Climatic preferences of myrtle rust fungal plant disease

In brief

Myrtle rust is a plant disease caused by the fungal pathogen *Austropuccinia psidii*. It was first detected in Australia in New South Wales in 2010. Numerous members of the Myrtaceae plant family are impacted by this disease to varying extents.

This study focused on watergum (*Tristaniopsis exiliflora*) to explore the climatic and microclimatic preferences of the myrtle rust disease. We surveyed populations of watergum in northern Queensland for long-term damage by myrtle rust and compared infection severity to environmental variables.

Infected fruit of Lithomyrtus obtusa *growing in sand communities in Cairns. Image: Jarrah Wills*

High annual rainfall, maximum temperatures below 32°C, dense canopy cover and the presence of flood plains were all associated with increased severity of myrtle rust on watergum. Intensive sampling in a small population found that trees with a lower canopy also experienced more severe infection.

In tropical environments with seasonal rainfall, myrtle rust virulence is reduced when mean annual rainfall is less than 1500mm. Virulence was also reduced when maximum temperatures exceed 32°C.

The climatic drivers identified in this study align with the optimal conditions found for myrtle rust germination and development in laboratory environments. This suggests that myrtle rust is limited by climatic conditions in natural ecosystems

Conservation efforts should focus on Myrtaceae species with narrow climatic distributions that occur within the optimal climatic conditions for myrtle rust. There should also be a conservation focus on species that mainly occur in highly susceptible regions such as the Wet Tropics World Heritage Area.

Background

Myrtle rust is an infectious disease caused by the fungus *Austropuccinia psidii*, which affects some plant species in the Myrtaceae family. The pathogen attacks actively growing leaves, shoots and stems, as well as flowers and fruits in some species. Severe or repeated infection can cause leaf distortion, reduced growth and even plant death.

Australia supports a large proportion of the Myrtaceae plant family, with around 88 genera and 2253 species. This includes ecologically and economically important groups such as eucalypts and paperbarks. Within the Myrtaceae family there is a high degree of variability in myrtle rust susceptibility, with approximately 358 of the 2253 known Myrtaceae species in Australia currently confirmed to be infected in the wild.

Myrtle rust susceptibility can vary from one plant population to another within a species. This could be partly due to climatic conditions, with either the climate unsuitable for infection or the optimal conditions for infection not coinciding with the timing of vulnerable new shoot growth and flowering. Successful germination and infection of myrtle rust requires high humidity, a wet leaf surface and low light.

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Background (continued)

The temperature requirements for germination appear to vary among host species.

Understanding variation in myrtle rust severity in natural ecosystems is crucial to informing the management of at-risk species. We focused this research on *Tristaniopsis exiliflora*, commonly known as watergum or kanuka, a tree that is highly susceptible to myrtle rust. Watergum is an ideal candidate for understanding the variation in myrtle rust severity as it has a large natural distribution. It also has an unusual growing habit, often growing at an angle low to the ground rather than upright, and is of great ecological importance. Watergum grows exclusively along watercourses and is important for stabilising creek beds within Great Barrier Reef catchment areas, preventing erosion. This potentially creates humid and sheltered microclimates at ground level that may increase the severity of myrtle rust infection.

Main aim of the research

This research aimed to predict the climatic preferences of myrtle rust in northern Queensland. To achieve this, we first determined whether the severity of myrtle rust infection varied throughout the natural geographical distribution of watergum *(Tristaniopsis exiliflora*). Second, we aimed to determine whether the severity of infection was related to climatic and environmental variables. Third, we aimed to determine whether the severity of infection on individual trees was influenced by the trees' architecture and microclimate.

What we did

The study area covered most of the known range of watergum, as shown in Figure 1, extending from Mount Elliot to the south to Lockhart River to the north in far north Queensland. We sampled 66 watergum populations, assessing the extent of myrtle rust infection on 10 trees in each population. We categorised active rust, branch dieback, and death as indicators of myrtle rust damage into one of five categories for each tree. These categories were: unaffected; minimal infection; intermediate infection; high infection; and extreme infection.

We conducted more extensive sampling at Lower Behana Gorge to investigate whether microclimate affected disease severity. We assessed 100 trees along a 250m transect. As well as damage from myrtle rust, we recorded trunk diameter at breast height, distance from the ground to canopy, and distance to the nearby stream.

We collated data for seven environmental variables that could have influenced disease spread and severity. These were: annual rainfall; recent rainfall; foliage projective cover; maximum temperature in the warmest month; valley confinement; site elevation; and distance from Cairns.

To explore the trends in infection among the natural populations of watergum, we modelled survey data in relation to selected environmental variables. We used a cumulative link mixed model approach in the R statistical package "ordinal". The best model included five of seven variables – annual rainfall, foliage projective cover, maximum temperature in the warmest month, valley confinement, and distance from Cairns.

To determine whether the severity of infection on individual trees was influenced by microclimate we used a cumulative link model, again using the R package "ordinal". The predictor variables we explored in the model were trunk diameter, vertical height and distance from stream.

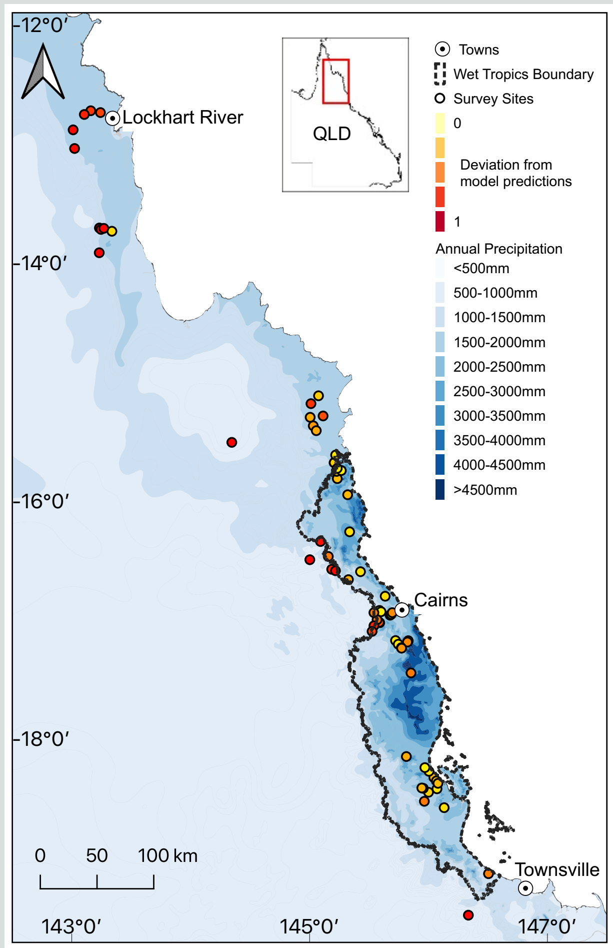

Figure 1: The location of the watergum survey sites in Queensland and the average annual rainfall of the area. Areas of high annual rainfall are indicated by dark shading. The colour gradient within the survey points represents the accuracy of the myrtle rust model, with lighter shading indicating greater similarity between the model predictions and field observations.

Key findings

Watergum populations located in areas which experienced high levels of annual rainfall, maximum temperatures below 32°C, and with dense canopy cover were likely to experience more severe infection from myrtle rust disease.

Of the 620 watergum trees we assessed across our study sites, 229 had neither current symptoms nor visible long-term damage from myrtle rust. One hundred and forty individuals exhibited minimal infection, 104 individuals moderate infection, 80 individuals high-level infection and 67 individuals extreme symptoms and long-term damage. Figure 2 shows the difference between uninfected and infected stands of watergum.

We found a positive relationship between annual rainfall and disease severity. As annual rainfall increased, the more severe categories of infection (minimal, intermediate and high) also increased slightly. Once annual rainfall reached 3000mm, extreme infections increased sharply as rainfall continued to increase. Extreme infections are when more than 75% of the leaf area is infected and more than 80% of the branches have dieback.

The disease response was also more variable at high levels of annual rainfall. In areas that received 3000mm of rainfall annually, the probability was almost equal of trees exhibiting anything from minimal to extreme levels of infection.

Areas which received less than 1000mm of rainfall per year had a high chance (80–100%) of no rust infection. In areas with less than 1000mm annual rainfall, when the infection was present it was never at an extreme level.

Foliage projective cover is an indicator of tree cover density. Watergum trees with a low amount of foliage (30% projective cover) had a high likelihood of having no infection. Trees with a large amount of foliage (100% projective cover) were most likely to have minimal to intermediate levels of infection.

As the maximum air temperature in the warmest month increased, the predicted disease severity decreased. At 32°C we saw a sharp decline in the probability of infection. At 30°C disease response was much more variable, with similar probabilities of minimal to extreme severity of infection.

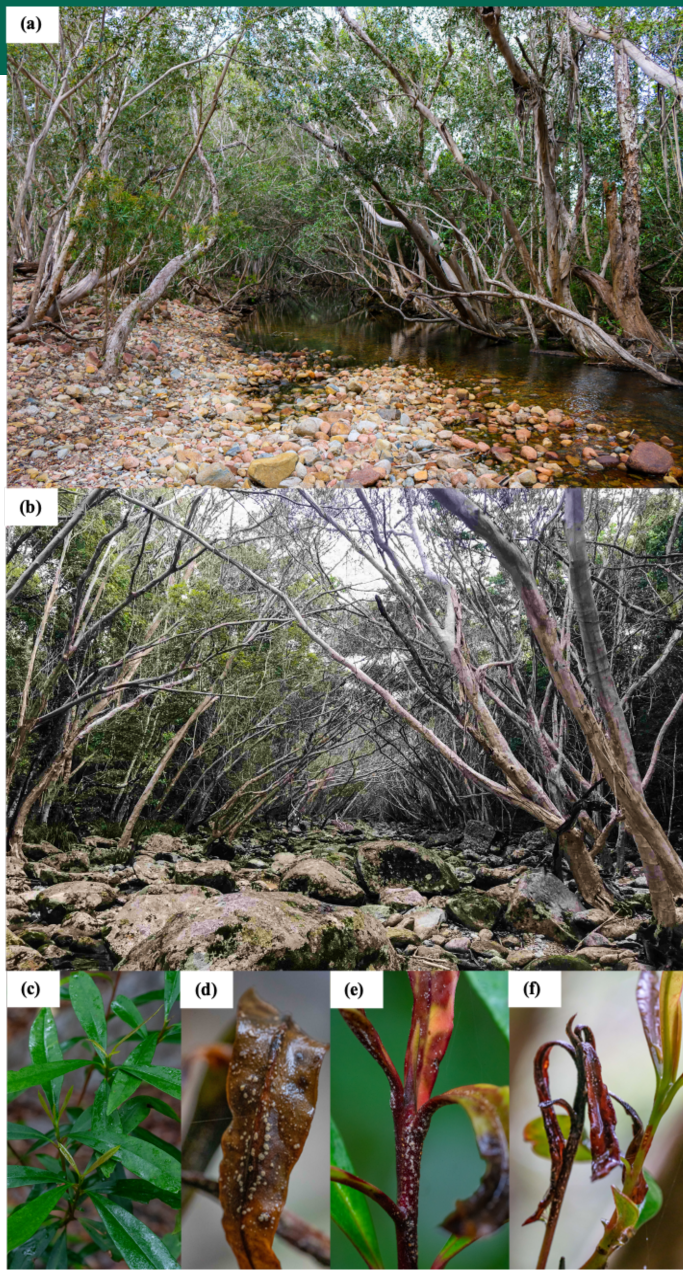

*Figure 2. (a) Healthy population of watergum (*Tristaniopsis exiliflora*) (photo credit Natalie Meiklejohn), and (b) a population substantially damaged by myrtle rust infection (photo credit Jarrah Wills) (c) Uninfected new growth (photo credit David George) (d), fungal pustules on leaf (photo credit David George) (e) infected stem, (Photo credit David George) (f) and severe infection of leaf resulting in distortion (photo credit David George).*

When flood plains were absent from the landscape (high valley confinement), the likelihood of no infection or minimal infection was much higher. Landscapes with more flood plains (less than 50% valley confinement) had greater variability in disease response, with a similar chance of low to extreme infection.

To account for differences in the amount of time since exposure to myrtle rust, we examined the distance from Cairns to each watergum population – as Cairns was the origin of the disease in north Queensland. However, we found no difference in the infection level in relation to this.

The predictions of myrtle rust infection severity made by the statistical model supported the field observations for the wetter and cooler regions of the study area. The model did not agree with

Key findings (continued)

field observations in hot and dry areas, and it overpredicted high and extreme levels of infection in these climates. This is indicated by the red dots on the map in Figure 1. Our model used mean conditions for some of the environmental predictor variables, and it could be that climate variation or climate thresholds may be important in driving myrtle rust severity in natural ecosystems.

All the intensively sampled watergum trees at the Lower Behana Gorge study site were infected by myrtle rust to some extent. The closer the tree canopy was to the ground the more likely the tree was to have a severe myrtle rust infection. This could be driven by the cooler and more humid microclimate closer to ground level which promotes myrtle rust. This finding is consistent with the results of the population model explained above. The level of infection did not markedly change with a tree's distance from the stream.

Implications and recommendations

We identified a strong influence of climate and microclimate on disease susceptibility to myrtle rust in watergum. Tropical environments with seasonal rainfall less than 1500mm per year, and high maximum temperatures, greater than 32°C, are associated with low levels of myrtle rust infection. The Cape York Peninsula may become even less climatically suitable for myrtle rust in the future with the changing climate.

High annual rainfall, maximum temperatures below 32°C, dense canopy cover and the presence of flood plains all significantly increased myrtle rust severity in natural populations of watergum. The climatic conditions regulating rust infection in watergum aligned with the known environmental tolerances of myrtle rust.

This suggests that these environmental thresholds may also regulate the myrtle rust infection of other plants in the Myrtaceae family in Australia.

Watergum is unlikely to face extinction from the impacts of myrtle rust, as relatively healthy populations were encountered in climates outside of myrtle rust tolerances, notably in the west and far north of Queensland.

Species whose entire geographic range falls within the suitable climatic conditions for infection may be at higher risk of extinction than species with a broad climatic distribution. Such species need to be identified, a task that could largely done using existing information.

The health of watergum populations within the Wet Tropics World Heritage Area is of concern. The probability of intermediate to extreme levels of myrtle rust infection increases substantially in areas receiving more than 2000mm of annual rainfall, which covers most of the Wet Tropics region. Dieback of a dominant riparian species could destabilise mountain streams and increase erosion, and this sediment would be flushed out to the Great Barrier Reef. Furthermore, the potential for watergum to regenerate could be impacted by myrtle rust, as smaller individuals are more likely to experience severe disease symptoms. The health of watergum trees within the Wet Tropics World Heritage Area needs to be monitored. If myrtle rust damage continues, long-term plans may be necessary to stabilise riparian zones where they once dominated.

Cited material

Meiklejohn, N., Staples, T. and Fensham, R. (In Review). Modelling the climate preference of the myrtle rust disease with a widespread host species. *Biological Invasions*

Further Information

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