Cereal models for climate adaptation

Insights and needs

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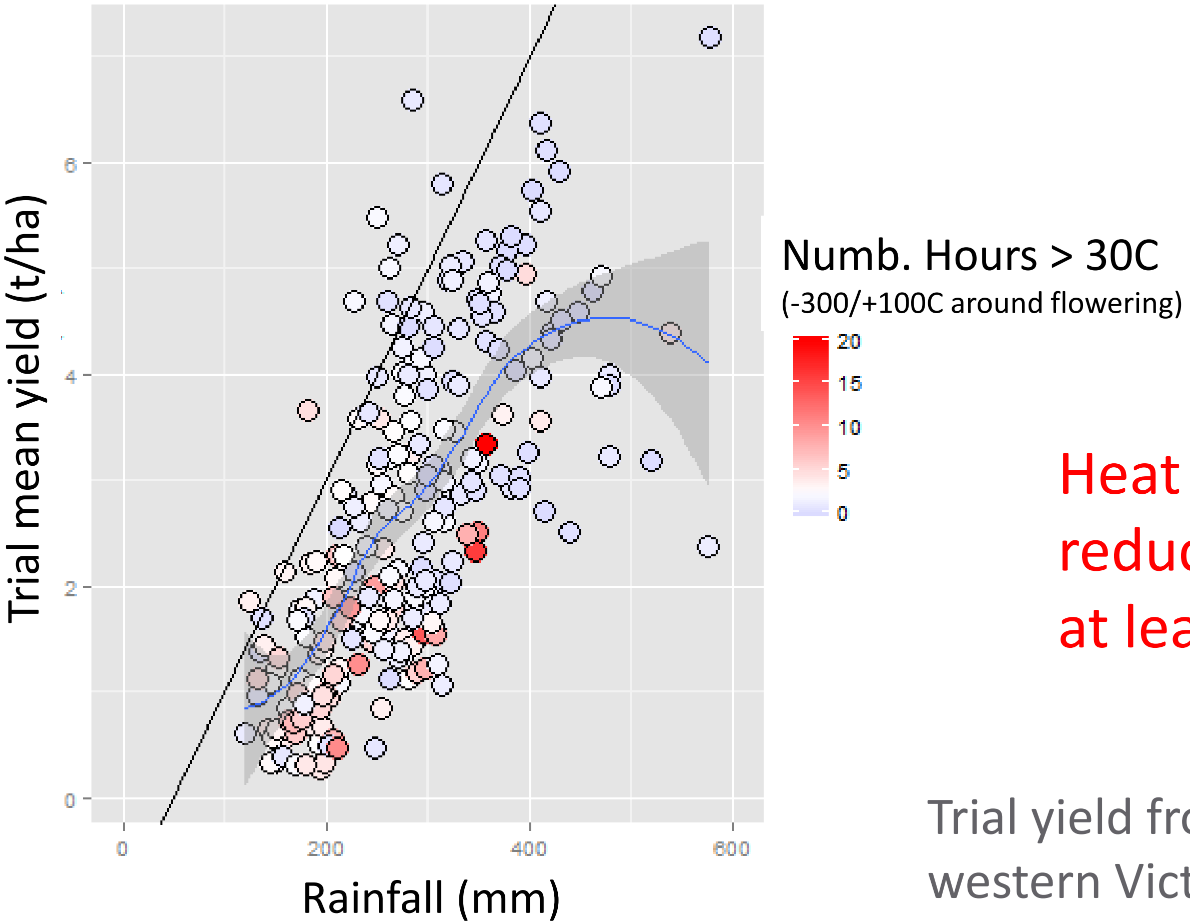
Heat effects in yield trials – Evidence from National Variety Trials



Heat around flowering reduced trial mean yield in at least 30 trials

Trial yield from South Australia and western Victoria (Australia)

Breeding and modelling adaptive traits

Issues in developing and using models for prediction of phenotype

Issues in modelling high temperature effects

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Issues in modelling high temperature effects

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Crop & Pasture Science, 2012, **63**, 251–268
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Plant adaptation to climate change—opportunities and priorities in breeding

Scott C. Chapman[A,C,D], *Sukumar Chakraborty*[A], *M. Fernanda Dreccer*[B,C], *and S. Mark Howden*[C]

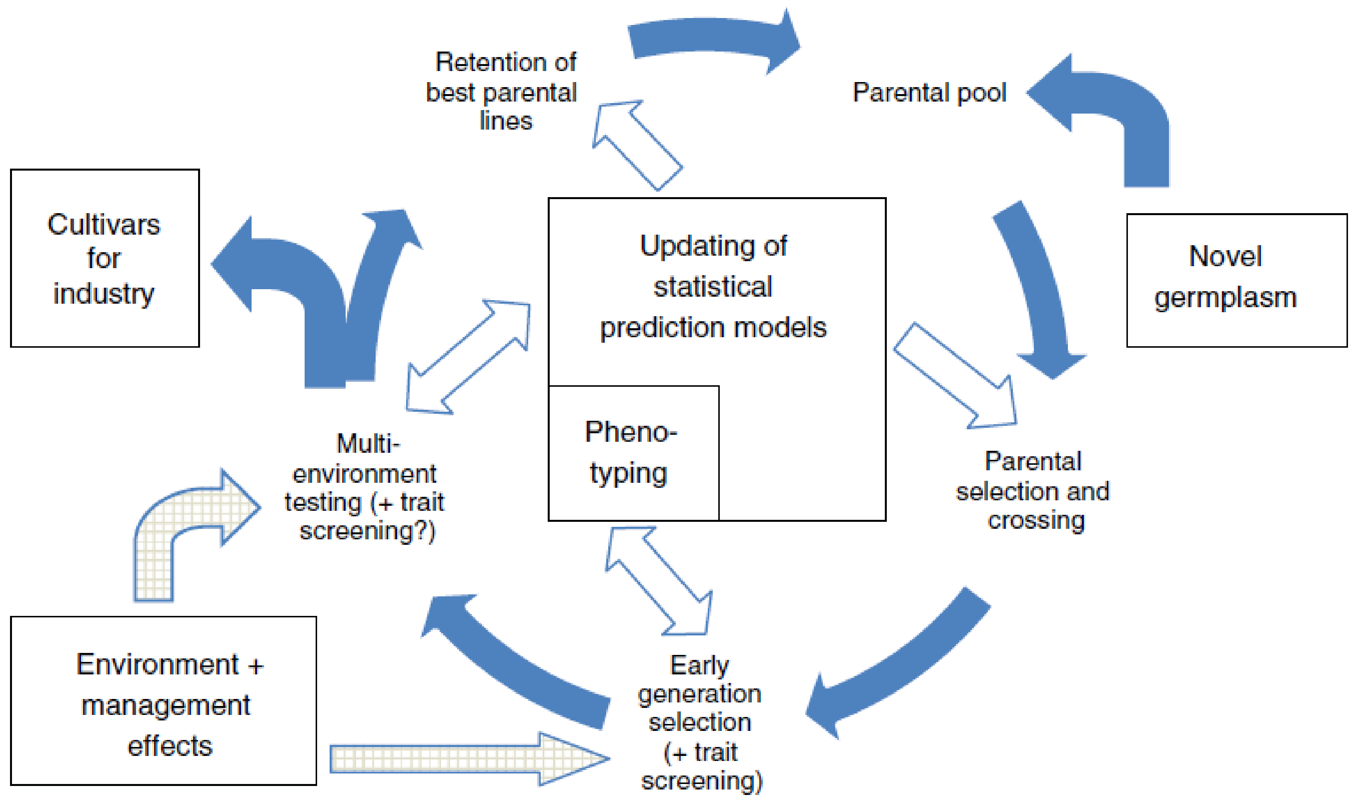
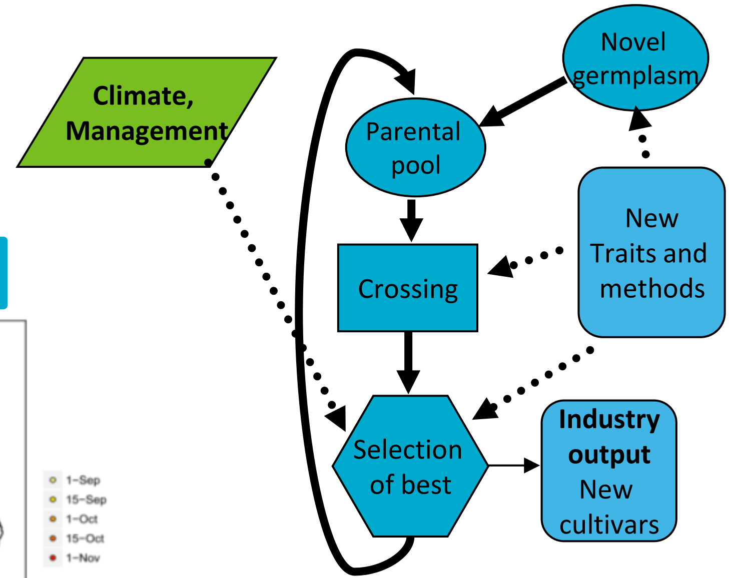
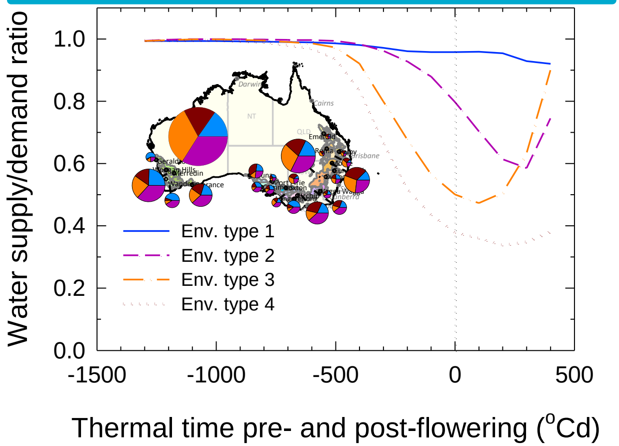


Fig. 1. Basic components of a modern breeding program. Solid arrows show germplasm flow as it is introduced, improved, and delivered as cultivars. Hatched arrows show where environment (either on-farm or managed in breeding program) impacts phenotyping and selection. Open arrows show information flow from core technologies of program (phenotyping methods, DNA analysis, statistical prediction) to select parents and cultivars.

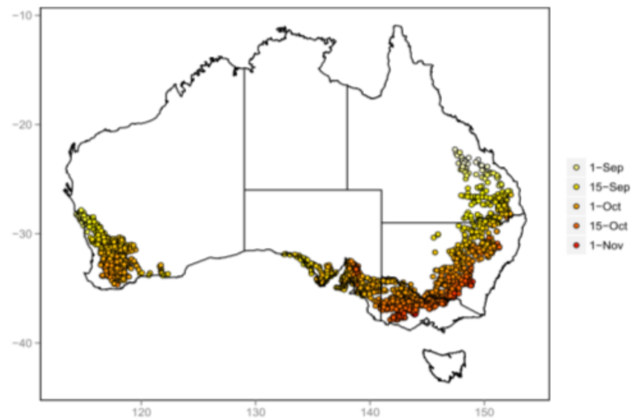
Modelling in breeding

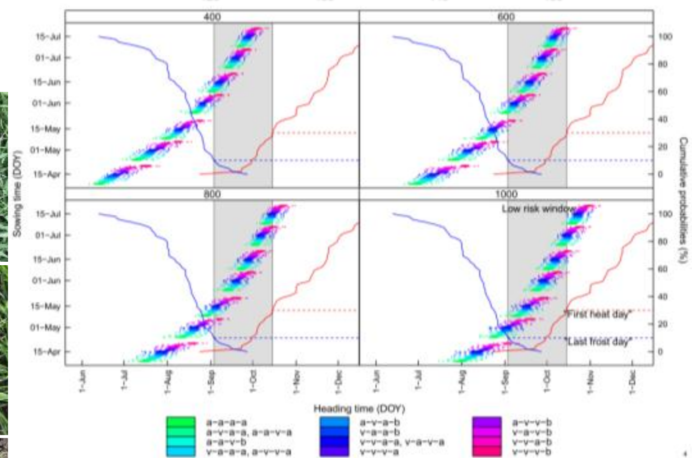


Environment characterisation - Drought patterns to interpret GxE

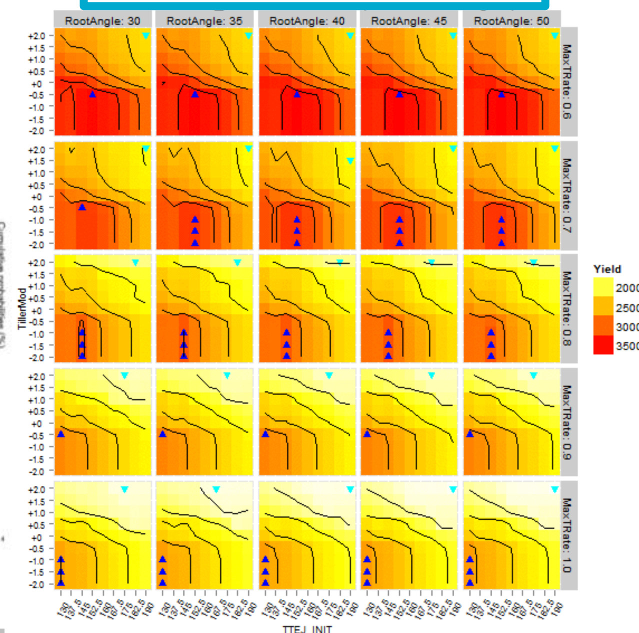


Prediction of Adaptation

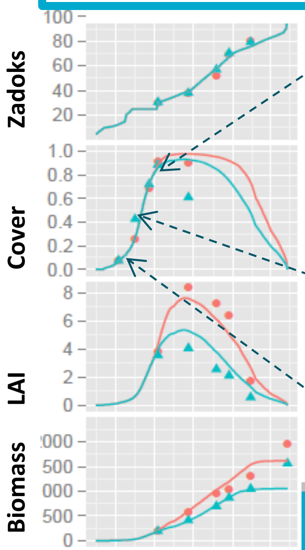


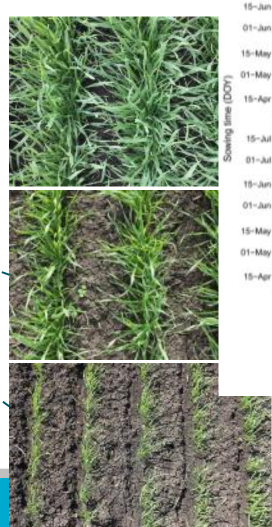


Evaluation of trait value



In-season 'phenotyping'





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Breeding and modelling adaptive traits

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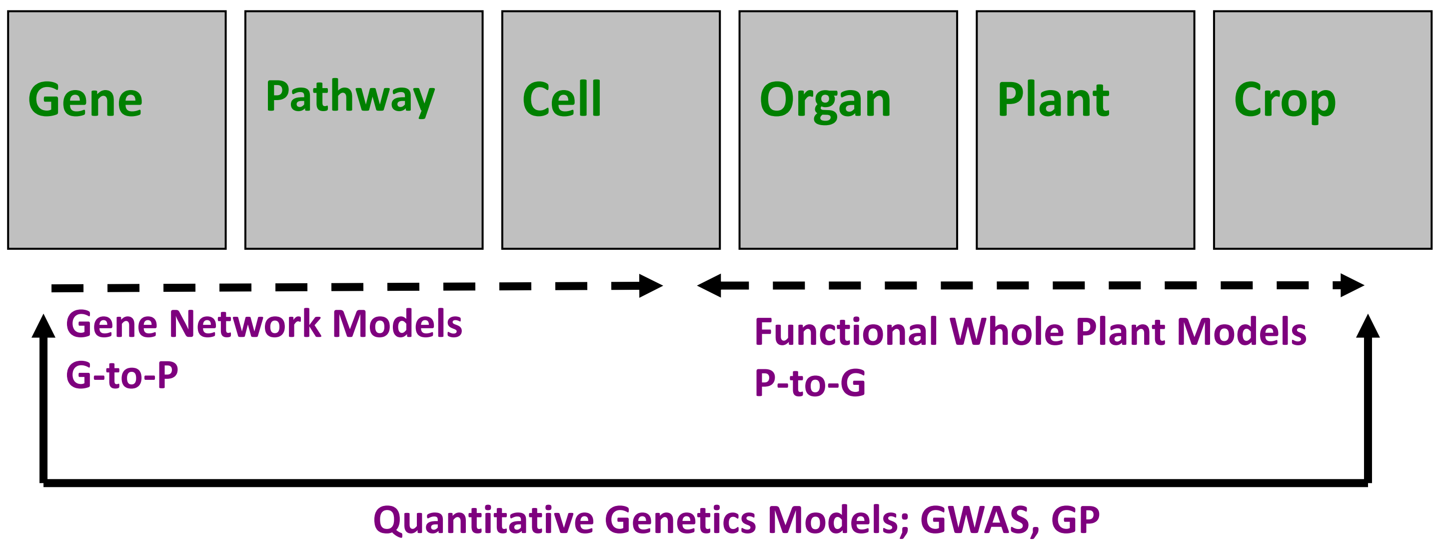
Gene-to-Phenotype Prediction

The “Phenotypic Distance” Issue

High temperature – direct and indirect effects....

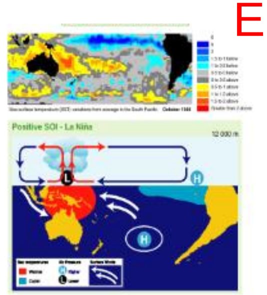


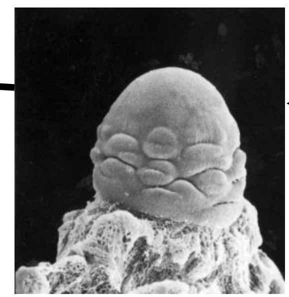
– G & E context dependencies

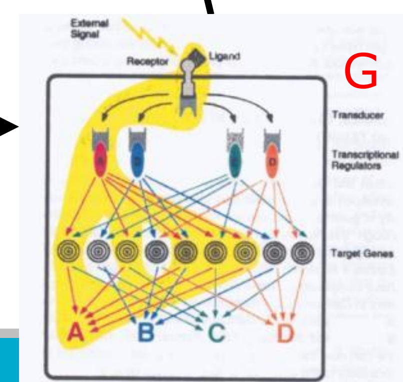
Cooper et al (2002) *In Silico Biology* 2:151-164. **Hammer et al (2004) *Plant Physiology* 134:909-911.**

Plants adapting across scales

- Sensing, signalling, responding
- (perception, memory, attention)?

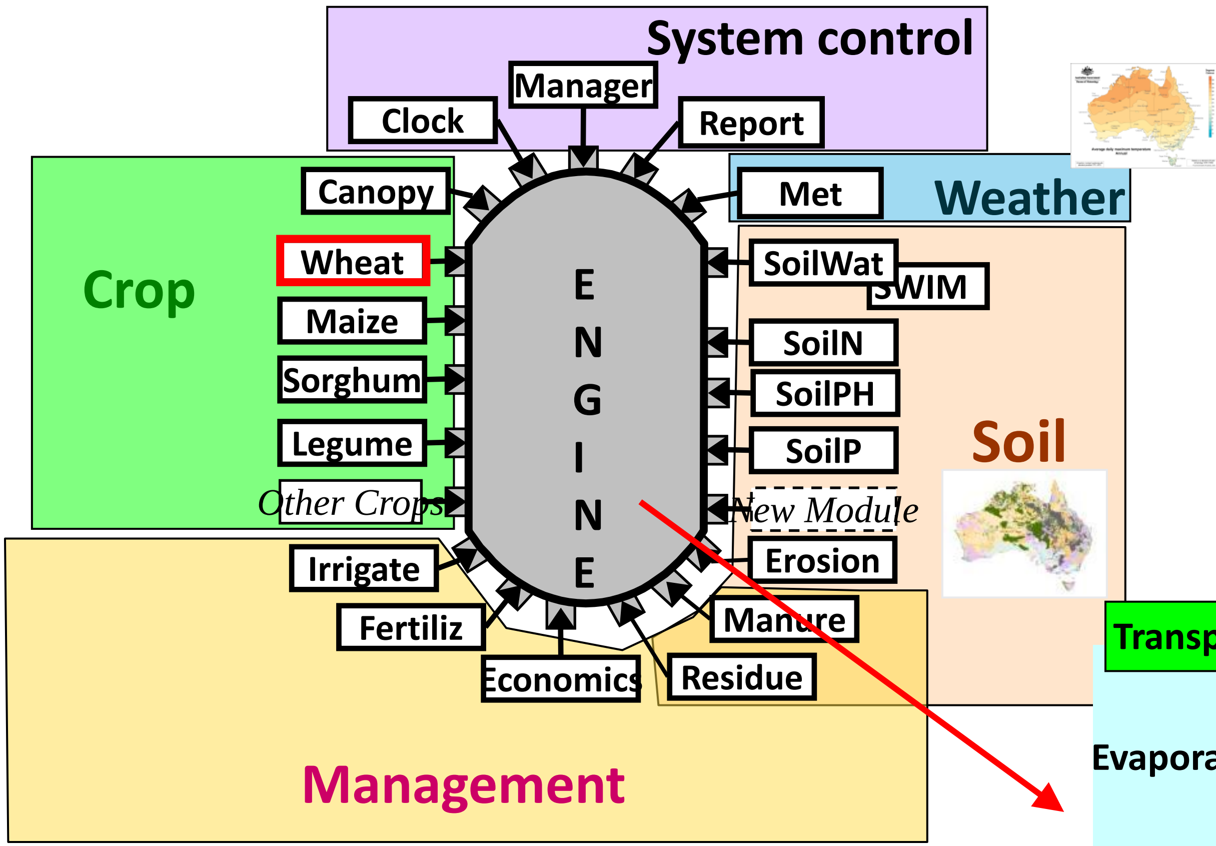


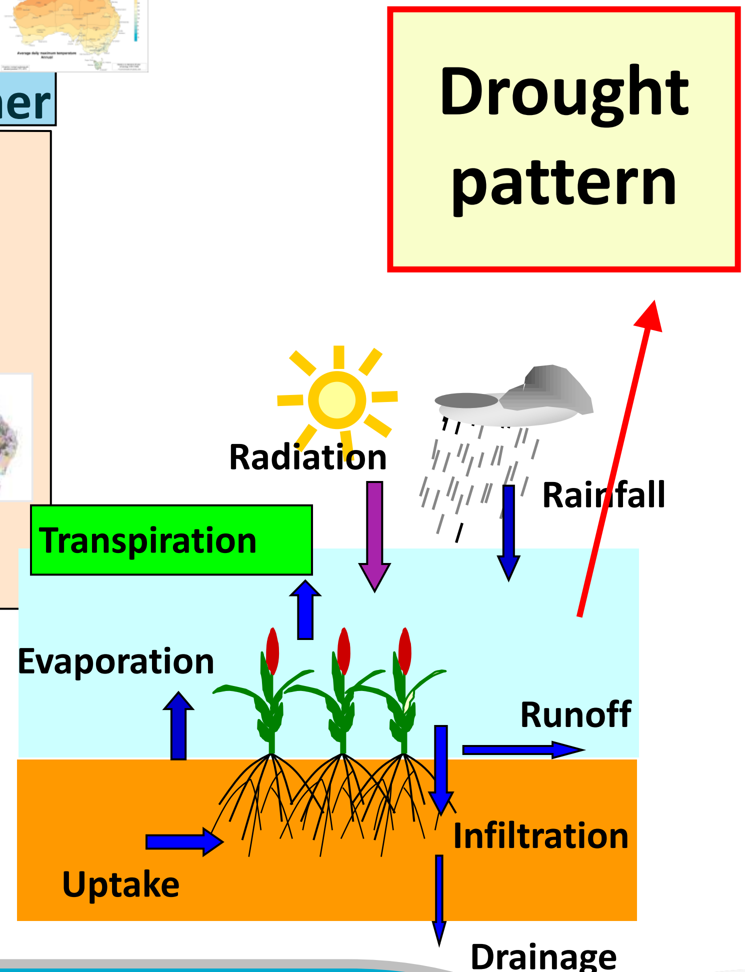




Chapman et al 2002 in 'Quantitaive Genetics, Genomics and Plant Breeding' (CABI)
Hammer et al 2006, Trends in Plant Sci.

Capturing physiology into a simulation model - APSIM

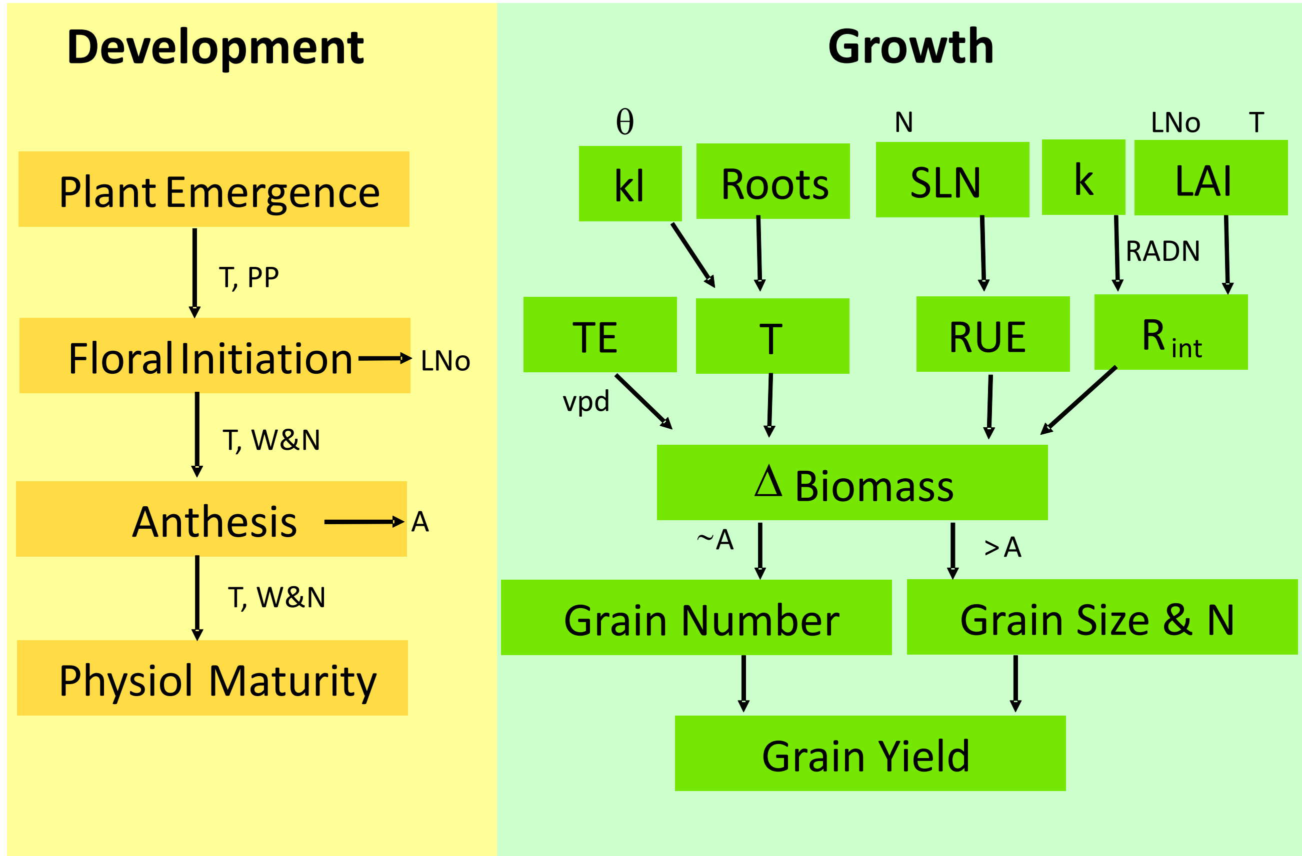




Keating et al 2003 EJA

Where does heat fit?

- Development
- Growth
- Partitioning
- Energy balance
- Water balance



Which needs are where?

Breeding and modelling adaptive traits

Issues in developing and using models for prediction of phenotype

Issues in modelling high temperature effects

Issues in modelling response to heat

- Adaptation
  - Avoidance/escape
    - Changes in cropping system, phenology, agronomy
  - Heat or VPD or both
  - Direct effects on growth, partitioning and yield
    - Supra-optimal effects
    - Extreme/catastrophic effects

- Specific issues with Model structure
  - Timestep
    - Daily timestep, but can be extended to hourly
  - Scaling
    - Estimating canopy and organ temperatures

Modelling needs to capture heat effects

Component	Modelling Needs	Urgency	Current
Phenology	Improved prediction of leaf number and sensitive growth stages	***	Good
	Variation associated with development (tillering etc)	*	Poor
Growth	Expansive growth (leaf, stem, root extension), inc. CO_2	**	Mod
	Photo-system function (leaf and spike function)	**	Poor
	Night-time temperature (development + respiration)	****	Poor
	Grain set and abortion	*****	Varies
Partitioning	Grain expansion (grain size) and filling	****	Poor
	Changes in allocation and senescence of biomass	*	Poor
	Grain quality	**	Varies
Energy balance	Canopy + soil + irrigation/rainfall effects	***	Poor
	Temperatures of organs	***	Poor
	Diurnal dynamics	**	Mod
Water balance	Simulation of leaf+root transpirational cooling (& CO_2?)	****	Poor
	Integration of heat and VPD effects on organ growth	****	Poor

Issues in modelling high temperature
- Development

- Heading time
  - Reasonable models for these
- Prediction of leaf number and sensitive growth stages
  - Over/under estimation of leaf initials (wheat, rice)
  - Interaction of warm temperature with leaf expansion rate and observed leaf appearance (all cereals)
- Variation associated with development of multiple organs
  - Tiller initiation and response to temperature (all except maize)
  - Uniformity of development and timing of sensitive stages
    - e.g. % of grains exposed to heat events

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This paper is available online free of all access charges (see http://jxb.oxfordjournals.org/open_access.html for further details)
Journal of Experimental Botany
www.jxb.oxfordjournals.org

RESEARCH PAPER

Quantification of the effects of *VRN1* and *Ppd-D1* to predict spring wheat (*Triticum aestivum*) heading time across diverse environments

Bangyou Zheng[1], Ben Biddulph[2], Dora Li[2], Haydn Kuchel[3] and Scott Chapman[1,*]

Global Change Biology
Global Change Biology (2012), doi: 10.1111/j.1365-2486.2012.02724.x

Breeding for the future: what are the potential impacts of future frost and heat events on sowing and flowering time requirements for Australian bread wheat (*Triticum aestivium*) varieties?

BANGYOU ZHENG†, KARINE CHENU‡, M. FERNANDA DRECCER§ and SCOTT C. CHAPMAN†

Zheng et al 2013 JExpBot, Zheng et al 2012 GCB

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Issues in modelling high temperature - Growth

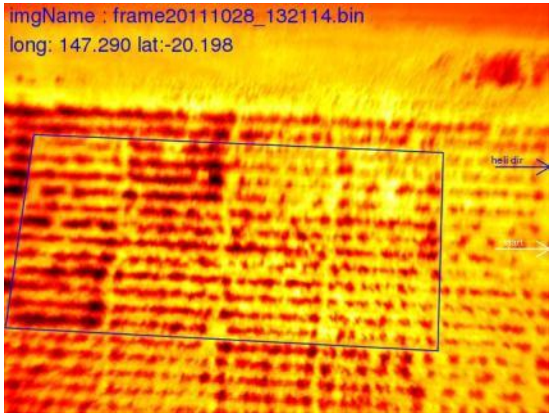
- Response of expansive growth to high temperature
  - Non-linear responses of leaf, stem and root growth
- Photo-system function (leaf and spike)
  - Supra-optimal temperature effects on photosynthesis
  - Radiation/heat induced senescence

- Night-time temperature (development and respiration)
  - Biomass ‘cost’
- Grain set and abortion
  - Direct influences on pollination, ovary development and initial grain growth

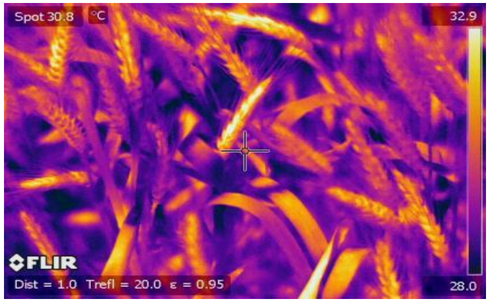
Issues in modelling high temperature - Partitioning

- Grain expansion rate and size
  - Setting limits on maximum size?
- Grain filling/translocation function
  - Influences on effectiveness of translocation
- Changes in allocation and senescence of biomass
  - Effects on premature leaf death
- Grain quality
  - Variation in quality components (dilution)

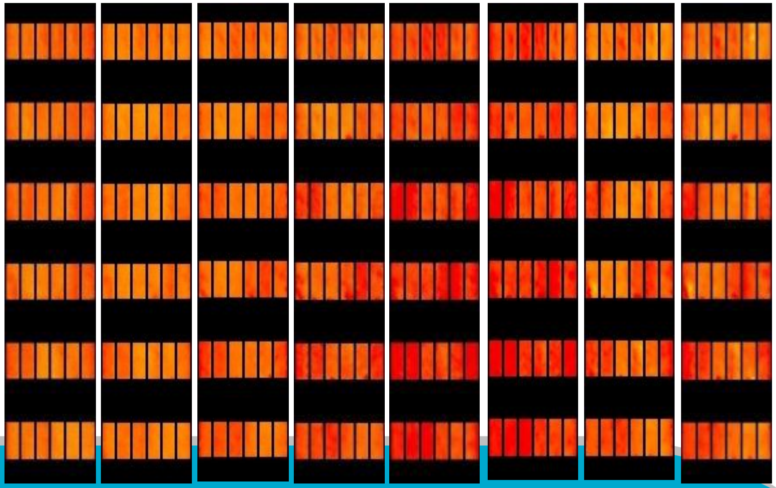
Issues in modelling high temperature - Energy balance



- Differential effects on ‘crop’ temperature
  - Canopy + soil + soil condition (wetness, mulch)



- Estimation of temperatures of organs
- Diurnal dynamics of temperature



Issues in modelling high temperature - Water balance

- Simulation of transpirational cooling
  - per se estimation
  - ‘Influence’ of biology in the dynamics of cooling

- Integration of heat and VPD effects on organ growth
  - Influences of VPD on organ expansion (maize leaf and grain)

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Acknowledgements

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