Adaptive pest management for horticulture under climate change – pilot pest scoping

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CSIRO Climate Adaption Flagship

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Purpose of the project

The purpose of this project was to use two case studies to demonstrate methods that will identify potential impacts of climate change on pest distribution, phenology and climate suitability on horticultural industries, and to explore adaptation options and strategies to respond to these issues.

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Acknowledgments

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Media summary

It is vital that Australia's horticultural industries consider how their pest risks could be impacted by climate change as the scientific evidence has shown that indeed the climate is changing. We used two case studies to examine the nature of these changes and tried to identify, with the help of growers and consultants, the potential impacts and changes in management practices that might be required.

The two case studies were silverleaf whitefly (*Bemisia tabaci*) in Bundaberg and diamondback moth (*Plutella xylostella*). Both pests were modelled to explore how their climate suitability might change under climate change scenarios. We found that both pests could increase the number of lifecycles they can complete each year by approximately 50%.

Our attempts to engage growers were difficult as there is clearly a general disbelief in climate change, and an unwillingness to consider possible future changes in growing conditions that could result from climate changes. In addition, there appeared to be a lack of uptake of the current recommended management practices.

We have made 3 recommendatons:

1. Determine if it is feasible to make periodic assessments of pest densities (e.g. every 5 years) to monitor how pest abundance changes over time.
2. Investigate the reasons for poor adoption of existing pest management recommendations.
3. Improve grower understanding of the nature of climate changes and no regrets options for adapting management practices to changing conditions.

Technical summary

There is a clear need to address the potential implications of climate change on the changes in pest dynamics and the horticultural industry's subsequent adaptations to these changes. We used two case studies; *Bemisia tabaci* in Bundaberg and *Plutella xylostella* in Werribee, to:

1. Determine the potential changes in insect dynamics of these two pests into the future under climate change, and
2. Enlisted the help of growers and consultants to discuss the possible changes in management practices that might be required to adapt to these potential changes.

We found significant potential increases in the number of generations of each of these pests in these two locations (50%). We also identified those current locations that most closely match the future climate of these two locations under a future climate scenario in order to identify locations that could be studied presently to build a picture of future pest risks.

We had significant difficulty engaging in growers in Werribee, and were unable to arrange a workshop there. In Bundaberg, there was significant hostility to the notion of climate change, as well as a general unwillingness or inability to consider how conditions might change in the future. In addition, there was a general lack of implementation of current recommended management practices for these pests.

We recommend:

1. Initiate a project to identify the feasibility of undertaking periodic analyses of changes in the spatio-temporal abundance of pests of concern to horticultural industries, and
2. Improve grower understanding of the nature of projected climate changes and no regrets options for adapting management practices to changing conditions.
3. Investigating the reasons for poor adoption of existing management recommendations.

1 Introduction

The potential impacts of climate change and climate variability on pest management have attracted attention from some within the Australian horticultural industry. Some claims in the media and the scientific literature about the potential impacts of climate change on pest, diseases and weeds are alarming, and taken collectively, can be confusing. This study builds on the foundations of a previous report prepared for HAL "Australian horticulture's response to climate change and climate variability (AH06019)". This project focuses on exploring a method to use scenario modelling to identify adaptive pest management options for horticultural regions.

The nature of the impacts a pest can have throughout its geographical range can vary substantially. In some cases, the presence of a pest species - even at very low densities may be sufficient to incur significant industry costs in terms of export-oriented pest treatments due to the loss of area freedom. In other cases, there may be an economic threshold that depends on the abundance of the pest, which in turn can depend on the number of generations a pest can complete in one year. In many cases, the impact that a pest has on a crop depends on the phenology of the crop at the time a critical life stage of the pest is present. All of these life history characteristics can vary as a function of climate, and hence from projected climatic changes.

Many previous studies have attempted to use climate change scenario data to forecast future risks and impacts. These studies have typically mistreated the climate scenario data as if it were a set of observations of future climate conditions. However, future climate change projections are inherently uncertain, depending on factors such as the rate of emission of various greenhouse gases, which depends in turn on the complexities of the global economic system (Dessai et al. 2009; Hulme & Dessai 2008). These irreducible uncertainties make these data and methods unsuitable for making predictions of what will unfold in the future or when the predictions will arise.

Fortunately, adaptive pest management strategies at the region or enterprise level do not require accurate or precise predictions of the climate for periods of decades into the future. Pest management techniques that have evolved to deal with significant climate variability confer an ability to cope with some climate changes, and most pest management strategies do not have implementation lead times that extend beyond about ten to twenty years (e.g. classical biological control or the development and deployment of resistant crop varieties). Hence, the fundamental premise of this project is that the Australian horticultural industry is likely to be best served by approaching anthropogenic climate change within an adaptive management framework, using scenario analyses (Moore et al. 2013; O'Neill et al. 2008) to cast ahead in a prospective manner to identify:

- potential pest management issues of concern,
- potential cost-effective solutions to the significant pest management issues, and the necessary lead time for implementation,
- lead indicators signalling that the pest management issue is likely to arise, and
- a system to monitor the lead indicators at a suitable frequency.

The main objective of this project was to use two case studies to explore this adaptive management framework in two steps. Firstly, modelling the potential changes in pest populations of horticulture industries under future climate scenarios, including the identification of current locations around the world, which are climatically similar to the two case study locations under the future climate scenarios (i.e., future climate analogues). Secondly, exploring with growers the adaptation options and strategies that could be employed to respond to potential changes in the case study pest management issues. The two case studies were *Bemisia tabaci* type MEAM1 (silverleaf whitefly) in the Bundaberg region and *Plutella xylostella* (diamondback moth) in the Werribee region. Workshops were planned for these two regions in order to present the model findings and discuss the potential impacts of these changes and the subsequent implications for pest management, as well as the lead indicators that could indicate these impacts are likely to be realised.

2 Materials and Methods

2.1 Pest modelling

CLIMEX (Sutherst & Maywald 1985; Sutherst et al. 2007) was used to model the potential distributions and phenology of *Bemisia tabaci* (DJK, unpub. data) and *Plutella xylostella* (Zalucki & Furlong 2011). We compared potential distribution maps under current climate and future scenarios (using the 2100 A2 CS emission scenario). We also identify current climate analogues for Bundaberg and Werribee under the future scenario, in order to identify those regions, which could indicate the future real world conditions of these two case study areas. For all analyses the CliMond climate dataset with 10' spatial resolution was used (Kriticos et al. 2012). The A2 future climate scenario was chosen because the greenhouse gas emission pathways are both plausible in relation to recent trends (Rahmstorf et al. 2007) and significant, without being the most extreme. For the purposes of identifying production risk sensitivities, it is not necessary that we predict accurately what will happen in the future. The role of this scenario is to 'stress test' the production system to identify system vulnerabilities deserving further risk management consideration. Hence, in no sense should the modelling results be taken as predictive of what will occur, but rather be taken as indicative of what could occur if the underlying greenhouse gas emission scenario was to eventuate, and the atmospheric dynamics behave as modelled.

For both species we included top-up irrigation. For Bundaberg, this was set at 1.8 mm day^{-1} (based on irrigation patterns described in Bundaberg Fruit and Vegetable Growers 2008), while for Werribee, this was set at 1.5 mm day^{-1} (Southern Rural Water 2009).

2.2 Grower workshops

Grower representatives were contacted from both the Bundaberg and Werribee regions, and asked to assist in the planning and organising of the workshops for their respective regions. It was not possible to organise a workshop for the Werribee region (see results) so a horticultural consultancy (IPM Technologies - Paul Horne and Jessica Page) active in the region was engaged as an alternative.

The Bundaberg workshop was conducted on 29 April, 2014 and there were four growers, two consultants and one representative from the Bundaberg Fruit and Vegetable Growers Cooperative.

The Werribee meeting with IPM Technologies was conducted on 13 June, 2014.

For both Bundaberg and Werribee, a PowerPoint presentation was prepared and used to provide information on climate change, the modelling outputs, and to stimulate subsequent discussions (see section 3.1 Pest modelling, for a summary of modelling outputs that were presented for each region). The aims of the subsequent discussions were:

1. Develop and understanding of the impacts of pest changes on enterprise conditions,
2. Assess the capacity of current pest management strategies and tactics to cope with projected changes in pest timing and abundance risks,
3. Identify possible responses of growers (based on their current pest management practices) to changes in insect abundances and lifecycles (identify automatic adaptation responses),
4. Identify the need to planned adaptation responses,
5. Identify early indicators in insect abundances and lifecycles that would predict future changes under climate change so as to provide growers with an early warning system.

3 Results

3.1 Pest modelling

3.1.1 *Bemisia tabaci*

The CLIMEX model showed that for Bundaberg, the number of generation of *B. tabaci* could increase from 9.4 generations currently to 13.8 generations under the future climate scenario, an increase of 46.3%. The reasons for this can be seen in the Weekly Growth Index (GI_W) throughout the year (Panel 2, Figure 1, Figure 2). The GI_W is currently constrained by the Temperature Index (December to June) and then by the Moisture Index (June to November) (Figure 1).

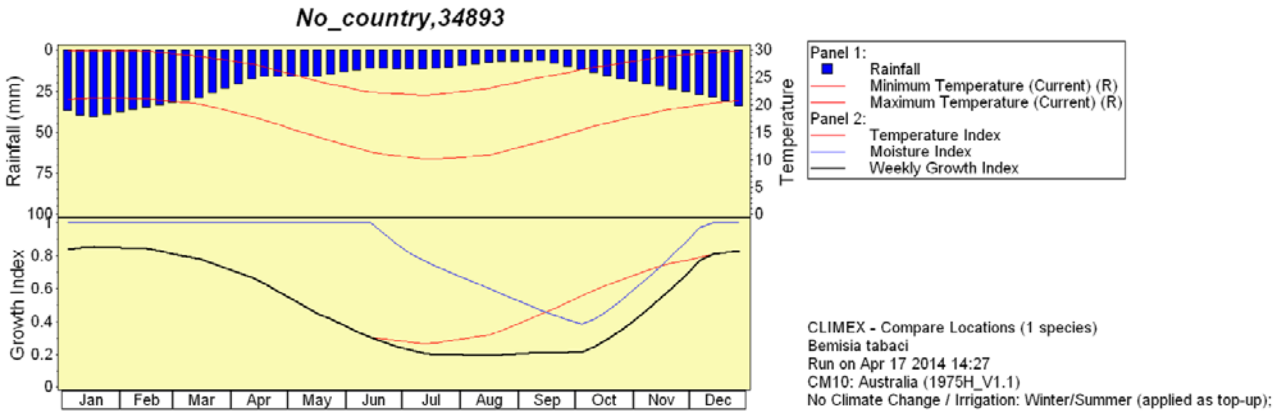

Figure 1. Climate suitability for for *Bemisia tabaci* modelled using CLIMEX (Panel 2) for the current climate (Panel 1) for Bundaberg (No_country,34893).

In the future climate scenario, with increasing temperatures, the GI_W attains the maximum value (1.0) throughout the months January to March, although it is kept low in the months October to November by the Moisture Index (Figure 2)

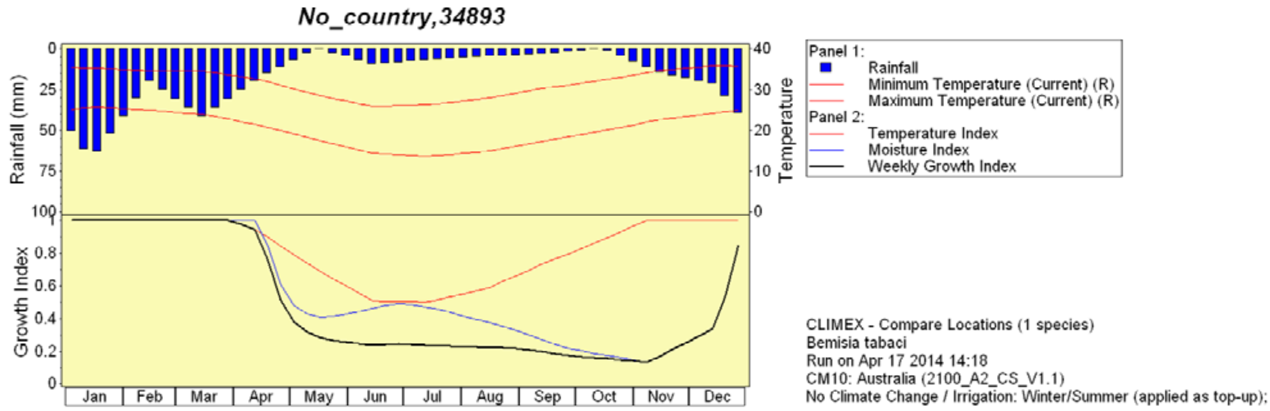

Figure 2. Climate suitability for for *Bemisia tabaci* modelled using CLIMEX (Panel 2) for the future climate (Panel 1) for Bundaberg (No_country,34893).

We also identified those regions around the world with similar climates to Bundaberg in the future under the future climate scenario (Figure 3). We found a large region throughout northern Australia as well as parts of eastern Africa (Tanzania and Mozambique), India, and Paraguay.

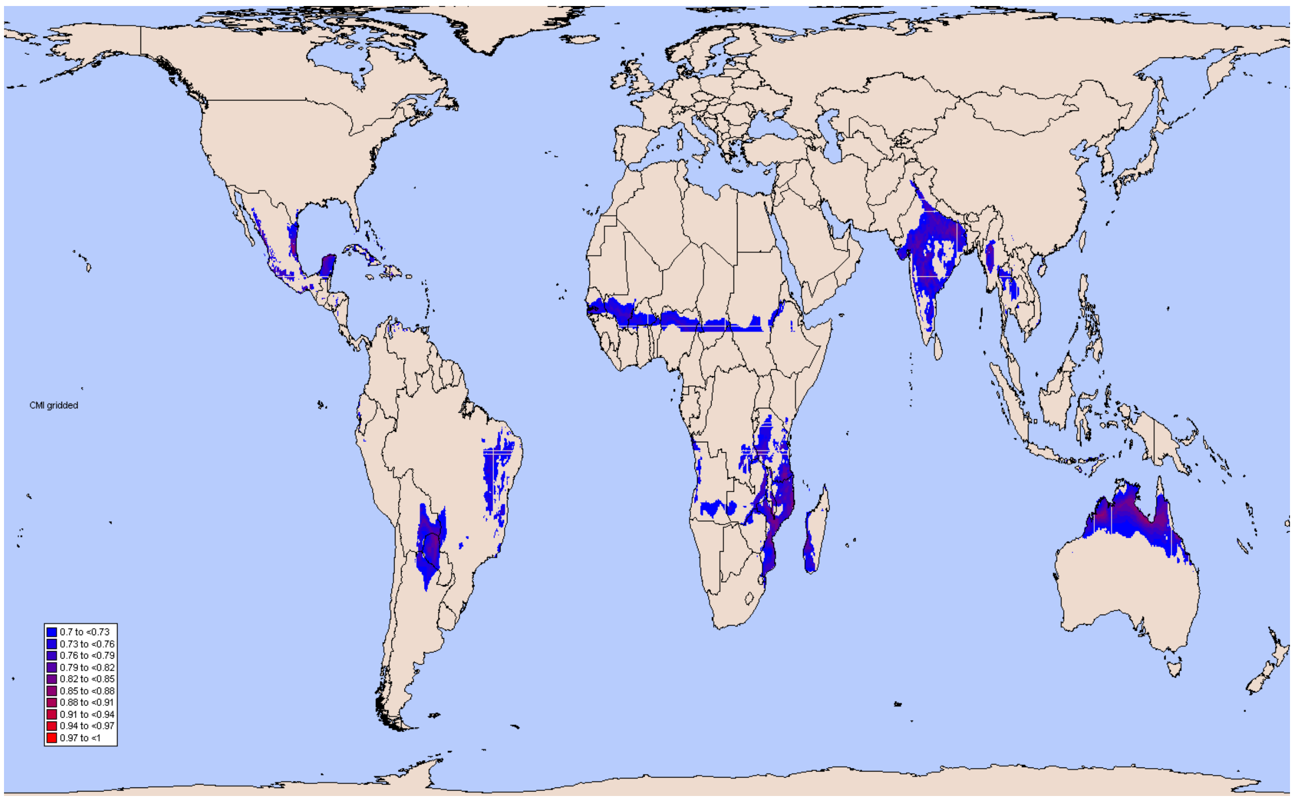

Figure 3. Current locations around the world, which show high similarity to Bundaberg under the future climate scenario.

3.1.2 *Plutella xyllostella*

The CLIMEX model showed that for Werribee, the number of generations of *P. xyllostella* could increase from 10.1 generations currently to 15.3 generations under the future climate scenario, an increase of 51.0%. The reasons for this can be seen in the GI_W throughout the year (Panel 2, Figure 4, Figure 5). The GI_W is currently constrained by the Temperature Index (May to October) and then by the Moisture Index for the remainder of the year.

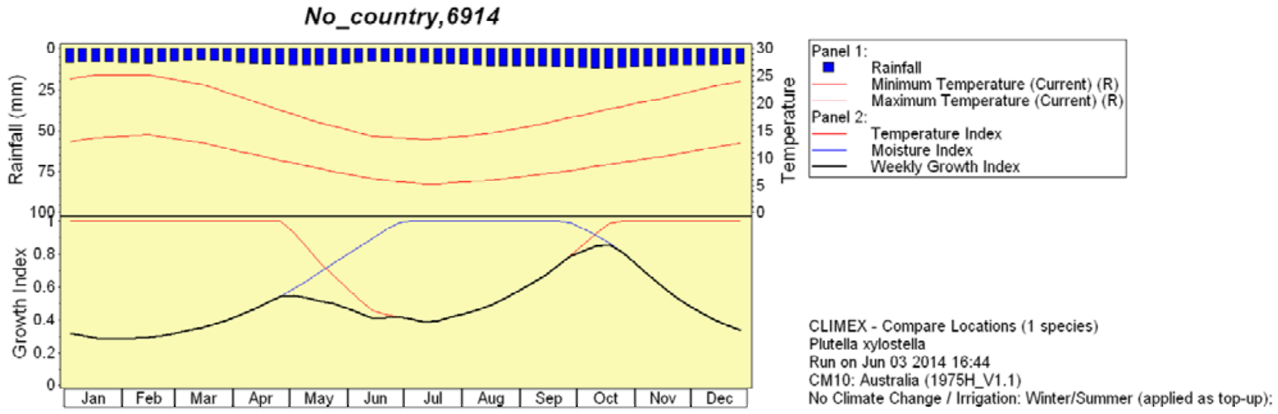

Figure 4. Climate suitability for for *Plutella xyllostella* modelled using CLIMEX (Panel 2) for the current climate (Panel 1) for Werribee (No_country,6914).

Under the future climate scenario the GI_W increases for May to October as the Temperature Index increases (Figure 5). This is approximately a 50-100% increase depending on the month.

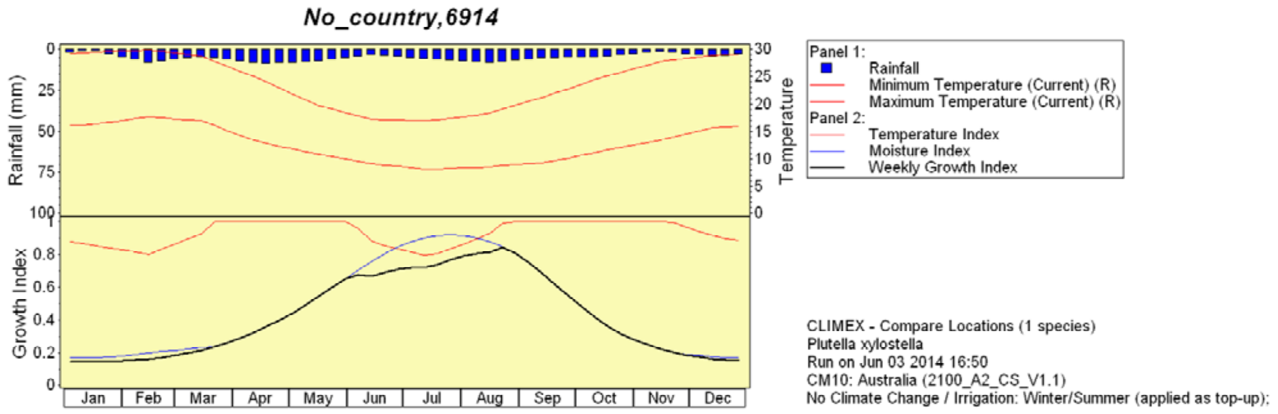

Figure 5. Climate suitability for for *Plutella xyllostella* modelled using CLIMEX (Panel 2) for the future climate (Panel 1) for Werribee (No_country,6914).

We also identified those regions around the world with similar climates to Werribee in the future and the future climate scenario (Figure 6). We found a large region throughout southern Australia as well as parts of South Africa, central Argentina, northern Africa (Morocco, Algeria, Tunisia), and northern Mexico.

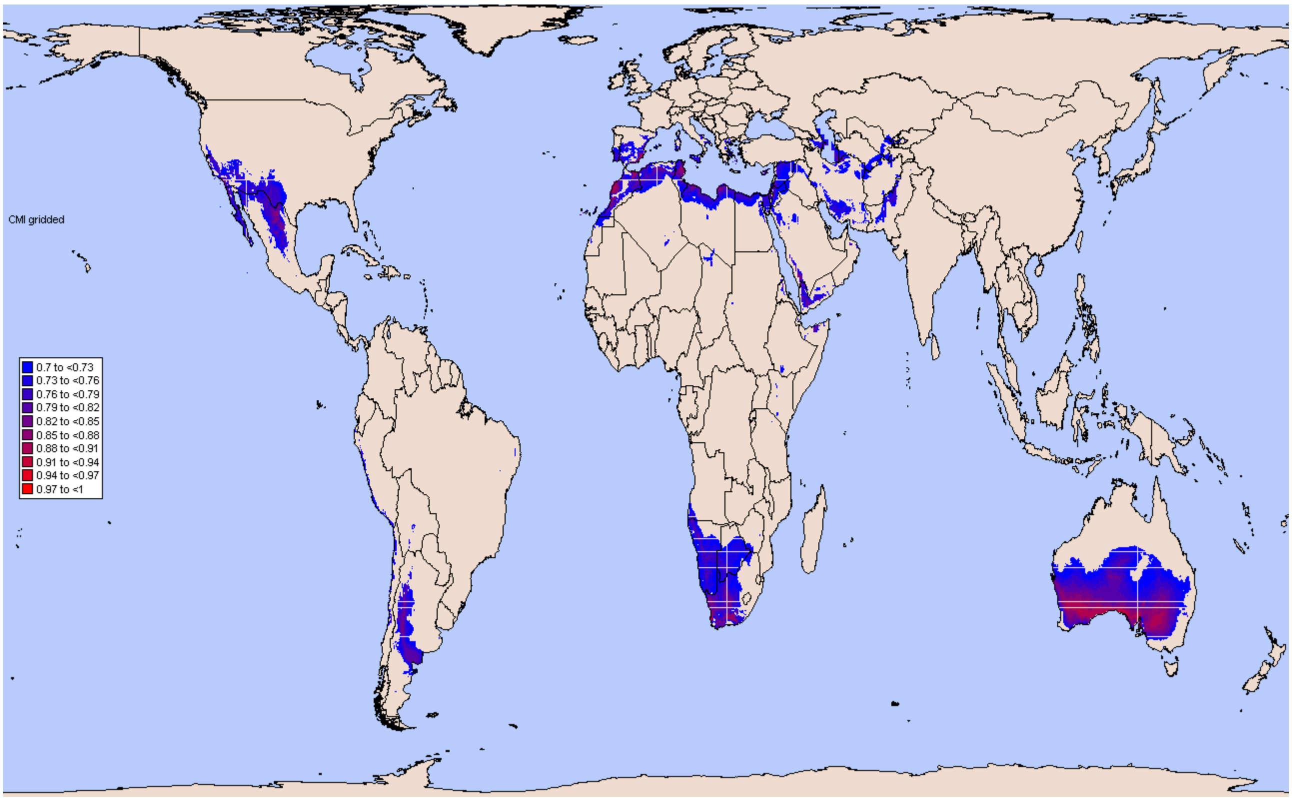

Figure 6. Current locations around the world, which show high similarity to Werribee under the future climate scenario.

3.2 Grower workshops

3.2.1 BUNDABERG

The growers participating in this workshop were clearly sceptical that climate change was a real phenomenon, and were generally unwilling or unable to consider how *B. tabaci* could change into the future. As a result, they were reluctant to discuss future changes in pest management. There was a general feeling amongst the group that the problems this pest presents are immediate and need to be addressed now, rather than considering the problem into the future. In following this lead from the growers, we explored what the current problems are, with the hope that it could lead to insights for management changes into the future.

The growers believed that they are past the tipping point in regards to *B. tabaci* pest status and were convinced the impact will be the same whether there are 9 generations (as the model predicts now) or 14 generations into the future. There were a number of factors identified by this group that have contributed to the current problems with this pest:

1. Year round cropping and the subsequent availability of hosts for *B. tabaci* all year
2. Lack of coordination and collaboration between the growers for the control of *B. tabaci*
3. Increasing resistance of *B. tabaci* to chemical control

Potential future changes identified by the growers were:

1. Co-ordinated area-wide IPM strategy
    a. Full engagement by all growers

   b. Coordinated application of pesticides and natural enemies
   c. Better farm practices (enforced clean up of fields post harvest)
2. New chemical control (though growers agreed this could only be temporary)
3. A break in the growing season to prevent the maintenance of *B. tabaci* populations throughout the year
4. Closer examination of what is happening in growing regions north of Bundaberg
5. Better weed host control
6. Growers admitted that there had been a move away from capsicum over the past 10-15 years due to *B. tabaci* and that this trend was likely to continue.

We then asked the growers to identify which organisations would or could be responsible for various changes

BFVG:

1. Area wide coordination of IPM strategy
2. Provision of pest reports to growers

HAL

1. Provide funding for area wide coordination,
2. Fund the identification and breeding of more natural enemies,
3. Fund a study into the influences on spatial variation if *B. tabaci* densities (bushland, spraying regimes, crop types, etc),
4. Investigation into northern growing regions and how they manage their pests. Also an assessment of how similar these regions are to Bundaberg,
5. International monitoring or cooperation for information exchange (e.g. what's happening in Tampa, Florida and does this indicate the future for Bundaberg?)

QDAFF

1. Entomologists and pathologists located in Bundaberg for advice and diagnostic services.

3.2.2 WERRIBEE

We contacted a number of growers, all of whom were unwilling to participate in a workshop to discuss these issues. These general grower attitudes were confirmed by two consultants who are active in the Werribee region (Stuart Grigg, Ag-Hort Consulting; and Paul Horne, IPM Technologies). As a result, we engaged Paul Horne and his colleague Jessica Page to discuss the model outputs and the implications for Werribee growers. It was not possible to arrange a meeting with Stuart Grigg due to his work load. The points made by Paul Horne and Jessica Page follow:

Similar to Bundaberg growers, Werribee growers are unwilling or unable to consider possible future changes in pest numbers due to climate change, which explains our difficulties in obtaining grower engagement for our proposed workshop in Werribee.

Characteristics of the current management practices and issues:

1. Crop management has deteriorated. There is little rotation or variation in crop types and this is a function of market driven forces and the fact that reducing on farm complexity makes it easier to manage for growers,
2. Year round production provides constant host sources for *Plutella xylostella*,
3. There is an overproduction of broccoli and cauliflower, which is creating a buyer's market and pushing down profits for growers,
4. Intense competition between growers (driven largely by market forces) and little subsequent desire to share IPM strategies,

5. Pest resistance to current chemical controls is increasing,
6. There can be conflict between pesticides and biocontrol if pesticides reduce the efficacy of biocontrol,
7. Though the growers would like new pesticides, there is nothing new on the horizon for at least eight years.

Paul and Jessica identified a number of changes that are required both for current and future management of pests in this region:

1. Area-wide coordination of IPM strategy,
2. Better application and explanation of IPM strategy (much research has already been done, but little has been articulated in a clear and simple manner to growers).

Paul and Jessica also identified which agencies could assist in the better management of pests in this region

HAL

1. Enabling better engagement in IPM strategies (e.g. simplifying instructions for growers in order to increase the likelihood of uptake),
2. Better engagement with consultants and resellers to encourage changing practices amongst growers.

4 Discussion

4.1 Pest Modelling

It is clear that in the future for both Bundaberg and Werribee, these pest species could increase in the number of generations by approximately 50% for both species. This is a significant increase, but it is unclear what impact this would have at the farm level if it were to eventuate. This increase in pest pressure is driven mainly by an increase in the temperatures projected for both these regions, which influences the Temperature Index, which in turn influences the GI_W of these species. It is likely that the temperature increases will increase the maximum risks faced in each region. In the tropics and sub-tropics, the extent to which these risks are realised in any given year may be governed to a greater extent by annual rainfall patterns. In Temperate regions such as Werribee, small fluctuations in winter temperatures (particularly during winter) could change the pest dynamics significantly.

The analogue climates analysis indicates for each region where researchers might start exploring comparisons of horticultural and pest management practices. Whilst these results are not predictive, it is probably safe to conclude that the climates in the case study regions will tend to move in the future toward the climates presently experienced in the regions indicated in Figure 3 and 6 respectively. Studying primary production industries in these analogue climates could alert growers and researchers to the types of challenges that they may face in the future. In making the comparisons it will of course be necessary to control for factors such as distance to market that could introduce significant differences into the response of producers to a given level of pest risk.

4.2 Grower Workshops

While it is apparent there is a clear need to educate growers regarding climate change, there also appears to be some significant structural faults in both these growing regions that are preventing appropriate management of both these pests, and likely other pests. Many of these issues appear to be a direct or indirect result of intense competition between growers to sell their produce at a profit that hampers any desire to share, collaborate, or co-ordinate pest management practices.

While Bundaberg growers claim there is a need to understand the area-wide population dynamics of *B. tabaci*, much of this work has already been completed (De Barro 2012), with clear recommendations on how growers can better manage *B. tabaci*. This report also indicated how on-farm management practices can significantly reduce the impact of this pest, thus removing the perceived need for area-wide management. Whilst grower guides have been produced to disseminate these recommendations, adoption appears poor.

It would appear that, while growers may have seen this information, it has not been incorporated into their current management practices. This point was also made by Paul Horne, the consultant active in Werribee, who argued that a great deal of research into better management of crop pests has been done, but little of it has been passed on in an appropriate way to growers. In the climate change and climate adaptation literature, this phenomenon has been termed an ‘adaptation gap’. This is where current practices are not best adapted to the current set of environmental circumstances because they do not make best use of available technologies.

In our experience during this project, grower hostility to the notion of climate change is impeding a useful discussion of the emerging challenges that may arise in a changing climate, and opportunities to improve pest risk management under uncertainty. To the extent that they were even remotely receptive to the notion that their pest management problems might change in the future, they were unreceptive to the idea of engaging in the development of solutions. Their repeated demands were for simple instructions on how to manage their pests. During the workshops it was clear that the pest management consultants were held in high regard by the growers. It seems clear that these organizations will have to play an important role in understanding the nature of future changes in pest threats, identifying appropriate pest management responses, and communicating these issues and management tactics to growers. It is also likely that the data they collect on pest abundance through time and space will be critical to the identification of trends in pest pressure.

4.3 Conclusion

While there appears to be substantial issues related to current management practices and their adoption, or lack thereof, by growers in both Bundaberg and Werribee, it is important that strategies and processes be put in place now that will prepare and forewarn growers into the future of the impacts of climate change.

The potential changes in pest management threats to horticulture are potentially serious. However, the nature and magnitude of these changing threats are highly uncertain. Managing these types of emerging risks has been widely acknowledged as being particularly challenging. There is a danger of both under- and over-reacting to the potential threats based on future climate forecasts.

It seems clear from our investigations that horticulturalists have little appetite for thinking about climate change issues, and very limited capacity to track the changes in pest problems over long periods. They are strongly reliant upon pest management consultants to provide simple timely pest management prescriptions. To the extent that horticultural industries are going to be able to adapt to emerging pest issues it will be necessary for some agencies to undertake periodic analyses of pest occurrence data within each growing region, noting changes in abundance and phenology of pests. To the extent that pest management consultants collect and store pest occurrence data, there may be a suitable dataset to base such analyses.

Detecting and forecasting changes in pest abundance and phenology due to climate change is likely to be a difficult task. The abundance of pests is a stochastic phenomenon, affected by climate variability at various scales, as well as the spatio-temporal variation in hosts of different suitability, the dynamics of natural enemies, and the human management interventions. Ultimately, it may make little difference whether causality is attributed specifically to climate change. It is possible, for example that a significant change in the nature and magnitude of pest problems could arise from cultural changes arising from the introduction of new crops in response to changing market conditions. Periodic (say five yearly) trend analyses could be a cost-effective means to help alert pest management consultants to robust changes in pest dynamics. A five-year frequency would help avoid over-reacting to noisy data, but be responsive enough to pick up rapid changes where non-linear ecological responses occur.

Given the temperature gradients within Australia, we can also use analogue climates to alert growers to changing threats. Instead of just viewing the pest management problems in each growing area in isolation, we view them as occurring along a gradient of environmental conditions, our temporal analyses can track changes in pest management through space and time. For example, growers in the Bundaberg region can benefit from seeing how pest management issues to the north change through time. To the extent that these changes can be correlated with changes in temperature and precipitation, the problems and solutions to the north might be seen as portents of the emerging problems for the Bundaberg region.

5 Recommendations

5.1 Climate change adaptation

1. Undertake a project to identify the feasibility of undertaking periodic analyses of changes in the spatio-temporal abundance of pests of concern to the horticultural industries. This study should identify the sources and qualities of pest abundance data, the types of questions that it is capable of supporting, and a suitable business model to support the ongoing analyses. To the extent that existing data sources are unable to support the spatio-temporal analyses, the study should investigate the feasibility of enhancing the pest monitoring activities to a standard capable of supporting the required analyses.
2. Improve grower understanding of the nature of projected climate changes and the need for climate adaptation within the context of a more general global change framework.

5.2 Extension of pest management information

3. Investigate the reasons for the poor adoption of existing pest management recommendations, and identify options for closing the adaptation gap through better extension of existing pest management knowledge.

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