GRDC National Invertebrate Pest Initiative Annual Workshop

Climate Change and IPM

Orange Agricultural Institute

12-13 November 2007

MEETING REPORT

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(Not complete)

Acknowledgements

Support from GRDC, CRDC, Cotton Catchment Communities CRC, Horticulture Australia Ltd

Executive Summary and Recommendations

- A one day workshop for the participants of the GRDC National Invertebrate Pest Initiative [NIPI] network was held at Orange Agricultural Research Station on November 12-13 2007.

- The Workshop included a brief session of updates on NIPI activities, but the main focus was to assess current understanding of the potential impacts of climate change on the implementation and success of integrated pest management practices in braodacre cropping systems.

- The Workshop was broadened beyond the grains industries to include consideration of cotton, horticulture, rice and forestry industries with representation from researchers in those industries and some financial support from cotton and horticulture.

- Overall the workshop served largely to raise awareness of the diverse issues associated with climate change and its potential impacts on IPM in a variety of contexts and to formulate some potential research opportunities where key questions might be addressed within NIPI or across broader agricultural collaborations.

- A particular focus was on the impact of climate cahnge on the **species interactions** which underpin IPM: the interactions across trophic levels among plants – pests – beneficials, the interactions of pests with control tactics and the interaction of climate with the regional ecology of key invertebrate pests.

- Participants gained considerable insight from the presentations and perspectives identified in the discussion sessions. A number of key areas for future research were identified and some specific recommendations were reached.

- It must be noted that while many of the recommendations suggest that the National Invertebrate Pest Initiative should recource a number of initiatives, the limited funding currently available for NIPI will not allow all these to be supported. Integrated projects with support from multiple agencies [grains, cotton, horticulture] will be needed.

Recommendations

General recommendation

- Considerable effort was made by research groups to summarise current understanding of climate changes impacts for the grains, cotton, rice, forestry and horticultural industries. NIPI will encourage and recsource lead researchers from each system to collaborate in producing a synthesis publication which summarises the current expectations of impact across industries.

Changing Production Systems

Recommendations

1. NIPI to coordinate pest and disease records from Vanguard crops / satellite areas
2. Commence a focus to identify best practices for protected systems [jointly with Horticulture?]
3. NIPI to provide a conduit for information on climate change research funding available through government or industry – perhaps coordinate applications for funding?

Pest Forecasting

Recommendations
1. NIPI to coordinate national monitoring networks of pest or climate information [SOI] or cropping information [crop/host areas for several pests etc]
2. NIPI to prioritise needs for pest forecasting
3. Provide extension and education on the limitations of a forecasting system, especially when it is being developed.

Systematic Records

Recommendations
1. NIPI to support experienced staff to database information from accumulated records in Departmental files
2. Provide incentives for more systematic reporting from wide network of participants – including professional consultants, researchers, agronomists.

Taxonomy

Recommendations
1. Incorporate taxonomy into project planning for ecosystem level diagnostic systems; involving Barcoding, User Friendly keys, Internet based tools
2. Provide greater support for taxonomic training (students) and focus on invertebrate groups where taxonomic knowledge is poor

Long Term Monitoring Sites

Recommendations
1. Explore mechanisms to establish long term monitoring sites where patterns of invertebrate fauna and abundance can be robustly recorded.
2. Consider establishing 30 long-term sites across all agricultural regions to incorporate crops, pastures, weeds, roadsides, native vegetation – to be sampled spring and autumn
3. Integrate a network of long term sites with other activities – Grain and Graze, LWA, NHT, NCRIS, GRDC, CRDC, RIRDC, CRCs

Establishing a Functional IPM Framework

Recommendations
1. Provide mechanisms for ongoing capability development and training of students, advisors and researchers.
2. Establish mechanisms for national data sharing derived from agreed and techniques
3. Identify gaps in IPM knowledge and target with research or students
4. Develop a set of IPM Guidelines for grains [modelled on the Cotton IPM Guidelines] to provide a training and reference tool

Opportunities from Modelling

Recommendations
1. Conduct Modelling workshops for high impact and priority species
2. Conduct case studies for key pests to evaluate models by validating against historical data
3. Develop web-based models for forecasting and capture of pest occurrence data from producers.

Agenda

Monday 12 November 2007

2.00-5pm **Update Meeting for the National Invertebrate Pest Initiative**

Introductory Comments - Gary Fitt (CSIRO)

SE Australia cropping systems project update Hainan Gu (CSIRO)

NIPI Extension Adoption team activities Peter Mangano (WA Department of Agriculture)/Judy Bellati (SARDI)/Paul Umina (University of Melbourne)

UQ IPM Website development/NIPI web presence Austin McLennan (Qld Dept of Primary Industries & Fisheries)

Special Edition Journal Update Paul Umina (University of Melbourne), Gary Fitt (CSIRO)

Update on UQ/CESAR Microsatellite project Andrew Weeks (CESAR)

Student Project Update John Roberts (University of Melbourne)

Overview NIPI 2 and Planning

DNA Barcode Project Andrew Mitchell (NSW Dept of Primary Industries)

6.30pmDinner (Parkview Restaurant, 281 Summer Street, Orange)

WORKSHOP - Climate Change Consequences for IPM

Introductory Session

Steve Crimp (CSIRO Sustainable Ecosystems) – *Future Climate Scenarios and the Big Picture for Australian Agriculture*

Ary Hoffmann (University of Melbourne) – *Evolutionary Limits to Adaptation*

Tuesday 13 November 2007

WORKSHOP - Climate Change Consequences for IPM

Session 1. Interactions, Tools and impacts

8.30-8.50 Nigel Andrew (University of New England)
Impacts of future climate scenarios on insect community structure and dynamics/Lessons from natural ecosystems

9.00-9.20 Darren Kriticos (CSIRO Ensis)
Role of modelling tools to explore climate interactions with invertebrate/ plant systems

9.25-9.45 Jo Luck (Victorian Department of Primary Industries)
FACE networks and experimental opportunities to explore climate change impacts

9.45–10.15 Table Discussion; Three key issues from these presentations

10.15 -10.40 Morning Tea

Session 2. Industry perspectives - potential climate change impacts on IPM

10.40-10.55 Northern Grains Systems (15min)
David Murray/Melina Miles (Qld Dept of Primary industries & Fisheries)

10.55-11.10 Southern/Western Grains Systems (15min)
Mike Keller (Waite Institute, University of Adelaide)/ Peter Mangano (DAWA, Perth)

11.10-11.25 Cotton IPM Systems (15min)
Robert Mensah (ACRI, NSW DPI)/ Lewis Wilson (CSIRO)

11.25-11.45 Table discussion; Three key issues from these presentations

11.45-12.00 Horticulture IPM Systems (15min)
Nancy Schellhorn (CSIRO), Andrew Jessup (NSW Dept of Primary Industries)

12.00- 12.10 Rice IPM systems (10 minutes)
Mark Stevens (NSW Dept of Primary Industries)

12.10- 12.30 Table discussion; Three key issues from these presentations

12.30 – 1.30 Lunch

Session 3. Discussion and Planning

1.30 - 3.45 Group Discussion and Planning; main factors to emerge, their implications and possible themes for future research

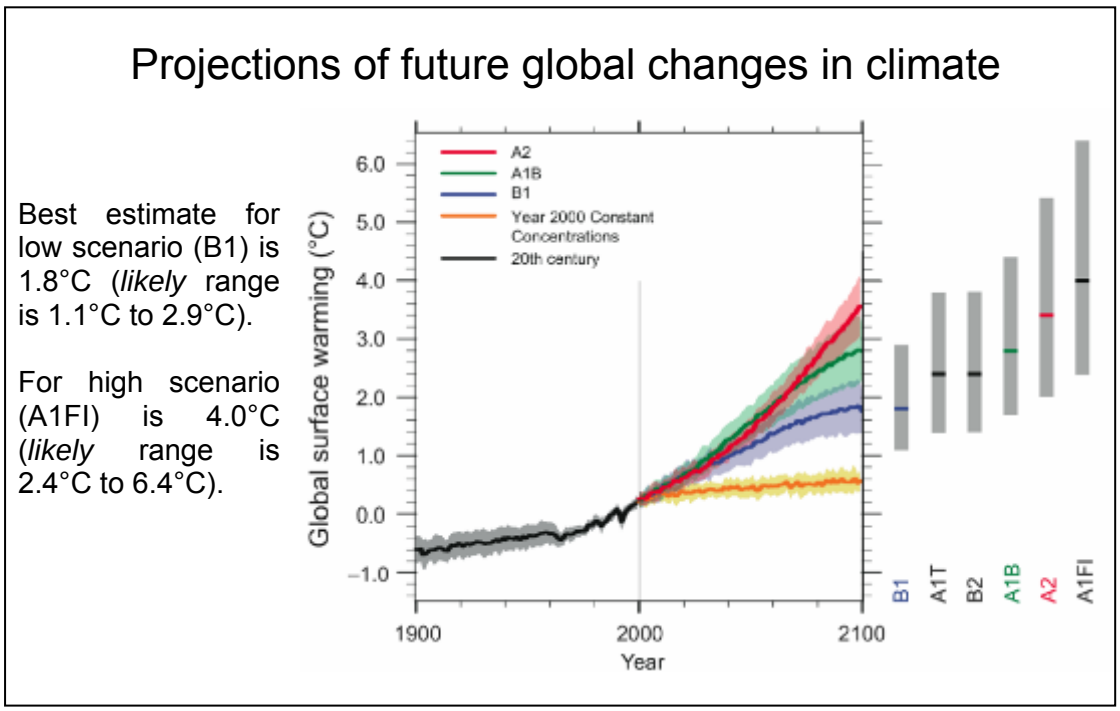
3.45- 4.00 Wrap-up – Gary Fitt (CSIRO)

1. Identifying Themes and Issues

The Introductory Session and Sessions 1 and 2 provided a series of presentations covering:

- future climate scenarios;
- evolutionary limits to adaptation;
- interactions, tools and impacts;
- industry perspectives on potential impacts

All presentations are included as .pdf documents on a CD accompanying this report. Key points from each presentation are given in Appendix 1.



From Steve Crimp (CSIRO)

Workshop contributors were invited to identify the key issues arising from each presentation that needed to be incorporated in planning future research needs for invertebrate pests of field crop systems within the context of a changing climate.

In summary, the identified issues raised three higher-order topics;

- **Climate Vision.**
  How significant will climate change be? What is the main role for research on invertebrates in these systems? What are the key questions?

- **Changing Crop Production Systems. [What will we eat?]**
  Teasing out the impacts and responses for crops and production systems in different regions in the future. This may be a task for industry focussed RDCs to lead. Which farming systems will change and how? What are the implications for species interactions (crop – pest –predators) and hence for pest management?

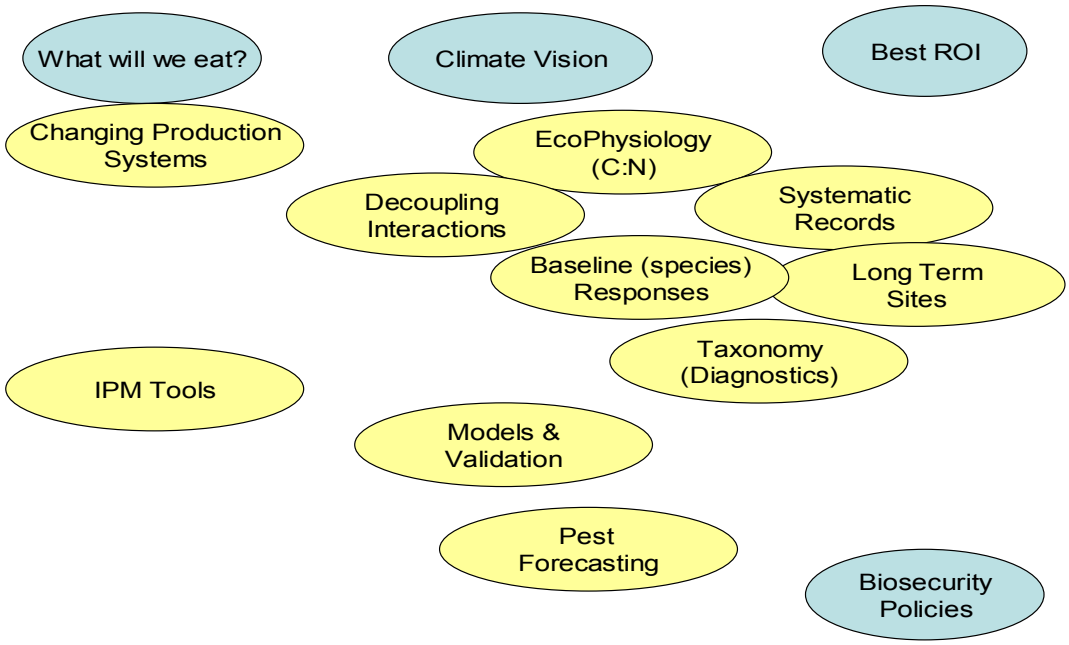
- **Return on Investment.**
  Will some styles of investigation, or some sets of research questions, provide better overall returns than others? Where should scare funds be invested and how?

Responses from Workshop participants suggest that a suite of related investigations would be productive in identifying the impact of climate change on species interactions and hence on the resilience of IPM approaches.

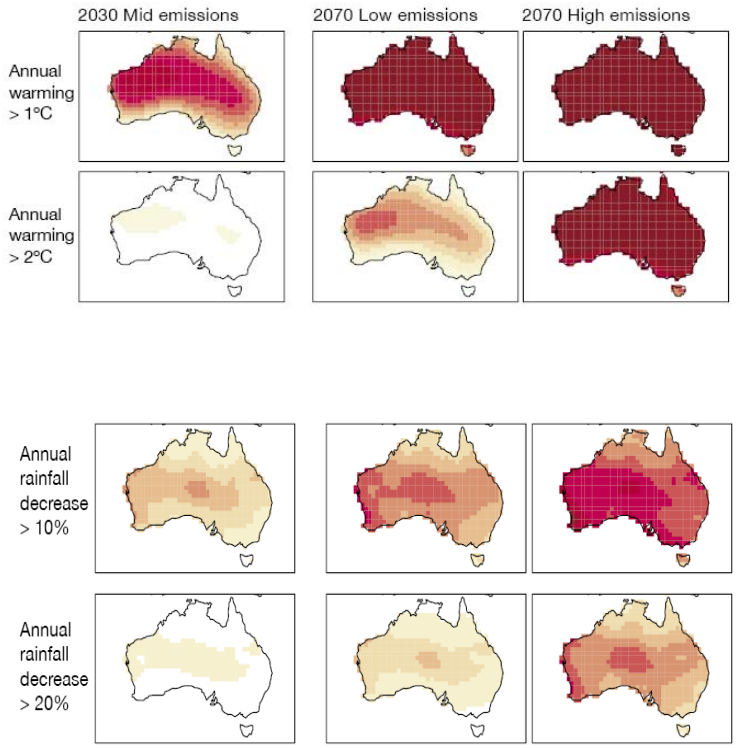
Research which quantifies **Baseline Responses** of key pest and beneficial species, combined with targeted **EcoPhysiology** to understand how different atmospheres – eg C:N ratios - may affect the life cycle and "fitness" of different pests and beneficial invertebrates should permit examination of the strength of interactions in changing climates and the possibility for **De-Coupling** (understanding the types of relationships that may be broken as a result climate change, whether there are predictable thresholds, and what the implications may be). These research issues would be supported by **Long Term Sites** (monitoring trends and changes and also revealing information about extreme events and seasons), collection of **Systematic Records** (establishing reporting and observation protocols to draw better information from real-life situations) and the need for improved **Diagnostics**.

Increasing variability and extreme events may make it harder for producers to apply integrated pest management approaches and could result in increased chemical use. Ongoing research investment and development will be required to ensure continuous improvement in **IPM Tools** available for producers.

The suite of research on climate change and species interactions will provide data for model development and validation. In turn, models will help to better focus future research through pre-experimental planning. **Models and Validation** will contribute to scenario development for future production systems and support the potential for **Pest Forecasting;** which might be applied to existing pests or to better inform **Biosecurity Policies** by identifying potential new priority source areas for pests or likely new pests.



Likely Future Changes



By 2030 annual warming is likely to be 1^{o}C based on a mid-range scenario.

By 2030 rainfall is projected to decline by up to 10% based on a mid-range scenario.

from Steve Crimp**(CSIRO)**

POTENTIAL IMPACTS – AGRICULTURE

- Southern Australian regions are likely to experience mean yield reductions but greater variability by 2070.
- In the north, warming trends have already reducing frost risk and may allow early plantings to offset heat stress.
- Grain quality is likely to be affected, through CO_2 fertilisation impacts on C:N ratio.
- Glyphosates may be less effective under elevated CO_2 so weed control may be a greater challenge.
- A rise in CO_2 concentration is likely to increase pasture growth, particularly in water-limited environments.
- The potential distribution and abundance of exotic weeds and native woody species is likely to change.
- Increased heat stress on animals is very likely although less cold-stress is likely to reduce lamb mortality.

2. Expanding on Themes and Issues

The individual issues identified above and a suite of comments associated with each are recorded as dot-points below; grouped under central themes.

Climate Vision

- Need to get climate related risks in "perspective" eg. Invertebrates vs other climate induced impacts and impacts on invertebrates due to climate change vs other drivers (eg, changing areas of certain crops like canola).
- Issue is to tease out the effect of climate change vs other factors.
- What is our vision in relation to climate change – do we want to be able to respond? Do we want tools? Do we just want to know what might happen?

Best Use of R&D Investment

- What is the best use of limited resources for manipulative experiments? Eg, beyond CO^2, temperature, and moisture stress.

Changing Production Systems

Key points:

- Need for predictions of future cropping systems - Where will we be cropping / what will be grown? Vanguard crops and pioneer farmers; what pest problems do they have?
- Crops which we will have with/without water. "Glasshouse Crops", increase in GM crops, choosing which crops for the future.
- Water and soil availability will determine what gets grown where – land use decisions /conflicts to resolve.
- Water intensive crops go where water is, so what are the pest implications?
- Drought tolerant crops and varieties including GM – how do pests interact with them?
- Protected cropping – may see a dramatic increase in glasshouse protected systems for crops
- Management practices on farms, changing rapidly – impacts on herbivores. Early prevention from different regions.
- Some research methods and management practices may become more economic as commodity prices and grower returns are likely to increase. Eg. NPV sorghum, mass release of beneficials.
- Intensification of potential cropping may enhance development of effective IPM.
- Need to understand how changes in water use efficiency affect C:N ratios and herbivore dynamics.
- Increased pest pressure over different regions. Understanding the underlying causes of differential pest intensity in current systems will help us prepare for impacts under changing geographical or temporal sequences in the future - generating pre-emptive scenarios.
- Irrigated crops may become islands focussing/attracting pest insects from increasingly arid surrounding areas.
- Responses will vary with different crops. Some crops eg. Cotton already provide a highly artificial environment; climate change may not have great affects on IPM systems. Need to prioritise crops at risk.

Eco Physiology

- Need to gain an understanding of how changing climate and C:N ratios affect
  - Baseline growth and yield response of host plants (wild and cultivated) to various climate drivers (C:N = response), (temperature rainfall/water), WUE
  - Life history traits of insects, herbivore dynamics, other trophic interactions, changing density-damage relations
  - C:N ratios and their effects on insect life cycles and on food consumption. Can investigate many questions using artificial diets.
  - Diapause; what are the implications of reduced diapause?
  - Follow-on impact on natural enemies. Change in insect feeding strategies – greater return for predators. C:N ratio – host – parasitoids, predator, host – longer development time – possible advantages and disadvantages; host – parasitoids – population dynamics.

- Plant Breeding to cope with climate change
  - must take into account potential for changing host/pest interaction.
  - Prioritise best resistance factors for selection of varieties (breeding resistance)
  - Given the C:N drift expected under climate change – how much is host breeding (inadvertently) corrected for this already (given annual/perennial limitations)?

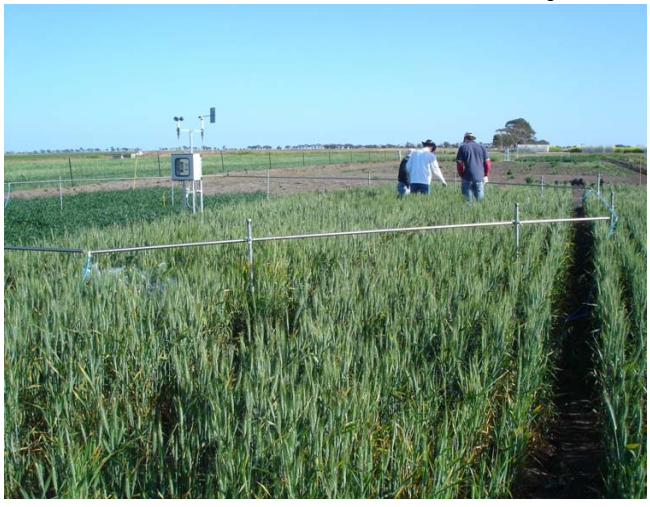
- FACE Facilities
  - Clear opportunities to add value to current FACE activities. Obviously important re canopy and herbivore interactions but equally important in inputs to nutrient cycling in soil communities and feedback loops via plant to pest status.\

- Pollination
  - issues for single species pollination systems eg paw paw. Need to look at pollination that is dependent on insect pollinators under climate change scenarios eg, shifts in distribution etc. Could be a major issue in smaller horticulture crops.

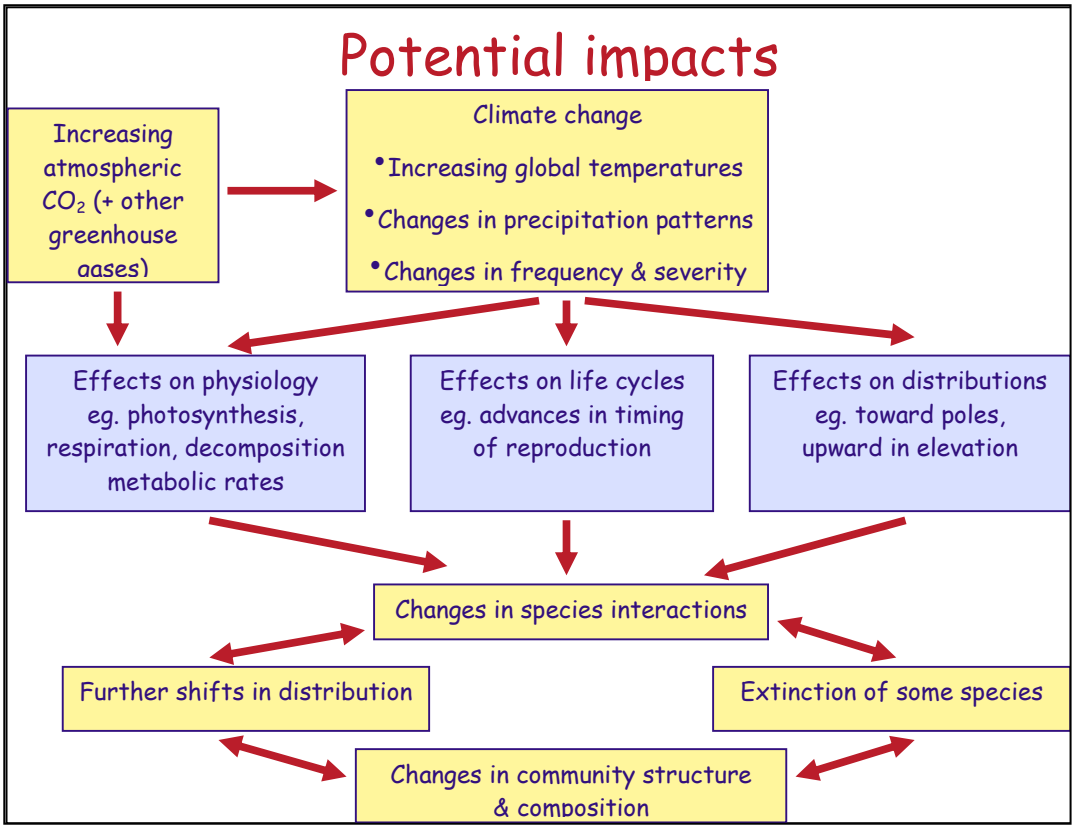
Baseline Species Responses

- Response of key pests to climate change factors.
  - Need enough basic data of key pests to determine variability in responses within a population and range of impacts.
  - Has been too much reliance on limited models – transplantation experiments
  - Opportunities with FACE arrays to examine single species responses
  - Generate baseline data on factors and constraints influencing pest and beneficial distributions and dynamics.
  - Effect of extreme weather events (rainfall, heat, frosts) on key pest and beneficial complexes – need more information and what is the impact?
  - Potential to focus effort on “model species”.
  - What are the relevant scales of reference? What is the importance of scale?

Australian Grains FACE Array



- Use “vanguard” cropping systems (eg cotton in Burdekin, mangoes in Southern WA) as current “transplant experiments” where we could closely study pests and disease communities and interactions.
- Establish efficient monitoring systems to track changes and link to causal factors.
- Need to improve base-line pest/predator dynamics knowledge – to build more effective IPM tools, to feed into climate models.
- Biosecurity threats posed by climate change. Have identified high risk species; cast light on potential distribution?
- Podsuckers moving south in rice.



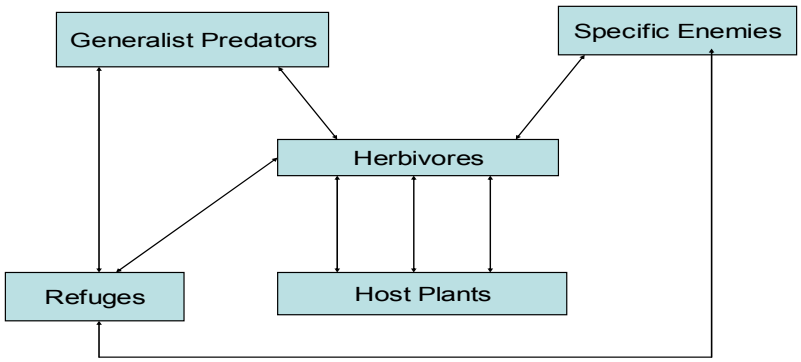
From Nigel Andrew (UNE)

Decoupling Interactions

The workshop noted that a key impact of climate change will be to modify the nature of interactions among trophic levels. These changes are most relevant to IPM. Single species studies of the impacts of changes in temperature or CO2 will not provide relevant information on integrated management needs. A key consideration is to define how interactions of pests with crops, predators with pests etc may be decoupled by differing responses of organisms to climate change.

- Decoupling
  - Of plant/herbivore/beneficials/ disease systems.
  - Does it occur? how significant, how much is it compensated for (because the shifts in species distributions are fluid)?
  - Decoupling of pests/natural enemy insects. How to deal with a variable environment and pest outbreaks.
- Plant – herbivore Interactions
  - Specialist invertebrates may be less tolerant of extreme events, have lower resistance to change?
  - Increase in weedy species or new pests caused by decoupling?
  - Opportunities with FACE arrays to examine species interactions
- Natural enemies
  - Which are the key natural enemies, which are vulnerable? Can we identify model beneficial species for manipulative experiments?
  - Resilience of beneficial populations – when is the system pushed too far? how can it be manipulated to improve abundance and effectiveness of beneficials?
- Landscape Scale Management
  - Effectiveness of maintaining refugia (non-crop, remnant) and maintaining diversity – natural balance. How to manage vegetation for stable, beneficial plants, avoiding community collapse and increased weeds.

Model Species



Need for integration

Small scale experiments → physiological mechanisms underlying ecological responses

Statistical/bioclimatic modelling

Monitoring and understanding patterns in distributions and interactions

Field manipulations including transplants

From Nigel Andrew (UNE)

Systematic Pest Records – Forwards and Back

- Need for national surveillance systems for key pests and beneficials in key cropping systems based on a standardised monitoring and recording system.
- Need for funding to engage grower groups, consultants, research stations in nationally coordinated data collection.
- Consistent long term monitoring of pest abundance and outbreaks has great value for
    - research
    - quantifying impacts of extreme weather events
    - validation of PestFAX/facts databases
    - landholders/ agronomists.
- Could help to encourage more consistent and effective crop monitoring by advisors, then capture input from growers/agronomists for feedback to users with maps and treatment information. Link to a limited number of long-term sites to give trends and detailed info.
- Incentives to report observations
    - Free PDAs
    - On-line reporting forms
    - Provision of pheromone traps
- Limitations
    - Misidentification
    - Lack of reports from some locations
    - Lack of reports on low pest levels
- Challenge of maintaining local quarantine (eg. fruit fly free areas) in the face of increasing pest density and new threats – better monitoring is needed.

Taxonomy and Diagnostics

- Taxonomic support is often invisible in current ecological or field based projects. Needs to be explicitly incorporated into project planning. Need for diagnostics to support field IDs
- How do you identify new and emerging pests for exotic and native insects?
- Lack of expertise for many significant groups
- Clear need for more investment in taxonomic training and research. Need for support for more students - industry support could be provided for ABRS funded taxonomic work.
- Greater need for taxonomic knowledge of exotic pests.

Long Term Monitoring Sites

- Establishment of long term ecological monitoring sites to track changes in relation to climate variability and change
    - Time series data required to identify “extreme” years, which give insights into future climate change scenarios.
    - need to be integrated with sites where research was conducted 20, 30, 50 years ago. Multiple sites across environmental gradients.
    - Might focus on perennials - less susceptible to change in farming practices.
- What is the aim of long term sites?
    - To monitor long term patterns in invertebrate fauna and abundance,
    - To identify new and emerging pests / beneficials,
    - Provide opportunities to understand ecology of pests.
- What sites, when or where?
    - Across all agricultural regions in Australia - 30 sites, sampling spring/autumn
    - Roadsides, native vegetation, pastures, Crops, weeds
- How?
    - Robust in design, but can change if needed,
    - Pitfall traps (ground dwellers), vacuum sampling (abundance data), sticky traps (flying insects).
- Who pays?
    - Link with existing; eg Grain and Graze,
    - Land and Water, NHT; GRDC, CRDC

IPM Tools and Framework

- A broad suite of IPM tools will continue to be essential to cope with challenging climate scenarios and cropping system change:
  - Focus on developing IPM tools with current application but adaptable for changed conditions – strategic tool development eg – monitoring with end point in mind.
  - Ongoing need for Selective pesticides for broadacre crops. Bio-pesticides?
  - More innovative ways to manipulate or manage beneficial species
    - Inundative releases eg. in Horticulture
    - Use of refuge crops for Beneficials
  - Need for improved rearing systems for bio-control agents

- Resistance threats
  - Both GM crops and conventional chemistry at risk
  - May result from increased chemical application used to control sporadic but severe pest outbreaks.
  - Resistance of beneficials vs pests in terms of adaptation to different climates.

- Data sharing
  - Opportunities to share monitoring and distribution data via central database which may provide foundation for early warning systems (eg Macadamia).
  - Need to provide easy methods for capture of data from consultants.

- Training
  - Pest and beneficial training for growers and consultants is essential
  - Support documentation (paper, electronic) – for use in training and in field applications.
  - Development and distribution of Lucid keys as diagnostic tools for a range of target audiences.

- Establishing the elements of an IPM Framework

  - Need a set of IPM guidelines incorporating:
    - a Seasonal activity guide
    - Beneficial disruption index for insecticides – supports selective use of chemical options
    - Agronomy, cultivar/ variety selection as key to minimising potential pest problems
    - Listing and explanation of IPM options – pesticides, bio-pesticides, no-spray options, beneficial conservation and augmentation etc
    - Presentation and justification of Broadacre thresholds
    - Recognition of ongoing gaps in knowledge of EILs and IPM options for some pests e.g. stink bugs.

Models – Development & Validation

- Modelling is the best means to accommodate changing and uncertain scenarios and responses to climate change.

- Need to be highly selective and produce generic models representative of key groups
  - Representative case studies to cover:
    - Variety of feeding guilds
    - Well-studied species
    - Targeted experimentation to fill KEY knowledge gaps ← use models to identify and workshops with stakeholders and experts
  - High profile / impact

- Avoid excessive complexity; focus of the biggest threats and key species

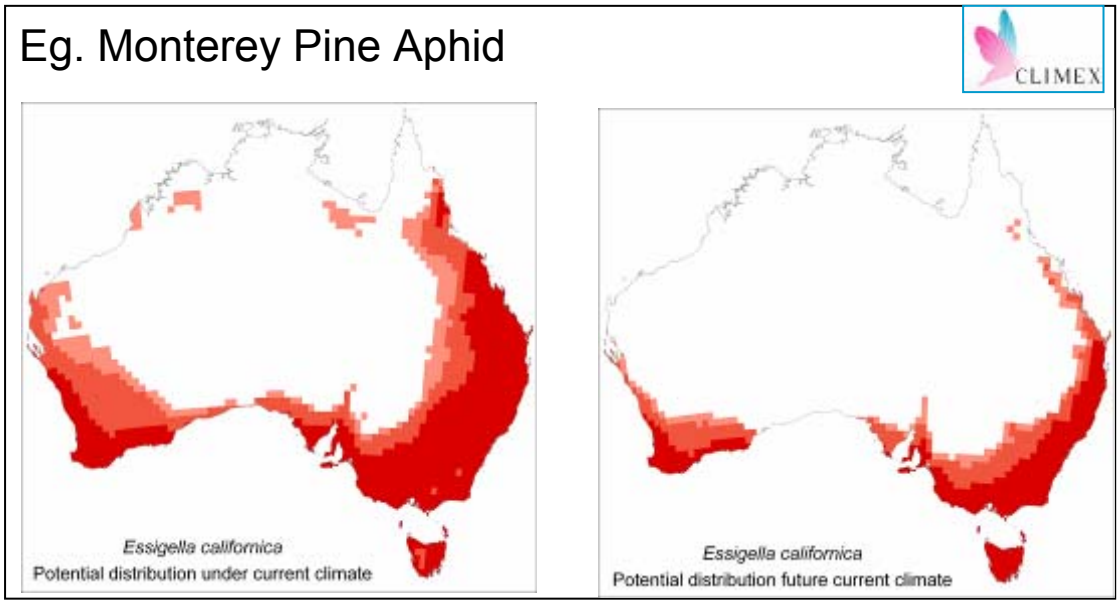
- Define key questions first, then model → define necessary model complexity to incorporate:
  - Potential Distribution
  - Phenology Climate Change
  - Population Dynamics
  - Web-based Biofixes (reality)
  - Forecasting (model)
  - Model Validation – Must do if at all possible!

- Models vs Reality
  - validation of different models is important.
  - Validate models using historical data of pest incidence.
  - Use existing data on past occurrences and abundances to validate models and make predictions.

- More robust bioclimatic models are needed for major pests; including land use changes, edaphic factors, adaptive capacity.

- Historical and current data (rather than new experiments) can be used to validate and improve models

- Models with have widespread application in biosecurity preparedness, monitoring and response.



From Darren Kriticos (CSIRO)

Pest Forecasting

- Forecasting across seasons or years can be a highly valuable application of models
- Can help to identify in which regions/pests will an increase in generation numbers lead to a problem – is this only an issue for grain production in the southern region?
- Southern expansion of current pest distributions, for perennial tree and horticultural crops.

- Can we predict 'worse' years? and respond with changes in crop choice, transgenics, or pesticides.
- Need forecasts in order to modify availability of IPM tools to be prepared for outbreak years
- Useful enhancement of current forecasting capability for highly mobile pests would be to reflect genetic plasticity and adaptive capacity. This would support more flexible management options.

Biosecurity Policy Issues

Many of the questions and approaches for quantifying impacts of climate change in IPM are also relevant to broader biosecurity issues which impinge on the changing likelihood of species introductions, establishment and spread within Australia. While this was not a focus of the workshop, some specific points were made in relation to:

- Changing Market Access due to spread of invasive species into new regions
- Need for "Pathway Analysis" for new incursions to take account of climate change scenarios
- An example - Fruit Fly Exclusion Zones – changed distribution of Dacine flies within Australia

Possible Approaches and Research Responses

The themes and issues were considered in more detail by small groups who identified the type of activities required to address them, and some specific actions that NIPI could take. These are prefaced by a high level overview of Drivers and the fit of IPM science and extension.

Drivers (Vision, ROI & Food Production) - Ary Hoffman

What are the Drivers for IPM in a climate changed world?

- Government policy - State and Federal
- Industry - Market access (Sustainable Food Production)
- Public perceptions - "Clean and Green", "Cultural", "Local", "Quality perception"
- International (Includes international protocols).
- Land use constraints.
- Waste reduction, food miles.

How is Pest Management influenced by these Drivers?

- They place boundaries on control options; Methyl Bromide, Pesticide residues (Codex, APVMA),
- Places boundaries and creates opportunities for landscape level changes
- Introduces a requirement to consider carbon footprints
- Changed expectation of product quality.

R & D Investment

- Long term market access to provide return on investment (Brad Wells, Industry).
- Core level of funding across research groups working from the genetic level to the community level to develop innovative tools for understanding pest complexes under climate change.

Changing Production Systems – presented by Peter Gregg

Key points:

- Water intensive crops go where water is, so what are the pest implications?
- Vanguard crops – pioneer farmers; what pest problems do they have?
- Drought tolerant crops and varieties including GM – how do pests interact with them?
- Move to protected systems e.g. glasshouses for crops.
- If products are pricey due to shortages, then more expensive IPM techniques may be feasible.

Recommendations

4. NIPI to coordinate pest and disease records from Vanguard crops / satellite areas

5. Commence a focus to identify best practices for protected systems [jointly with Horticulture?]

6. NIPI to provide a conduit for information on climate change research funding available through government or industry – perhaps coordinate applications for funding?

Pest Forecasting – presented by Peter Gregg

Key Points

1. Why Forecast? Forecasting is the acid test of our understanding of pest dynamics and interactions across differing temporal and spatial scales
2. Forecasting may have practical value:

   a. Alerting crop scouts
   b. Ordering of Insecticide stock
   c. Making Planting decisions (e.g. Bollgard cotton or not),
   d. Incidence vs damage e.g. reject levels in horticultural (historical data available).
3. Forecasting models will become a reference point for climate change.
4. Hindcasting will assist in model validation.

Recommendations

4. NIPI to coordinate national monitoring networks of pest or climate information {SOI] or cropping information [crop/host areas for several pests etc]

5. NIPI to prioritise needs for pest forecasting

6. Provide extension and education on the limitations of a forecasting system, especially when it is being developed.

Systematic Records – presented by Peter Mangano

Recommendations

3. NIPI to support experienced staff to database information from accumulated records in Departmental files

4. Provide incentives for more systematic reporting from wide network of participants – including professional consultants, researchers, agronomists.

Taxonomy – presented by Murray Fletcher

Recommendations

3. Incorporate taxonomy into project planning for ecosystem level diagnostic systems; involving Barcoding, User Friendly keys, Internet based tools

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Long Term Monitoring Sites

Recommendations

4. Explore mechanisms to establish long term monitoring sites where patterns of invertebrate fauna and abundance can be robustly recorded.

5. Consider establishing 30 long-term sites across all agricultural regions to incorporate crops, pastures, weeds, roadsides, native vegetation – to be sampled spring and autumn

6. Integrate a network of long term sites with other activities – Grain and Graze, LWA, NHT, NCRIS, GRDC, CRDC, RIRDC, CRCs

Establishing a Functional IPM Framework – presented by Melina Miles

Recommendations

1. Provide mechanisms for ongoing capability development and training of students, advisors and researchers.
2. Establish mechanisms for national data sharing of data collected using agreed and robust techniques
3. Identify gaps in IPM knowledge and target with research or students
4. Develop a set of IPM Guidelines for grains [modelled on the Cotton IPM Guidelines] to provide a training and reference tool

Opportunities from Modelling – presented by Darren Kriticos

Recommendations

4. Conduct Modelling workshops for high impact and priority species
5. Conduct case studies for key pests to evaluate models by validating against historical data
6. Develop web-based models for forecasting and capture of pest occurrence data from producers.

Appendix 1 Key Points from Presentations

Predictions under climate change: evolving beyond climate envelopes

Ary Hoffmann, CESAR, University of Melbourne

Distribution shifts under climate change

Ability of species to TOLERATE - MOVE – EVOLVE

- Tolerate: depends on acclimation ability, acclimation costs
- Move: depends on empty space, biotic interactions, dispersal ability,
- Evolve: depends on genetic variation, generation time, selection

Nature of the ENVIRONMENTAL CHANGES

- Changes in climate
- Changes in management practices
- Human adaptation

Predicting distribution changes

Climate envelope (BIOCLIM, CLIMEX) Regression models

- Tolerate (partial)
- Move (perfect)
- Evolve X
- Management changes and human adaptation X

Mechanistic models

- Tolerate (potentially)
- Move (potentially)
- Evolve (potentially)
- Management changes and human adaptation (potentially)

Climate Change: farming in an even more sunburnt country

Steven Crimp, Mark Howden, Rohan Nelson, Kevin Hennessy et al (CSIRO)

Evidence for climate change

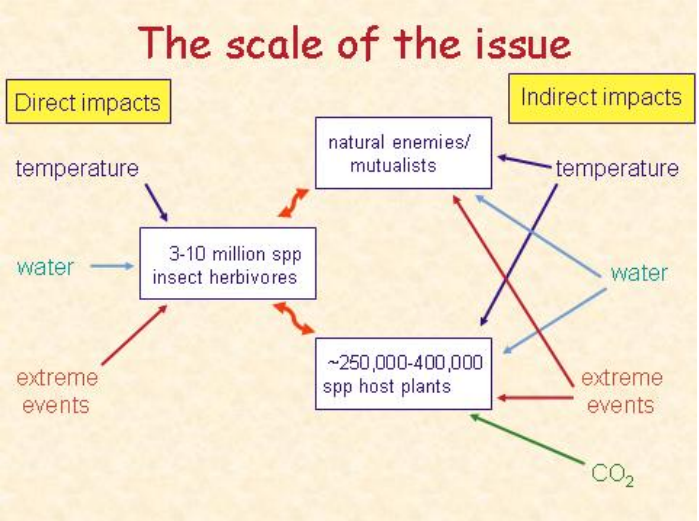
- Global warming of 0.7°C and sea-level rise of 17 cm since 1900
- Past 11 years are amongst the 12 warmest years since 1850
- Warming of the upper 3000 m of ocean
- Warming in the lowest 8 km of atmosphere similar to surface warming
- More intense cyclones in North Atlantic since 1970, but no clear trend in numbers
- Oceans have become more acidic due to higher carbon dioxide
- Glaciers and Arctic sea-ice have decreased, but little change in Antarctic sea-ice
- Shifts in plant and animal locations and behaviour

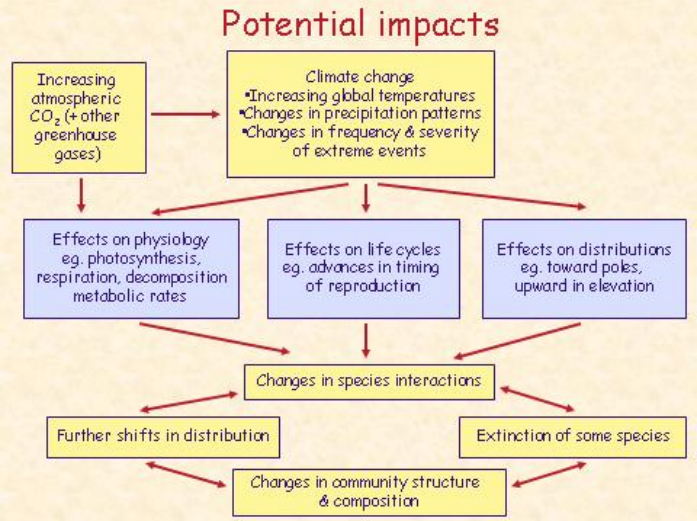
Potential impacts - Agriculture

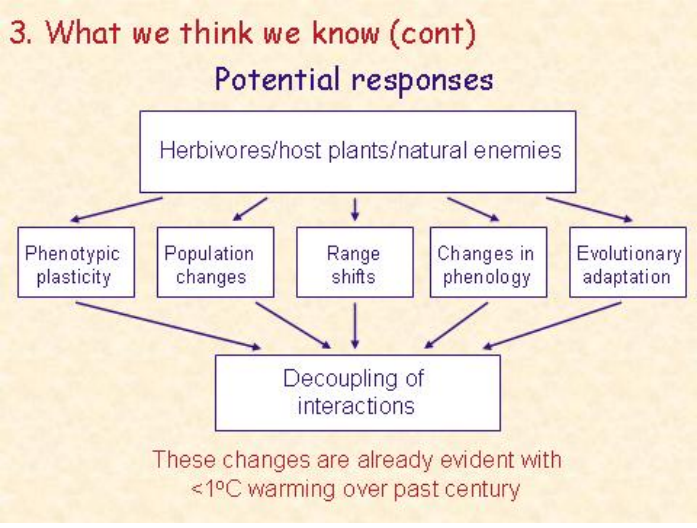
- Southern Australian regions are likely to experience mean yield reductions but greater variability by 2070.
- In the north, warming trends have already reducing frost risk and may allow early plantings to offset heat stress.
- Grain quality is likely to be affected, through CO_2 fertilisation impacts on C:N ratio.
- Glyphosates may be less effective under elevated CO_2 - weed control challenge.
- CO2 rise likely to increase pasture growth, particularly in water-limited environments.
- Potential distribution and abundance of exotic weeds and native woody species is likely to change.
- Increased heat stress on animals is very likely although less cold-stress is likely to reduce lamb mortality.
- Pests may become a more difficult to manage, however significant uncertainty surrounds this due to limited data.

Impacts of future climate scenarios on insect community structure and dynamics/Lessons from natural ecosystems *Nigel Andrew* (UNE)

1. The scale of the issue
2. What we know
3. What we think we know
4. What we'd like to know
5. Where to from here?







Climate change impacts on invertebrates: Ecological and physiological process. *Darren Kriticos* (CSIRO)

Outline

Insect distributions

- Range constraints
- Range extension polewards and in altitude of pests already present in a given country
- Arrival & establishment of new pests that could previously not persist (too cold, etc.)

Population dynamics

- Increased damage due to faster development and reproduction with increased temp
- Reduced tree resistance to pests (drought stress)
- C:N ratios
- Phenology and number of generations
- Complications with diapause
- Human adaptations

Conclusions

- Impacts on silviculture, agriculture, horticulture and pastoralism could be profound
- Pests, disease and weeds will shift their potential ranges
- Existing pest problems may intensify
- C:N changes could increase or decrease pest problems - Big unknown!!
- Look to warmer sites in the north to identify future pests and pest management techniques

Potential impacts of climate change on IPM in Southern/Western Grains Systems *Michael Keller*, School of Agriculture, Food & Wine, The University of Adelaide and *Peter Mangano*, Department of Agriculture and Food Western Australia

What practical measures can be made to manage pests of these crops as climate changes?

- What pests attack these crops?
- How might climate change affect them?
- Practical responses to climate change:
  - Statistical forecasting models
  - Improved IPM systems

Statistical forecasting models

- Problem: long time series of abundance data are not available for most pests
- PestFax / Pest Facts provide an alternative to long time series
- Use statistical modelling to forecast the risk of pest damage
  - Maelzer and Zalucki (1999) *Helicoverpa* spp. in Australia
  - Worner et al. (2002) neural networks to forecast aphid flights in New Zealand
- Prioritise pests based on distribution, frequency & adequacy of control

Improved IPM Systems

- IPM programs are flexible and responsive to changing circumstances
- Develop and promote standardised sampling and reporting practices so the quality of data improves
- Use regional reporting data to update and improve the accuracy of pest forecasts
- Well developed IPM systems with regional integration offer the best practical response to climate change

Australian Grains FACE Array - Examining the effects of elevated CO_2 on key wheat pathogens and vectors

Jo Luck (Victorian Dept of primary industries)

Rising Co2 and Plants

- Higher crop yield under elevated CO2 in chambers (C fertilisation)
- Greater water-use efficiency due to partial closing of stomata under high CO2
- Changes to C:N ratio
- Increased waxes and terpenoids - physical and chemical resistance
- Increased surface area
- Less well understood how increased CO2 interacts with light, temperature, soil and other environmental factors
- Little consideration to effects of pests and diseases on crops under enriched CO2
- Lower than expected crop yield under enriched CO2 in FACE (Long *et al*, Science 2006)

Enriched CO2 and insects

- Relatively little experimental evidence of the direct effects of CO2 on insects (Bale *et al*., 2002, Stiling and Cornelissen, 2007)
- Increasing food consumption rates to compensate for lower food quality, "compensatory feeding" (Hunter, 2001)
- Diminished escape response in aphids in the presence of alarm pheromone under high CO2 (Mondor *et al*, 2004)

Horticulture Systems: potential impacts of climate change on IPM

Nancy Schellhorn, CSIRO Entomology, *Mike Furlong*, University of QLD, *Andrew Jessup*, NSW DPI, *Peter Deuter*, QDPI&F, *Sandra McDougall*, NSW DPI

What's being done in AUS in relation to horticulture IPM and climate change?

Horticulture generally

1. Scoping study HAL – P. Deuter QDPI&F – climate change and variability
2. Current HAL (AH06019) – P. Deuter QDPI&F – identifying most vulnerable regions & potential for tools to manage climate variability
3. Literature review DPI VIC – J. Aurambout et al – climate change on plant biosecurity

IPM Specifically

NOT MUCH

What are the key questions and where could we go from here?

1. Generate Scenarios
   - Systems w/ detailed biological information
   - (Hort / Cotton / Grains)
   - Run simple pop'n models & attach to real places
2. Depending on outcomes of Scenarios:
   - Consider management options – can we implement = adapt

3. Establish Long Term Ecological Research Sites (LTERs)
   - Marginal Areas where change is expected

Global Climate Change: Impact on Cotton Production system in Australia. *Robert Mensah* (NSW DPI) and *Lewis Wilson* (CSIRO)

Climate change and variability

- Temperature x rainfall drives the system
- Temperature - determines rate of development
- Rain – determines what there is to develop on (hosts) and distribution
- Strong evidence from seasons we have already experienced

Some observations…..

- Similar pests in cotton from Ord to Hillston
- Similar beneficials in cotton from Ord to Hillston – many generalists
- Species broadly adaptable – temperature and humidity

Some scenarios?

Higher temperatures and Wetter Years (eg 98-99)

- Winter rains – abundant winter weed hosts – high overwinter survival
- Summer rains – weed hosts plus cropping = pest build-up
- Challenges - Weed control, Pest abundance, secondary pests
- Outcomes - Insecticide and weed resistance ↑, Pressure on Bt resistance, High cost, low yield and quality

Higher temperatures and Dry Years (eg 05-06)

- Low host availability = few crops or weeds
- Poor local insect build up
- Migratory species (Helicoverpa / mirids) – pops from cotton regions and elsewhere
- Weeds ↔ winter control (good); summer control (easier)
- Diseases ↔ lower risks
- Conditions conducive to high yields/low costs

Potential effects of climate change on rice IPM systems in Australia
Mark Stevens (NSW DPI)

What will happen with our current pests?

- Warmer winters will improve survival of overwintering stages (especially stink bugs)
- 1°C increase in winter temperatures improves stink bug survival by 15%
- Bigger populations earlier in the crop
- Some pests (bloodworms) less likely to be seriously affected

Quarantine Threats

- Major threat species: Golden Apple Snail, Rice Water Weevil, Khapra Beetle
- All three capable of survival here at present
- Damage potential of all 3 (esp. Khapra beetle) greater under warmer conditions

Southwards Movements – what to expect

- Rice in northern Australia had many pests not known to occur in NSW
  - brown planthopper, paddy bug, green leafhopper
  - assorted lepidopteran pests
    - *Nymphula depunctalis* (caseworm), *Cnaphalocrocis medinalis* (leaf folder), *Chilo* spp. (stemborers), *Parnara* sp. (rice skipper)
- Warmer temperatures will facilitate expansion of ranges southwards – although low humidity may be a constraint.