


# Impact of Climate Change on weeds, pest, diseases and others and Crop Improvement

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# Outline

- Introduction
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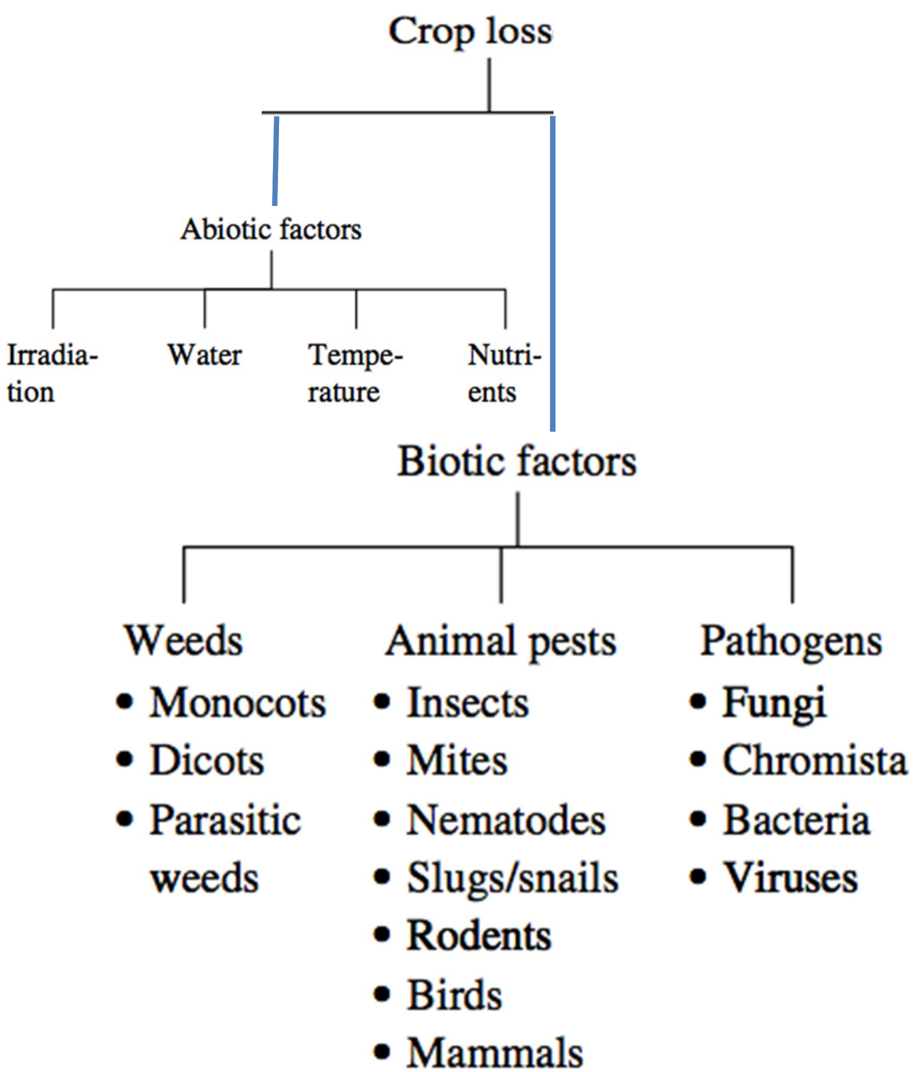
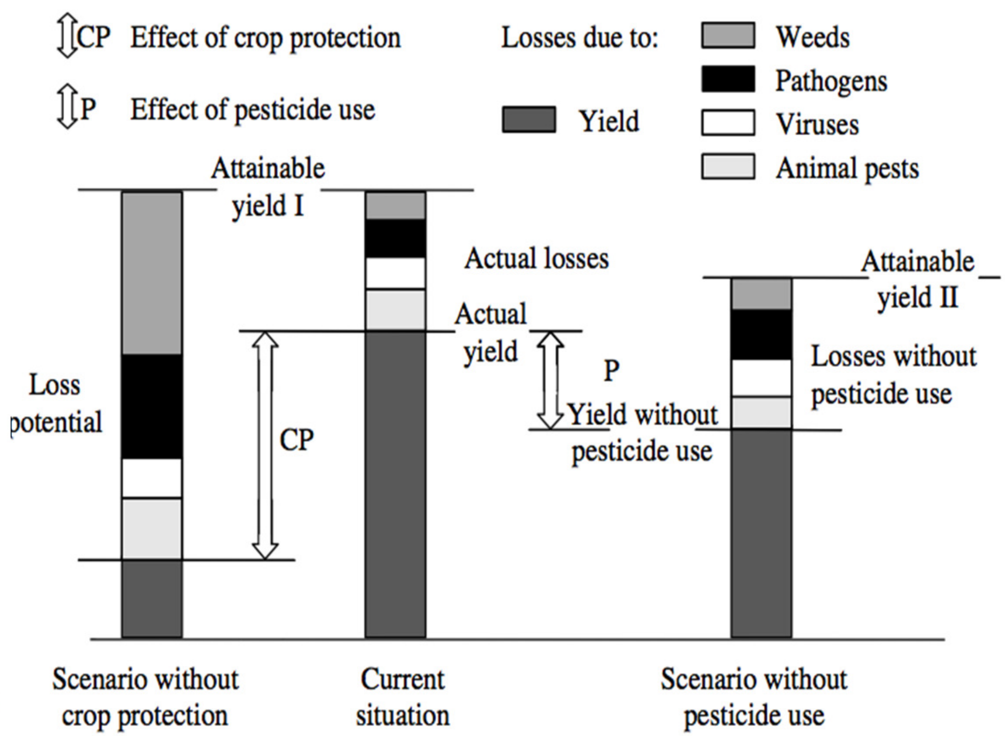
- Impacts of Climate Change on Pests
- Impacts of Climate Change on Diseases
- Adapting to Climate Change
- Crop Improvement
- Conclusions & Future directions

# Introduction

- climate change affects Agriculture
- Agro-ecosystem : crops / pests / Natural enemies / others
- Diseases and insect pests damage : ~42% loss in 8 important food and cash crops ~300 billion $
- Climate change influences the ecology of weeds, pests and disease, with possible implications for crop protection and pesticide use.

# Abiotic and biotic factors causing crop losses




Oerke, 2006

# CLIMATE CHANGE AND WEEDS

46 major crops but, over 410 "troublesome" weed species

# WEEDS

- Short life cycles - High reproductive rates - Rapid response to rainfall events - Adapted to a wide range of environments & soil – "struggle for existence"
- Compete with crops for nutrients, water, light
- Impact: Reduces yield & quality/inhibit harvest.
- Health problem (poisonous plants, allergens)

Climate change affect weeds as much as crops

- Higher CO2 : stimulate photosynthesis and growth, reduce ET and increase WUE
- Competitive : greater genetic variation / physiological plasticity / may gain more advantages from climate change than crops
- Possess many pre-adaptations at the molecular, biochemical or whole plant level to respond more positively to CC



# Impacts of Higher Temperature

- Offset benefits of elevated $CO_2$ (Bunce & Ziska 2000).
- Allow sleeper weeds to become invasive
- Expansion of weeds into higher latitudes or higher altitudes
- Very aggressive weeds that are currently found in the lower latitudes are limited in the higher latitudes
- Itchgrass, a profusely tillering, robust grass weed could invade the central Midwest and California with a 3° warming trend (Patterson, 1995).



# Impacts of Precipitation

- Response to drought in agronomic conditions is dependent on species and cultural conditions.
- Any factor which increases environmental stress on crops may make them more vulnerable to attack by insects and plant pathogens and less competitive with weeds (Patterson, 1995).

# C4 weeds in C3 crops

- 14 of the world's worst weeds are C4 plants
- 76% of the harvested crop area is with C3 crops
- **Hypothesis**: C3 crops would benefit more from elevated CO2 than C4 weeds, losses due to C4 weeds might decrease. Patterson & Flints (1980), Coleman & Bazzaz (1992) and Ziska (2003).
- **Research gap** : Temperature increase /drought in combination with elevated CO2 trends are not clear (Fuhrer 2003, Bunce & Ziska 2000).
- Optimal temperatures for growth in C4 plants are generally higher than optimal temperatures for C3 plants (Flint & Patterson 1983), but with higher CO2 the optimum temperature of many C3 plants also increases (Bunce & Ziska 2000).
- In drought situations C4 weeds might also have advantages over C3 crops under elevated CO2 (Ward et al. 1999).

# *C3 weeds in C4 crops*

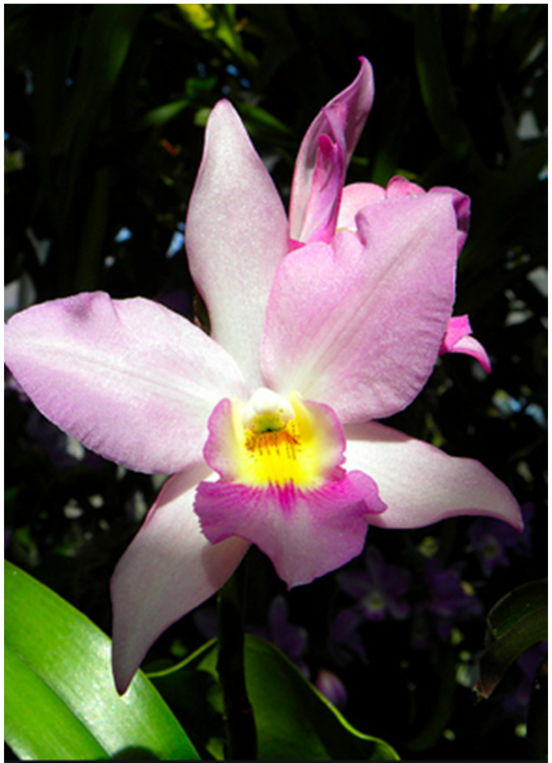
Elevated CO2 under sufficient water condition will lead to higher C3 weed competitiveness in C4 crops.

At elevated CO2, seed yield or total above ground biomass of sorghum was significantly reduced by C3 weeds (Ziska 2003).

C3 weed dandelion (Taraxacum officinale) produced more fertile seeds and larger seedlings under elevated CO2 (McPeek & Wang, 2007).

C4 crops might out-compete better growing C3 weed i drought situations (Tang et al. 2009).

# *C3 weeds in C3 crops & C4 weeds in C4 crops*



- Logic : Same type of plants in the same ecosystem would react to changes in environment a similar way. But, the magnitude differs.
- Biomass accumulation from CO2 doubling in crops: +31% in wheat, +30% in barley, +27% in rice, +39% in soybean, +57% in alfalfa, and +84% in cotton.
- Biomass accumulation from CO2 doubling in C3 weeds: 79% to 272% compared to ambient CO2 (Patterson 1995).

# Invasive Weeds

- Introduction:  Warming polar regions will see increased traffic and new invasives.
- Colonization: More frequent or severe storms provides opportunities for establishment of new invasives.
- Distribution:  Many invasives are range-limited by cold temperatures.
- Management:  Chemical control of invasive plants can be altered with rising CO2 / climate

# Response of some C3 and C4 weeds to doubled CO2

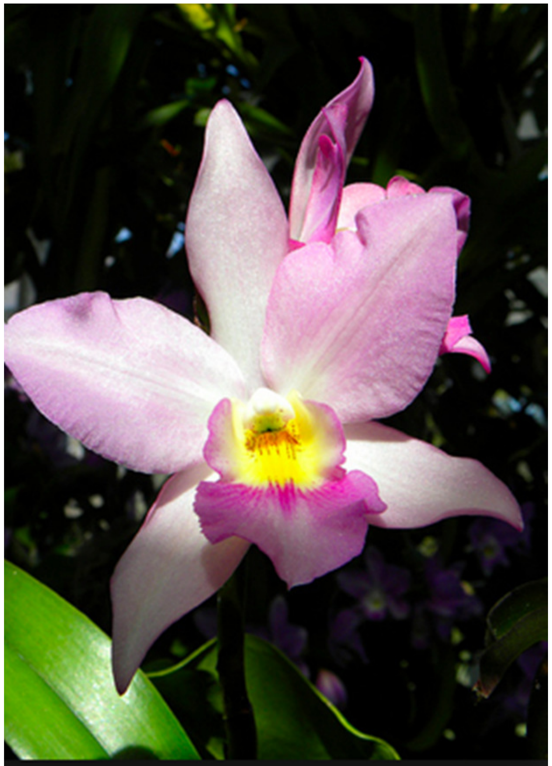
| $C_3$ species | Range of response (x growth at ambient) | | $C_4$ species | Range of response (x growth at ambient) | |
|---|---|---|---|---|---|
| | Biomass | Leaf area | | Biomass | Leaf area |
| *Abutilon theophratsii* | 1.0-1.52 | 0.87-1.17 | *Amaranthus retroflexus* | 0.9-1.41 | 0.94-1.25 |
| *Bromus mollis* | 1.37 | 1.04 | *Andropogon virginicus* | 0.8-1.17 | 0.88-1.29 |
| *Bromus tectorum* | 1.54 | 1.46 | *Cyperus rotundus* | 1.02 | 0.92 |
| *Cassia obtusifolia* | 1.4-1.6 | 1.1-1.34 | *Digitaria ciliaris* | 1.06-1.6 | 1.04-1.66 |
| *Chenopodium album* | 1.0-1.6 | 1.22 | *Echinochloa crus-galli* | 0.95-1.6 | 0.95-1.77 |
| *Datura stramonium* | 1.7-2.72 | 1.46 | *Eleusine indica* | 1.02-1.2 | 0.95-1.32 |
| *Elytrigia repens* | 1.64 | 1.3 | *Paspalum plicatum* | 1.08 | 1.02 |
| *Phalaris aquatica* | 1.43 | 1.31 | *Rottboellia cochinchinensis* | 1.21 | 1.13 |
| *Plantago lanceolata* | 1.0-1.33 | 1.33 | *Setaria faberii* | 0.93-1.35 | 1.0-1.4 |
| *Rumex crispus* | 1.18 | 0.96 | *Sorghum halepense* | 0.56-1.1 | 0.99-1.3 |

Patterson, 1985

# Potential impacts of climate change on weeds significant to agriculture in southern Australia

| Weed | Impact |
|---|---|
| Blackberry | Expected to retreat southwards and to higher altitudes because it is sensitive to higher temperatures and drought |
| Chilean needle grass | Expected to increase its range because it is highly invasive (long lived, seed dispersed by wind and water) and drought tolerant |
| Gorse | Expected to retreat southwards because it is drought sensitive. |
| Lantana | Expected to continue its move southwards into high-rainfall zones of northern New South Wales |
| Mesquite | Some risk that it may move into lower-rainfall areas because it is very drought tolerant. |
| Parthenium | Not suited to winter-dominant rainfall areas. May move into summer-dominant, higher-rainfall (>500 mm) regions. |
| Serrated tussock | Expected to retreat southwards and to higher altitudes because it is sensitive to higher temperatures.<br>As a drought-tolerant plant, it should become more invasive in areas where temperature allows. |
| Prickly acacia | Expected to move southwards and into arid areas. |

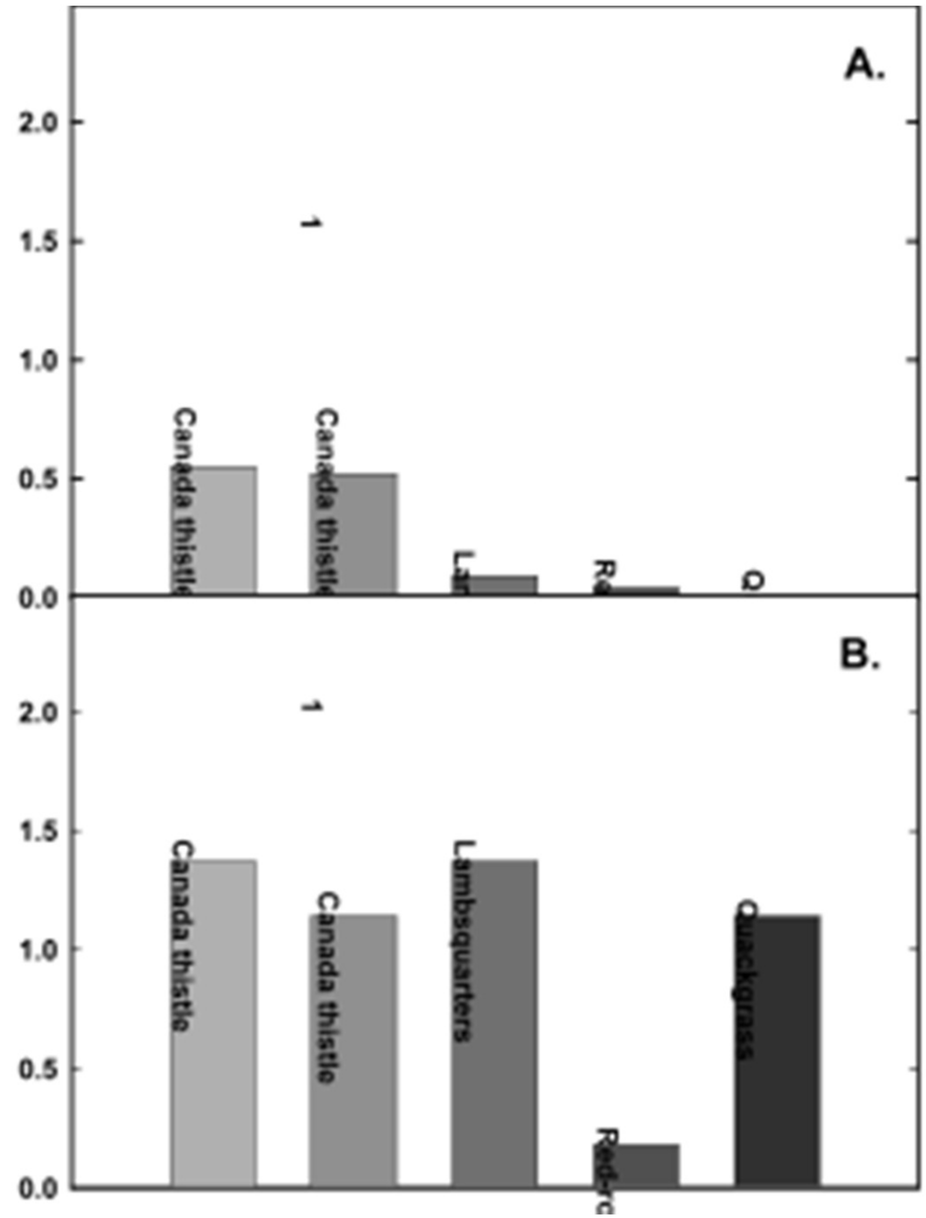
CSIRO and the Bureau of Meteorology 2007, Climate Change in Australia, a report, CSIRO, Canberra. http://www.climatechangeinaustralia.com.au



# Weed control

- The Differential effects of $CO_2$ and CC will alter the weed-crop competitive interactions
- Changes in temp, precip, wind and humidity may affect the effectiveness of herbicides
- Climate models can predict the likely impacts on the future distribution of weeds (management)
- Greater increase in biomass will result in dilution of herbicide applied, making weed control more difficult and costly (Patterson, 1995)
- Due to change in anatomical, morphological and physiological changes - increase leaf thickness, reduce stomatal number and conductance that possibly limited uptake of foliar applied herbicide

# $CO_2$ impact on herbicide efficacy


**As carbon dioxide increases, glyphosate efficacy is reduced**

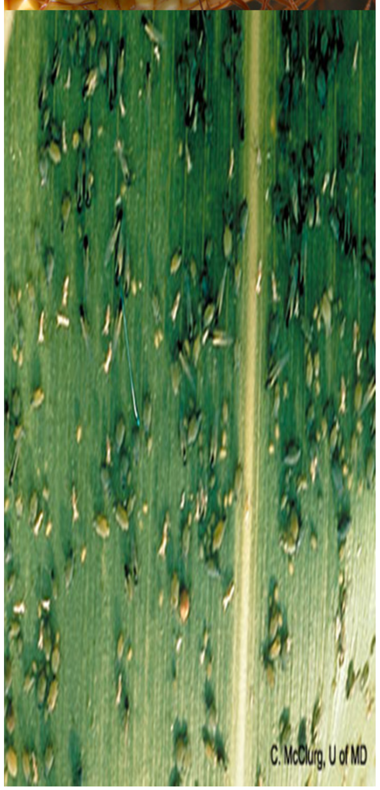
Herbicide Efficacy is reduced. The basis for the reduction is not entirely known. However, if more pesticides are needed to kill weeds, then more trace chemicals are likely in the environment.

# CLIMATE CHANGE AND PESTS

Globally 360,000 insects species, mainly live from plant material.
Damage by chewing on plant tissues / sucking the plant sap / transmit viruses.

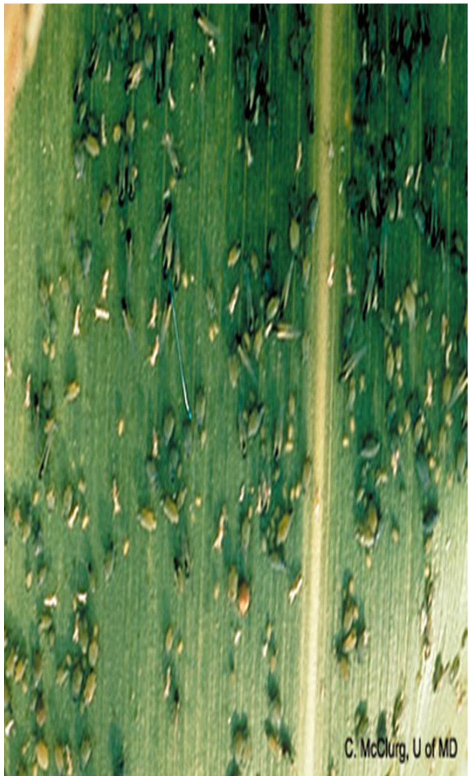
# Drivers

- **higher temperature** may be more favourable for the proliferation of insect pests (longer growing seasons, higher possibility to survive during winter time)
- **Enhanced $CO_2$** may affect insect pests through amount and quality of the host biomass (higher consumption rate of insect herbivores due to reduced leaf N)
- **Altered wind patterns** may change the spread of both wind-borne pests and of bacteria and fungi
- **Increased frequency of floods** may increase outbreaks of epizootic diseases (i.e. African Horse Sickness)




# CC and insect pest on crops

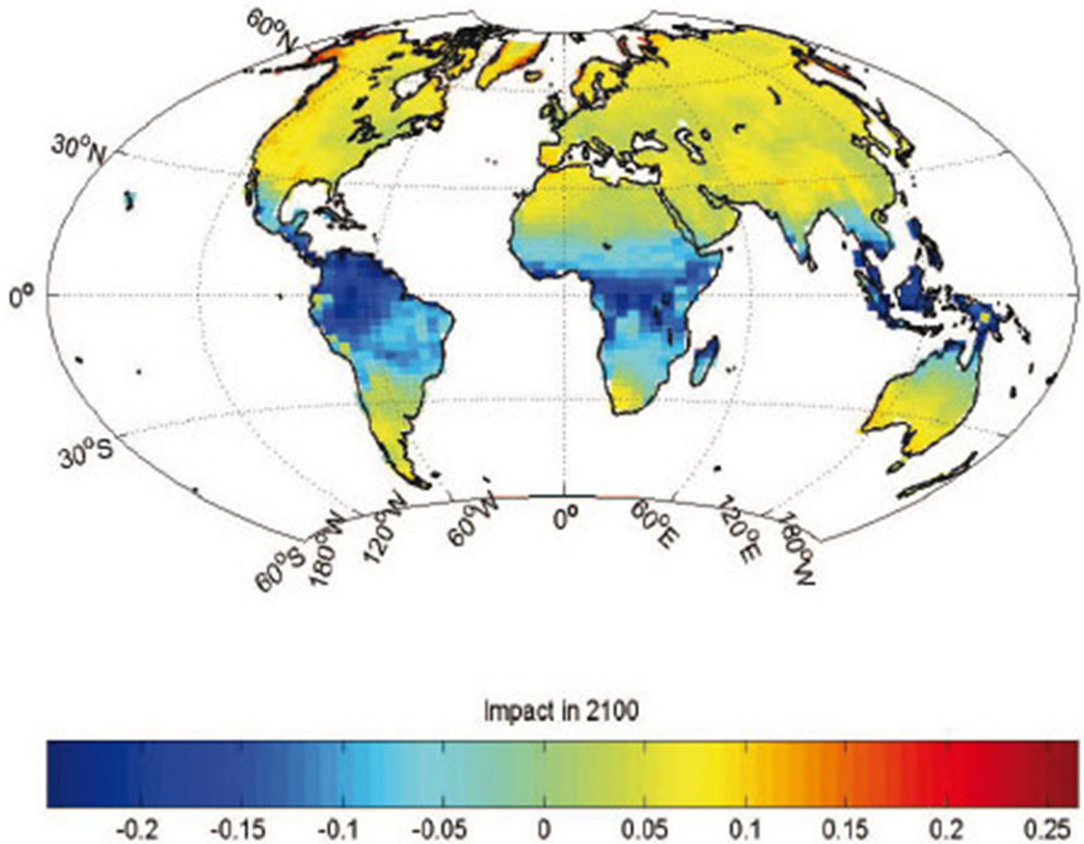
- Herbivory :
  - Global warming will increase insect herbivory (Price, 2002).
  - In contrast, Fajer (1989) argues that an enriched $CO_2$, leading to low plant quality, will reduce herbivore densities and increase the probability of extinction.
- Insects are ectothermic, very sensitive to temperature, and cannot sustain living below and above certain thresholds.
- Global warming might benefit many insect species in the temperate regions
  - Changes in geographical distribution
  - Increased overwintering
  - Changes in population growth rates
  - Increases in the number of generations
  - Extension of the development season
  - Changes in crop-pest synchrony
  - Changes in inter-specific interactions and increased risk of invasion by migrant pests




# CC and insect pest on crops

- Many tropical insect species may become extinct as they are already living at environmental temperatures close to their optimum
- Reduced nutrient quality of C3 plants might lead to a compensation by increased feeding of many insects (Lincoln et al. 1986, Whittaker 1999, Emmerson et al. 2004, DeLucia 2008, Barbehenn et al. 2004).
- Population densities of chewing insects would be unaffected or decrease, but do not increase while sap sucker population densities might increase under increased CO2 concentrations (Whittaker, 1999)

# Predicted impact of global warming by 2100 on insect species




Deutsch et al. (2008).

**Positive impacts (positive values) are displayed yellow to red, while negative impacts (negative values) are shown in blue**

***Nematodes***

- **Severe droughts resulting in a reduction of soil water will negatively affect soil nematodes.**
- **Higher average temperatures will probably have little effect, since thermal conductivity of soils is low (Larcher 2001).**

# Expected responses of Heteroptera species and communities under two scenarios of further climate change

| Categories of responses | Slight temperature increase (<2°C) | Substantial temperature increase (>2°C) |
|---|---|---|
| Distribution range | Likely to shift in some species, especially those capable of long-distance flights and associated with ornamental plants and/or urban habitats | Likely to shift in many species |
| Abundance | Likely to increase in multivoltine species with flexible life cycles | Likely to change, depending on the community response |
| Phenology | Slight to moderate advance of early-season events | Substantial advance of early-season and some delay of late-season events |
| Voltinism | An additional generation in some multivoltine species with flexible life cycles | One or more additional generation(s) in some multivoltine and univoltine species (with facultative diapause) |
| Physiology and behaviour | Slight/ undetectable changes | Evident/detectable changes (e.g. in parameters of photoperiodic responses) |
| Community structure | Similar to currently observed | Increased species richness; substantial changes in structure |

## Increased $CO_2$ effects depend on insect-plant interaction

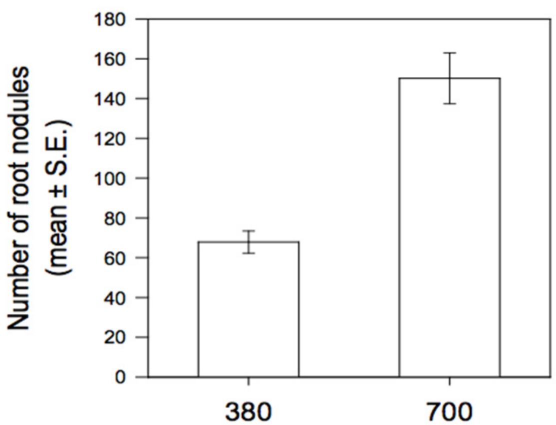
- **Increased carbon : nitrogen ratio in plants makes for poorer forage for insects**
- **Shift in plant defenses :** *Fewer toxins, tougher leaves, more tannins/ phenols*
- **Deficiencies in micronutrients**
- **Help for insects:**
  - *Nitrogen addition can make for better forage*
  - *Shift in plant defenses from nitrogen to carbon based*
  - *Consume more plant to make up for less nitrogen*

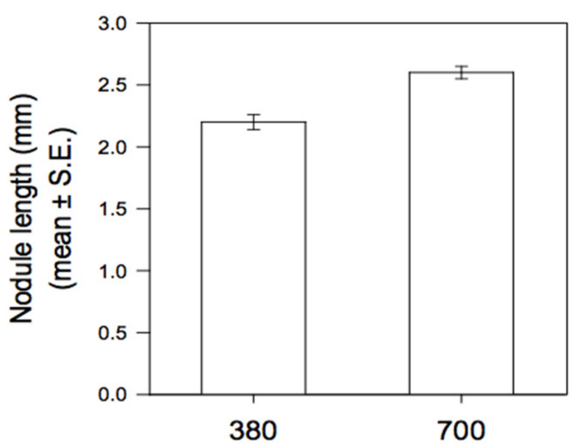
R. Srygley ,USDA

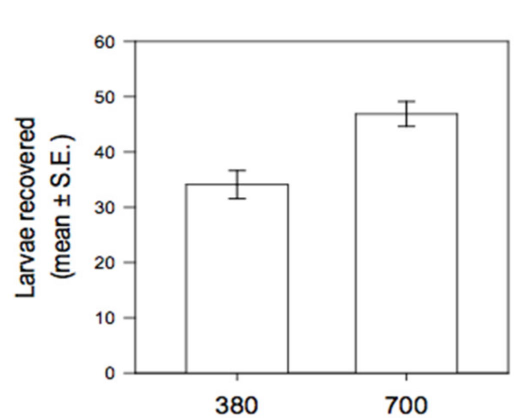
# Non-crop pests could have an impact on arable rotations

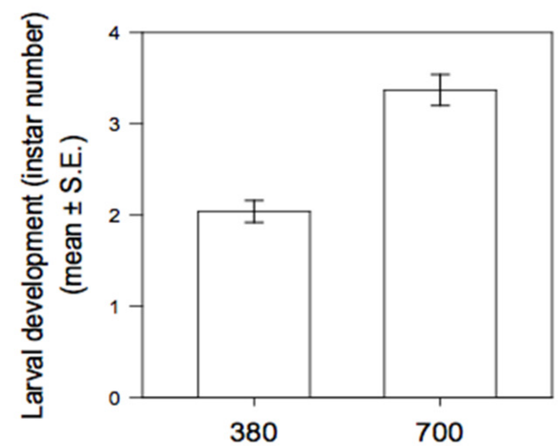
- Elevated $CO_2$ - increased N fixation in legumes
- Numerous and bigger root nodules = more N fixed

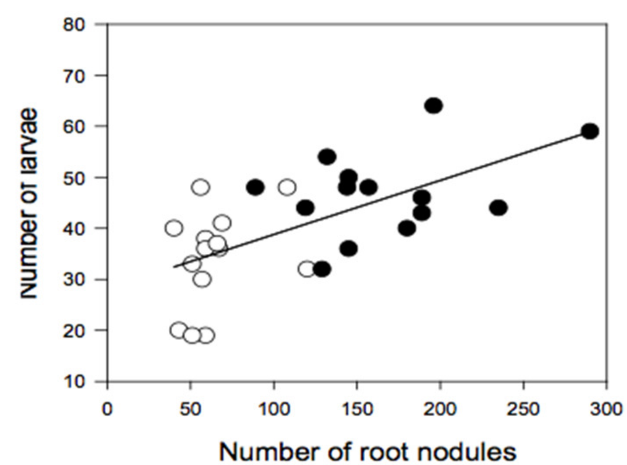
- Elevated $CO_2$ - results in more weevils
- more root nodules - a surge in root pests
- *Sitona* spp. weevils – new born stages specifically target root nodules



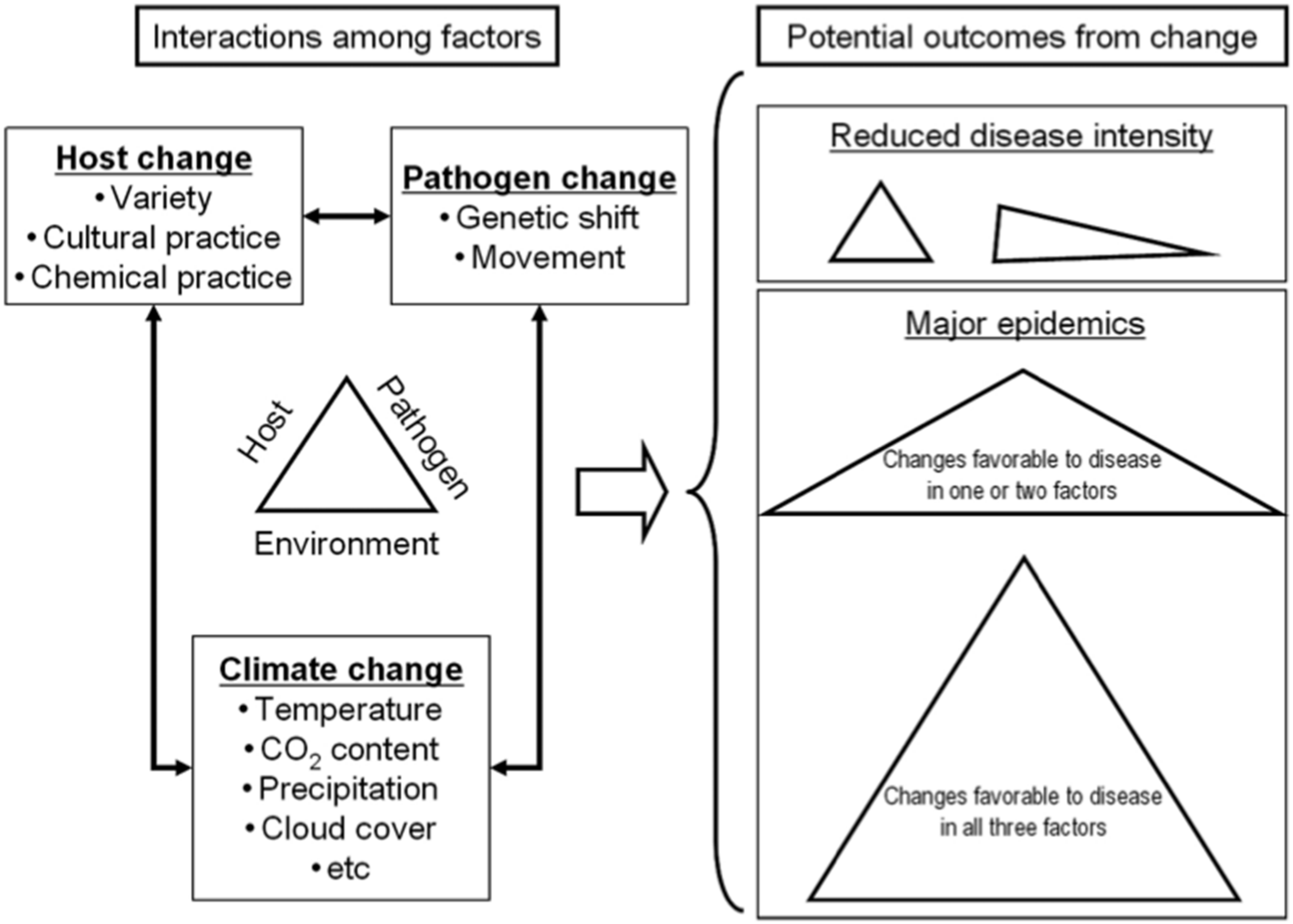




(Soussana & Hartwig, 1996; Zanetti *et al.*, 1996; Hungate *et al.*, 1999)

# CLIMATE CHANGE AND Diseases

# Interactions among components of the disease triangle and potential outcomes



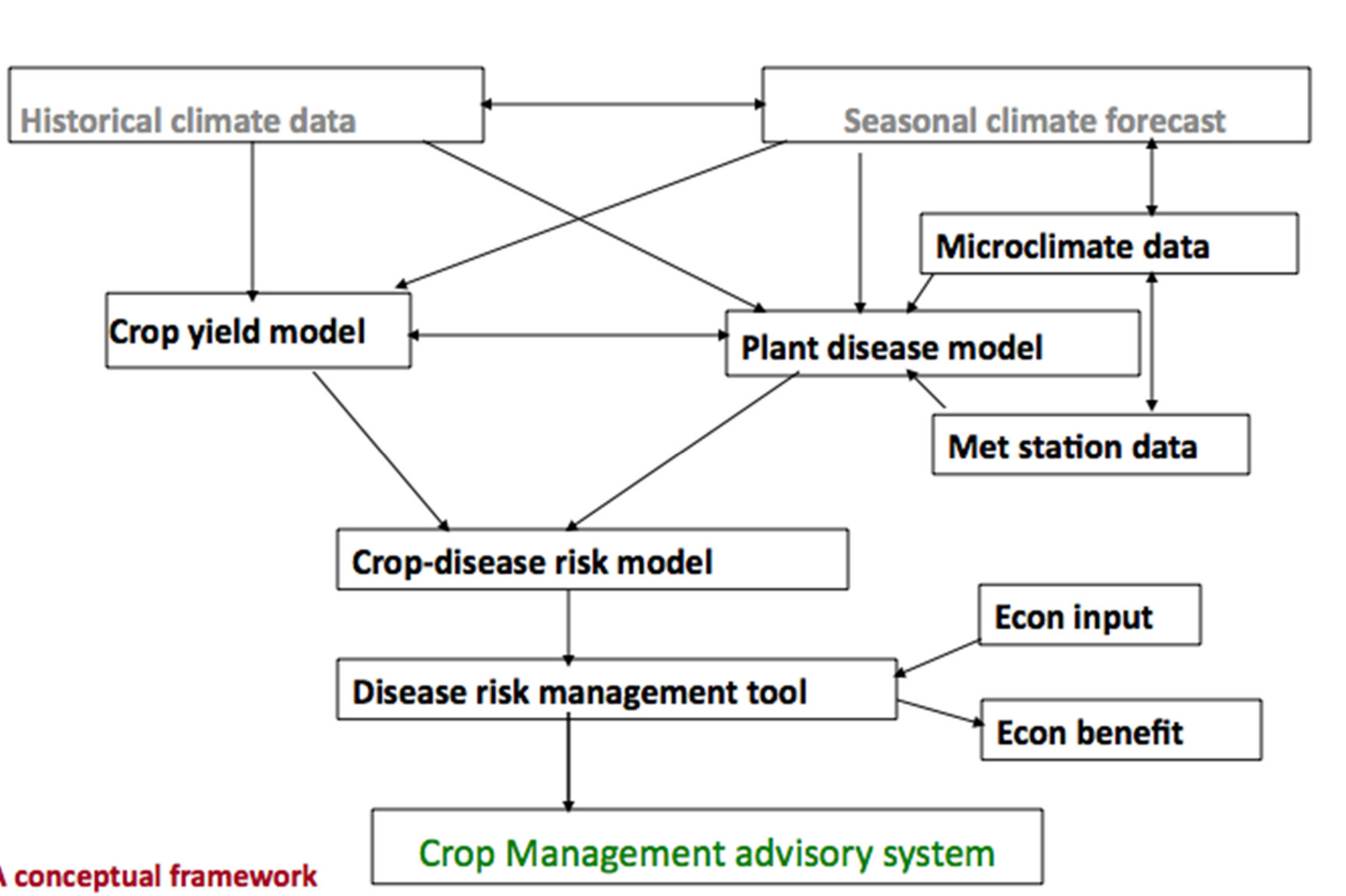

Changes in host, pathogen and climate can increase or decrease the amount of disease as a result of their interactions

Garrett et.al. (2009)

# CC influence on Plant Diseases

- Increased frequency of heat and drought
  - may contribute to disease susceptibility/resistance.
  - Drought can aggravate the effects of soil borne diseases, like Macophomina, Fusaria and others
- Temp governs the rate of reproduction for many pathogens
- Elevated CO2 levels
  - change plant structure- increased leaf thickness, higher leaf area, higher plant biomass- all these would influence infection by pathogens
  - CO2 increases pathogen load on C3/C4 plants/grasses
- Elevated O3 can change the leaf surface structure- affecting physical topography and chemical composition, structure of epicuticular wax- may influence pathogen infection- likely enhanced infection by necrotrophic pathogens and root-rot fungi

# Climate information-Disease risk management




A conceptual framework

# Effects on Plant Pest & disease management

- Delayed/adjusting planting dates less effective
- Increased vulnerability to biocontrol agents
- Reduced efficacy of chemical control
- Risk of movement of invasive pathogen species
- Reduced effectiveness of durable resistance
- uncertainty for management method decision making
- Changing disease management strategy

# Crop Improvement

- To overcome the pessimistic influence of abiotic stresses
- New, improved and tolerant crop varieties
- Contemporary breeding techniques
- Through understanding of the mechanisms that counteract detrimental climate changes

## Increasing the Yield Potential of Rice : Various strategies

*(1) conventional hybridization and selection procedures,*
*(2) Ideotype breeding,*
*(3) Heterosis breeding,*
*(4) Wide hybridization,*
*(5) Genetic engineering*

# Application of GE in resistance development

TRANSVER OF GENES ACROSS SPECIES BARRIER

- **Yeast gene in Tomato for salinity tolerance**
- **Barley gene in Rice for drought tolerance**

NOVEL GENES IDENTIFICATION

- **Drought resistance gene in legume *M. truncatula.***

OVER EXPRESSION WITH IN SPECIES

- **Overexpressing a NAM, ATAF, and CUC in rice**
- **Over-expression of hsp101 in rice**

TO CHANGE FATTY ACIDS UNSATURATION

- **Alteration in the chilling sensitivity of plants**

TO INCREASE OSMOLITES PRODUCTION

- **Increased glycine betaine synthesis**

Lakshmanan, IARI. (2009)

# Conclusions..

- CC affects the pest / disease by increasing/decreasing the encounter rates between host and pathogens by changing the ranges of the two species
- Disease severity-positively correlated with increased virulence of pathogens which are mediated by host resistance that is affected by climate change
- CC will affect plant pest and diseases in relation to other global change phenomena- new species, new vectors, shifts in land use, expansion of tropical/temperate areas, loss of biodiversity etc.

# Adapting to Climate Change

- For growers
  - Early warning systems for managing pests within-season by tactical decision making
  - Constructing longer-term (season) decision support system
- For plant breeders and pesticide developers
  - Prioritization of diseases/weeds/pests
  - Identification of vulnerable regions / hotspots
- For policy makers / donors
  - Identification of important problems for future investment
  - Application of financial tools as buffer for protecting the farmers from increased variability
- In natural systems
  - Distribution of resistance genes

# Future directions

Increased focus needed on:

- How a changing environment affects host-pathogen evolution

  - pathogen characteristics, such as frequency of generation and proportion of sexual reproduction affect the rate of adaptation

  - host characteristics, such as life span affects rates of adaptation

  of both host and pathogen populations
- Are invasive plant species better able to adapt to CC and move to new areas rapidly?
- Local, regional and international cooperation and collaboration needed to understand the problem and find solutions

Thank you