Mr Batini, canopy removal during logging operations will result in increased site wetness until regeneration is large enough to re-establish hydrological control, but he doubts that the amount of logging after 1920 would have been sufficient to contribute to significantly raising water tables in the 1940s to 1960s. This is a general observation, but may not be true in specific locations. Hamilton (1951), for example, provides the logging

history of the Teesdale Experimental plot where he established a transect through an area of dying jarrah trees:

'.. The first logging for sleepers was done about 1910, and heavy cutting of Jarrah for milling was made about 1919. ... The next important removal of tree crowns was effected when regeneration work was undertaken ... in 1931 and 1934. In this work all malformed Jarrah and most Marri trees were ring-barked. This resulted in a further significant reduction of the original crown cover. ... A coppice cleaning was carried out in 1939 and 1940 ... When the Teesdale [Fire] Tower was erected on the hill .. (1934), a large part of the hill top was cleared of timber and the regrowth has been cut down regularly ever since. ... Below the cleared area of the hill top, regeneration of Jarrah and Marri has been sufficient to restock the heavily depleted stand, but on lower slopes and in the drainage basin, regeneration of Jarrah has been very poor and has since died over much of these parts. ... in dying areas, Marri has shown that it can regenerate and several very fine little patches have resulted. ..'

The association of these jarrah deaths with waterlogging resulting from canopy removal cannot be discounted.

Chronic waterlogging, resulting from rising water tables over the long term will reduce rooting depth, with trees growing on such sites being more susceptible to drought. However, it is acute, short term soil inundation that is so damaging, particularly if this occurs in summer. Gravel soils have low air filled porosity, so that they are saturated quickly, but also drain quickly unless there is some form of impeding layer in the profile. When saturated, the soil becomes anoxic, quickly in summer but more slowly in winter, and this in turn affects all processes that require efficient aerobic respiration: root growth, root elongation, water uptake and the ability to respond to damage. In jarrah the xylem vessels in the roots become blocked by tyloses, so that conduction of water through the sapwood is reduced. These non-

functional vessels can be replaced by the vascular cambium, but it takes time. The roots are not necessarily killed; they just do not work efficiently. From my reading, the most effective way for a pest or pathogen to kill a tree is to cause dysfunction in the sapwood, because this means that water can no longer reach the foliage. This occurs in wilt diseases such as Dutch elm disease, oak wilt, chestnut canker and pine wilt. *Phytophthora cinnamomi* cannot cause extensive xylem dysfunction because it primarily invades the bark, not the sapwood. The only damage to jarrah sapwood that could be of sufficient magnitude to kill is as a result of waterlogging damage – which causes a physiological wilt.

It is not known when *P. cinnamomi* was introduced into Western Australia; it was only isolated in 1965 (Podger et al. 1965). Jarrah deaths in 1921 at Karragullen have been interpreted as being caused by *P. cinnamomi* (Shearer and Tippett 1989), but waterlogging damage cannot be discounted because of heavy rainfall at Mundaring in June and August 1920 (Table 2 in Davison 2018).

My aim in writing this paper is to provide an explanation for past jarrah deaths, that covers not only the where and when they occurred, but also how and why this could have happened. I realise that many will disagree with my interpretation, but by providing the opportunity to discuss the site conditions, associated weather and role of pathogen(s), it may result in a better appreciation of the sites where jarrah trees will do well, it may assist in answering questions about jarrah's distribution within its range, and why it is out competed by marri and bulllich on wetter sites.

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