Climate change, plant health and biosecurity

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Introduction

Although observations of climate change are well documented, the potential effects on pests and diseases and their hosts are not clearly understood. A review was conducted to; 1. determine how future climates may influence the behaviour and distribution of key plant pest and pathogens, 2. assess the modelling tools available to predict the effects of climate change on pests and diseases and 3. identify the research required to allow Australia's plant industries and quarantine agencies to be better prepared for climate change.

Because of the close interactions between the pest, the plant and the environment, it was important to examine the effects of climate change on each component of the disease triangle. The complexities of these interactions present a significant challenge for accurate predictions necessary for decision making.

Key climate change predictions

Climate change projections for Australia have been developed by CSIRO based on CO_2 emission scenarios examined by the Intergovernmental Panel of Climate Change. Predicted changes to average climate made for the whole of Australia include:

- Annual average temperature increases of between 0.4 to 2.0°C by 2030 and 1.0 – 6.0°C by 2070.
- Changes in daily temperature extremes resulting in more hot days (over 35°C) over summer and fewer cold days (below 0°C) in winter
- Changes in annual average rainfall patterns resulting in excesses or deficits, depending on geographic region, potentially resulting in floods and droughts
- An increase in the frequency of extreme weather events such as intense rainfall, storms and tropical cyclones (IPCC, 2001, CSIRO,2001).

Influence of climate change on plant health and development

An increase in minimum temperature is likely to have a significant impact on tree growth and development. One of the more fundamental effects may be changes in plant phenology which is cued by interactions between temperature and photoperiod (Bale *et al.* 2002). An increase in minimum temperature could allow plants to start growing earlier in the season and advanced flowering dates and early onset of bud break has already been reported for numerous species in the northern hemisphere (Walther 2003). Warmer winters may reduce cold hardening, fail to stimulate flowering and disrupt synchronised activity between plants and insects, leading to decreased pollination. Around a quarter of Australian eucalypts would not be able to tolerate a 1°C shift in temperature or more than a 20% variation in rainfall (Hughes *et al.* 1996).

Warmer winter temperatures will however, result in fewer frosts which will result in reduced injury to buds, fruits, flowers and foliage.

Increased plant growth under elevated levels of CO_2 has been well documented but where water and nutrient supply is limited, the 'CO_2 fertilisation effect' may be minimal (Hughes 2003). Hotter summers may increase heat stress and moisture loss, although this may be partially offset by a greater water use efficiency seen in plants grown under elevated CO_2 conditions. Higher levels of atmospheric CO_2 can induce plants to close their stomata, through which CO_2 is absorbed and water vapour is released. Thus, under CO_2 enrichment, plants may use less water even while they produce more carbohydrates. This dual effect is likely to improve water-use efficiency.

An increase in the frequency of droughts may reduce a tree's ability to recover between drought years, leading to decline and death. Trees are also likely to be affected by the predicted increased storms and cyclones, through direct damage to tree structure. Irrigated trees with shallow root zones may be at more risk of failure with the predicted increase in severe storms. Trees with deeper root zones will therefore be better adapted to survive reduced rainfall and increased storm events.

Urban trees already exist in a highly unnatural localised environment. Urban heat island effects make cities generally warmer than the surrounding rural areas (Parmesan 2006). Hard surfaces tend to reduce water infiltration and tall buildings can modify wind patterns. Due to a range of processes (deliberate fertiliser use, past waste disposal practices, atmospheric pollution) soil nutrients tend to be higher than pre-urbanisation levels. Climate change effects are therefore overlain on already highly modified, and sometimes, stressful conditions. However, the relatively small number and high value of amenity trees creates the potential for more intervention to manage climate change than for trees in natural areas or commercial plantations.

The influence of climate change on soil

A change in temperature and rainfall patterns may damage the physical structure of soils likely to leave some soils more vulnerable to damage by erosion. Other soil factors that may be affected are organic matter, water holding capacity and soil micro-organisms (Rosenweig and Hillel, 1995).

Warmer conditions are likely to increase the natural decomposition rate of organic matter and other soil processes that affect fertility. The process of nitrogen fixation, associated with greater root development, is also predicted to increase in warmer conditions, if soil moisture is not limiting (Rosenweig and Hillel, 1995).

The widely held belief that increased CO_2 levels will have a positive influence on plant growth does not extend to plants growing on all soil types (Czerniakowski et al., 2006). Field studies have shown that elevated atmospheric CO_2 accelerates soil weathering processes (Andrews and Schlesigner, 2001) and increases the concentration of dissolved inorganic carbonates (Karberg et al. 2005). In some soils it could contribute to elevated soil alkalinity, acidity, salinity, sodicity, and nutrient deficiencies and toxicities. This phenomenon has been postulated as being a contributing factor in the native tree decline, Mundulla Yellows (Czerniakowski et al., 2006). The link between accelerated soil processes, due to rising CO_2 and global tree decline needs to be examined closely to prevent the future loss of important species, growing in vulnerable landscapes.

Influence of climate change on pests and diseases

Pest and disease outbreaks occur when changes in climatic conditions such as temperature and moisture are most favourable for growth, survival and dissemination. A change in climatic conditions can cause a pest or disease to expand its normal range into a new environment, extending losses and affecting natural plant communities (Rosenzweig *et al.* 2001). A pole-ward shift in the geographical range of some pests and pathogens has been observed during the last century. While future spatial distribution can be predicted under climate change scenarios using models and examining trends, there appears to be limited knowledge of how climate change will impact on the biology of pests and diseases (Aurambout et al, 2006).

Temperature is one of the dominant factors affecting the growth rate and development of insect pests (Patterson *et al.* 1999, Bale *et al.* 2002). Higher summer temperatures would favour growth of temperate zone insects leading to faster development times and additional generations per year (Bale *et al.* 2002, Porter *et al*. 1991). Higher winter temperatures are likely to result increased over-wintering thereby increasing population levels in the following season (Porter *et al*. 1991).

Higher carbohydrate concentration of CO_2 enriched leaves can promote the development of some rusts (Chakraborty and Datta 2003). Enlarged plant canopies can provide a humid microclimate conducive to increased sporulation, spread and severity of some fungi (Coakley *et al.* 1999). Chakraborty and Datta (2003) found that aggressiveness (defined as the percentage of leaf area diseased) of the fungal pathogen *Colletrotrichum gloeosporioides* increased under twice-ambient CO_2. Combined with an enhanced ability to produce offspring, pathogen evolution could be accelerated. It is unknown whether the evolution of pathogens will keep pace with the predicted rate of climate change.

DPI Victoria and the University of Melbourne have established a Free Air CO_2 Enrichment (FACE) research facility at Horsham, Victoria, to study the effects of elevated CO_2 on crop production in Victoria. This facility provides a unique opportunity to study the changes in the host pathogen-interaction that may occur in the presence of elevated CO_2 in the field and study. Worldwide, there have been limited studies in the field of the host-pathogen interaction in the presence of elevated CO_2.

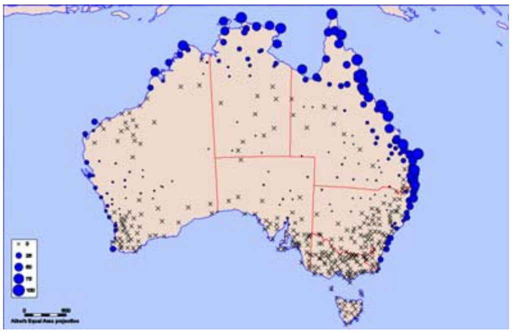
More extreme weather events such as droughts and flood are likely to lead to pest and disease outbreaks (Anderson *et al.* 2004, Fuhrer 2003, Rosenzweig *et al.* 2001). Drought stress affects plant physiology, causing some plants to become more susceptible to pests and pathogens, especially when combined with higher temperatures, which can suppress plant defence responses (Fuhrer 2003, Rosenzweig *et al.* 2001). Dry conditions and warm temperatures associated with drought can cause increases in populations of insects such as aphids, which can transmit viruses as well as being damaging to the trees themselves (Rosenzweig *et al.* 2001). Conversely, drought may reduce the incidence of some pathogens that require water or humidity for development (Chakraborty 2005). For instance, rust fungi favour periods of high humidity and if these become less common due to lower rainfall, rust incidence may decrease.

Fewer frosts may be important since they can be a limiting factor for plant pest and disease development. A reduced number of frosts may result in less injury points on plants, which act as potential entry sites for various pathogens, leading to less disease (Chakraborty 2005).

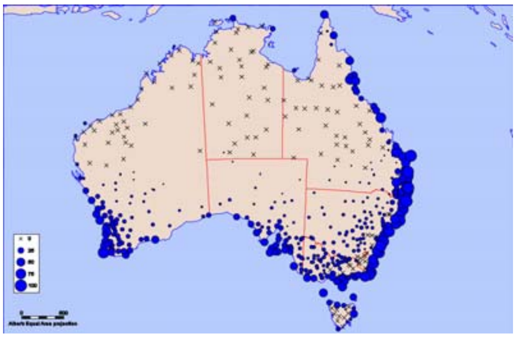
Increased winds and driving rains will enable widespread dispersal of pests and pathogens, possibly resulting in new disease incursions in previously uninfected sites and facilitating infection and survival rates (Anderson *et al*. 2004, Rosenzweig *et al.* 2001). The damage to plants under these conditions is likely to facilitate infection through stress and wounding.

Examining the potential impact of climate change on key pests and diseases

The current tools available for modelling climate change impacts on pests and diseases were reviewed. Climate matching models such as CLIMEX (© 2004 CSIRO Australia) and DYMEX are the most common models used to predict the geographical range of pests and diseases. A predictive study using CLIMEX was undertaken to determine the distribution of citrus canker in Australia, under current and projected climatic conditions. Under current conditions, major commercial citrus production areas, such as the Central Burnett region (Queensland), the Central Coast (New South Wales) and Darwin (Northern Territory), were most likely to favour the growth and establishment of citrus canker. With increasing temperature in line with predictions for 2070, southern coastal and inland commercial citrus production areas including the Riverland, Riverina and Sunraysia districts also become suitable for survival and development of citrus canker. Northern coastal areas become less suitable, especially the Northern Territory, northern Western Australia and north Queensland (van Rijswijk et al, 2007).



Predicted distribution of citrus canker (2006)



Predicted distribution of citrus canker with a 3 °C increase in average temperature (2070)

Some species have very complex life histories with multiple life stages, each sensitive to different physical or climatic thresholds. Consequently the validity of these models may be limited. Our current research links climatic models, plant growth models and insect population models to provide more accurate methods of predicting the likely impact of future climates on pests and diseases. In a pilot study we are investigating the predicted distribution of the Asiatic citrus psyllid, which vectors the bacteria that causes citrus greening. This has been achieved by coupling daily temperature data with citrus physiology data and linked them to psyllid population models. The result is a more accurate prediction of the shift in geographic range of this vector under increasing temperature. Further work will focus on increasing the resolution of this model at a regional level.

Conclusion

In the long term it may be necessary to select new species and cultivars that will tolerate variable climate conditions and are more pest and disease resistant. Given the importance of amenity trees to urban areas, climate change will become an increasingly important issue for tree managers in the future. An understanding of the effects of climate change on tree health and biosecurity will enable long-term planning to minimise the risk of tree failure and severe pest and disease spread.

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