The Relationship between Bark Moisture and Invasion of *Eucalyptus marginata* by *Phytophthora cinnamomi*

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Lesion development caused by the invasion of secondary phloem of *Eucalyptus marginata* Sm. by *Phytophthora cinnamomi* Rands has been followed over the past two years. Coppice stems and large roots were inoculated during spring, summer and autumn and typical lesions have been described (Tippett *et al*. 1983). It has been shown that jarrah can express resistance during most of the year; the fungus was arrested and lesions were bound by necrophylactic ('wound') periderm in at least 60% of the inoculated coppice stems and most of the inoculated roots. Initial establishment of the fungus in the phloem was most rapid during early summer (Shea & Deegan, unpublished) when day temperatures were already near optimal for fungal growth (Zentmyer, 1980). Inoculations made during February and March generally resulted in shorter lesions. When lesions were left to develop for at least 12 months, stem dissections indicated that fungal activity had been intermittent; under certain circumstances the fungus renewed advance from lesions which had been temporarily confined (Tippett *et al*. 1983). The fungus girdled stems when initial establishment was rapid or when it 'broke-out' from existing lesions. Marks *et al*. (1981) has also stated that fungal activity was sometimes intermittent in susceptible Victorian eucalypts.

Although temperature has been acknowledged as having a major influence on fungal growth other environmental factors were sought which adversely affected jarrah's ability to resist invasion. Water stress affects the rate of some defence reactions in trees (Puritch and Mullick, 1975) and previous work has shown

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that Populus and French prune were most susceptible to canker organisms (e.g. Crypodiaporthe salicella, Fusarium lateritum, Cytospora leucostoma) when bark moisture levels were at their lowest (Bier, 1961; Bertrand et al. 1976). Despite the possibility that water stress could cause a decrease in resistance, or predispose jarrah to rapid colonization by P. cinnamomi, we also had observed renewed and rapid invasion of inoculated jarrah coppice stems after unusually heavy rainfall at Dwellingup during January 1982 (January rainfall, 1982 was 237 mm; average 13 mm).

In order to examine the relationship between bark moisture and lesion development, three different sets of trees were inoculated during March 1983 near Jarrahdale, Western Australia. Fifteen jarrah saplings near a permanent creek ('R' site vegetation type, Havel (1975) classification), 15 similar saplings on a drier upland site ('S' site vegetation type) and thirty coppice stems growing from stumps on an area logged over two years previously (upland site, 'S' type) were inoculated. Inoculation was carried out by a method similar to that described by Tippett et al. (1983). Since the mean maximum day temperatures for the duration of the experiment was near 28^{0}C, (Perth recordings) temperature would not have limited the growth of P. cinnamomi to any great extent (Shea, 1977). At the time of harvest, 19 days post-inoculation, relative bark moisture levels were determined using the method of Bier (1961) and lesions were measured and mapped.

Bark moisture was shown to be an important factor affecting lesion development. Of the saplings growing near the creek, the mean relative bark moisture level was 84.8%. Mean lesion length was 12.2cm. Bark moisture levels in these stems varied between 74% and 90%. There was a linear relationship between lesion length and bark moisture ($r = 0.71$). The mean bark moisture level in the upland saplings ('S' type) was considerably lower, 73.6%, and the mean lesion length was 2.0cm; only 3 lesions were recorded. Ten stems from this group had relative bark moisture levels below 75%. The coppice stems had a mean relative bark moisture level of 89.8%. This was the highest of the three groups of stems. This may in part be explained by the fact that the coppice had sprouted from large existing root systems. Mean lesion length for the coppice was 19.1cm.

In some cases two or three coppice stems from single old root stocks were inoculated and such stems from the same root stock had similar or the same relative bark moisture levels. In five clumps lesion lengths were also similar in the 'sibling' stems. The growth rates of the fungus were fast (up to 8.9mm per day) in some stems during the experiment. In one stem from the moist 'R' site with a relative bark moisture of 89%, lesion length was 26cm and a lesion of 30cm was recorded in a coppice stem with bark moisture of 90%.

Lesion data from the moist 'R' site saplings and coppice was pooled and is shown in Figure 1. As only three lesions were recorded in the 15 upland ('S' site type) stems, one of which was atypical, they were not included in the pool. The coppice stem data when pooled with the 'R' site sapling data, does weight the results in favour of our conclusion that bark moisture is an important factor in determining the rate of fungal growth within the host. Other circumstantial and experimental data supports our conclusion. Bark moisture levels below 75% are probably limiting to growth of _P. cinnamomi_; this may correspond with a water potential of less than -2 MPa (deduced from bark moisture levels relative to water potential of other tree species; Kramer, 1969). Moisture characteristics of the tissue are yet to be determined. Adebayo and Harris (1971) and Sommers _et al_. (1970) have shown a marked reduction in growth of _P. cinnamomi_ in media or soils at osmotic potentials below -2 MPa. Bark moisture in jarrah may well start to become limiting in jarrah growing on very dry sites by mid to later summer, unless there is unseasonally heavy rainfall as was experienced in January 1982.

It has been observed in the past that dieback epidemics often occur after heavy summer rainfall (Marks _et al_. 1972). It seems probable that such conditions not only favour fungal sporulation and infection but that eucalypts are predisposed to rapid invasion if relative bark moisture is maintained at a high level. During most of the wetter periods of the year fungal growth in jarrah will be limited by low temperatures rather than low bark moistures. The combination of high bark moisture and high day temperatures will favour fast rates of invasion which result in jarrah's resistance being overwhelmed. As summer temperatures are usually adequate for fungal growth, the relationship between bark moisture and fungal growth may help explain why many disease boundaries in the jarrah forest have remained static and deaths have been less common on well drained, dry, upland sites. Although we consider bark moisture to be an important factor in determining the rate of growth of P. cinnamomi within jarrah, other factors, for example, carbohydrate levels in the phloem, may also affect the outcome of interactions.

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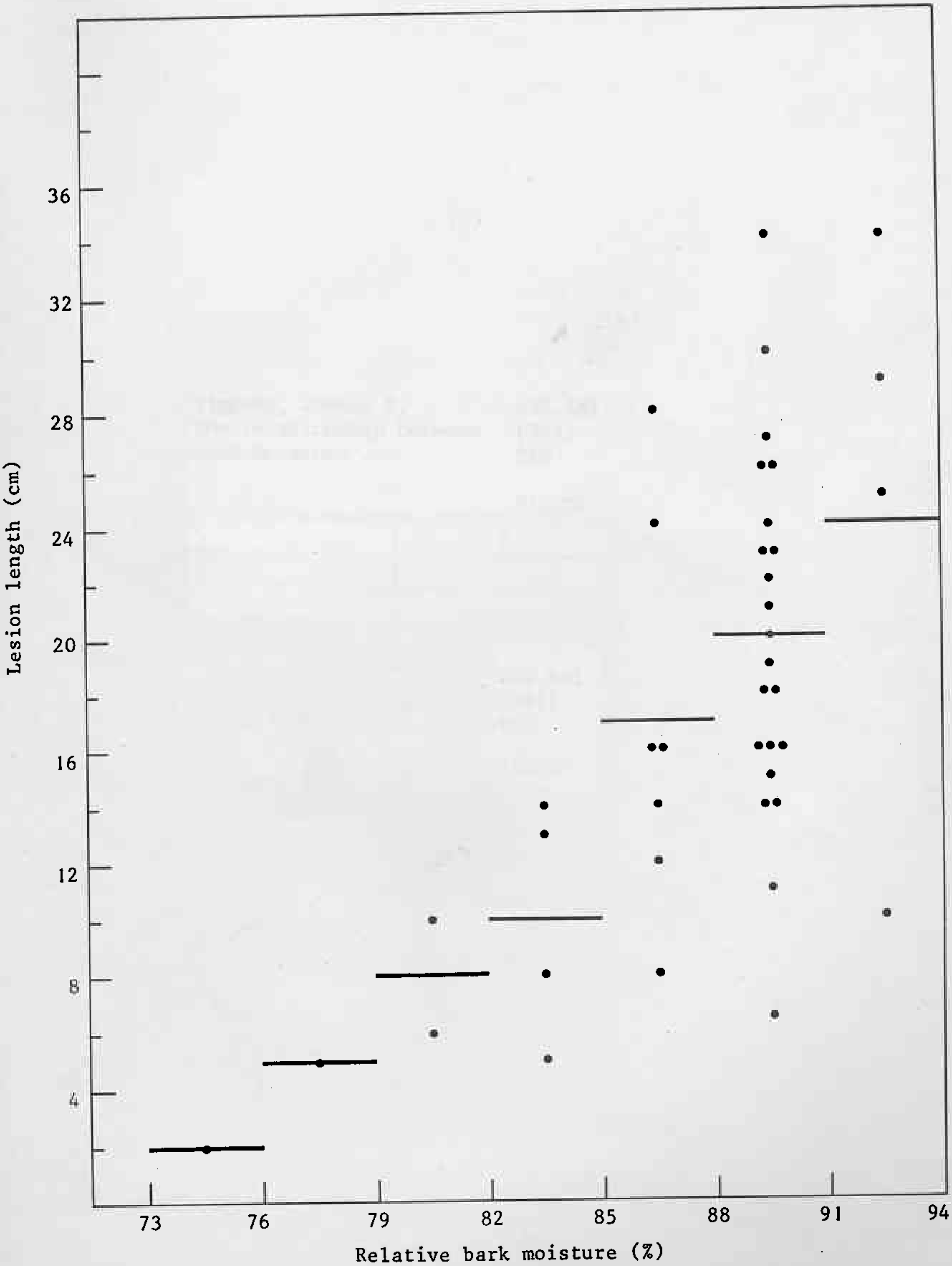

Fig. 1. Bar diagram showing mean lesion lengths for coppice and 'R' site sapling stems at bark moisture increments of 3%. Points represent length of individual lesions recorded within each bark moisture increment.