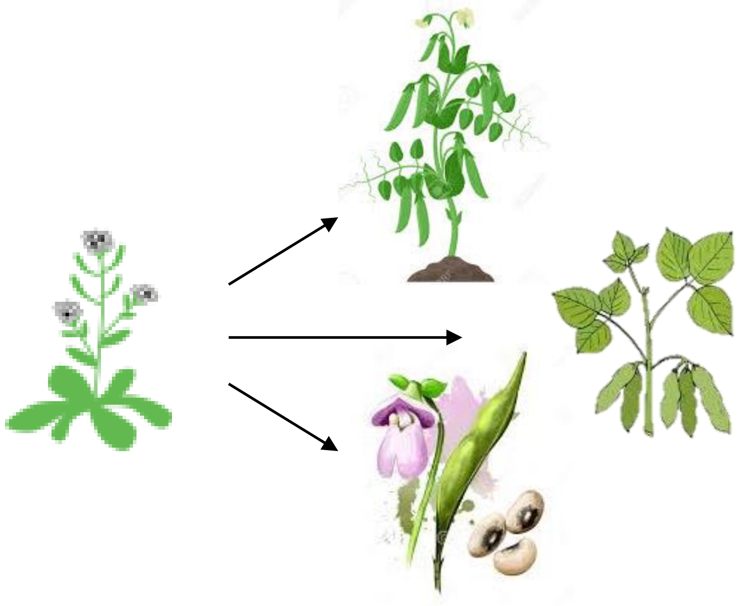

Fertility Under Heat Stress

Natasha Yelina
Crop Science Centre Research Fellow

GFS Coffee Break Seminar
February 4th, 2022

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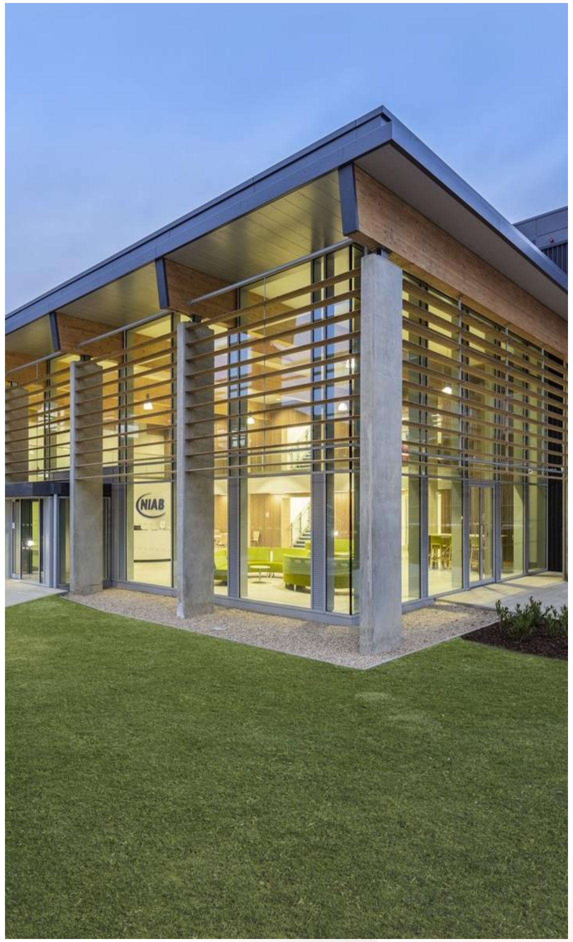


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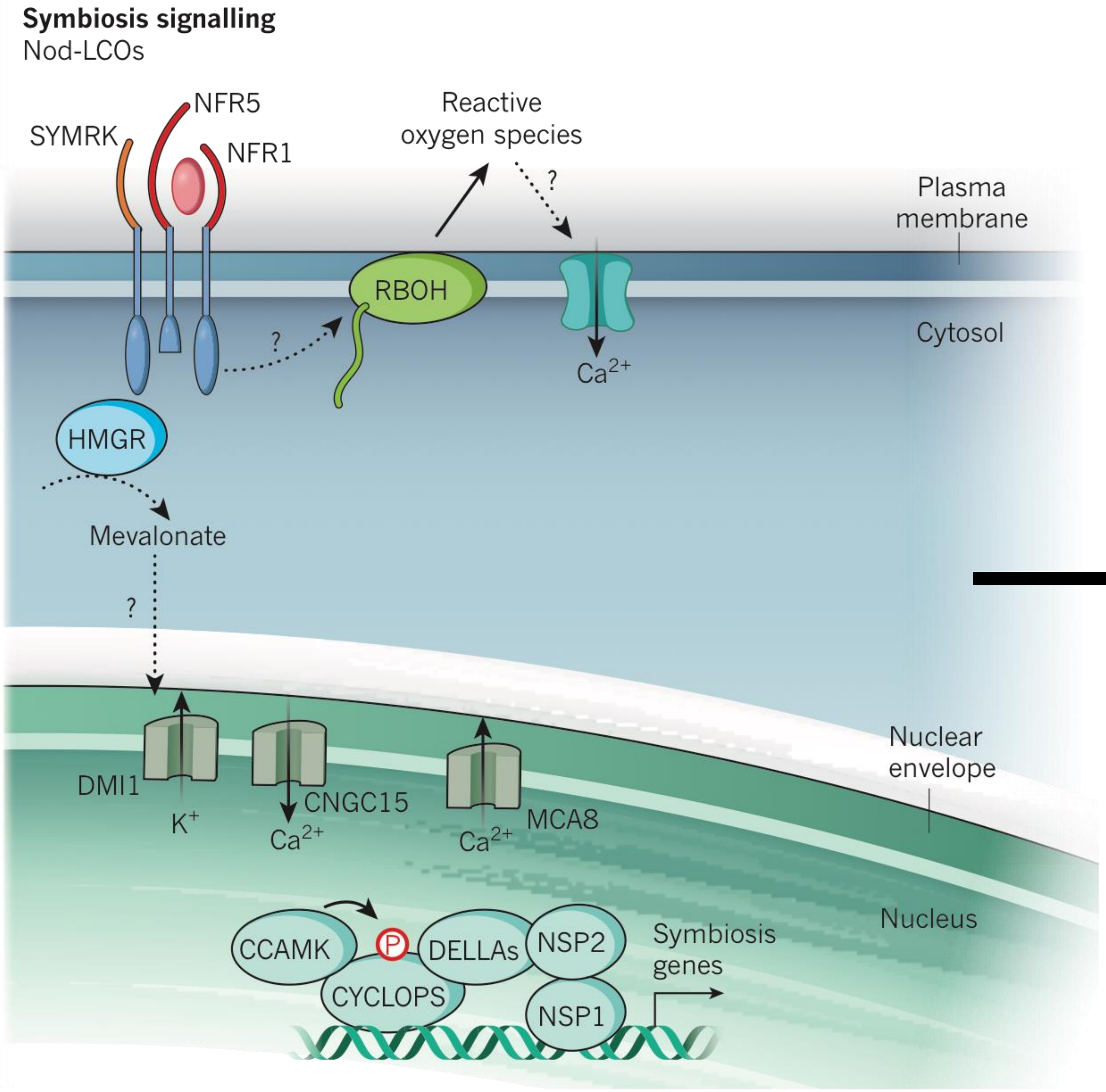
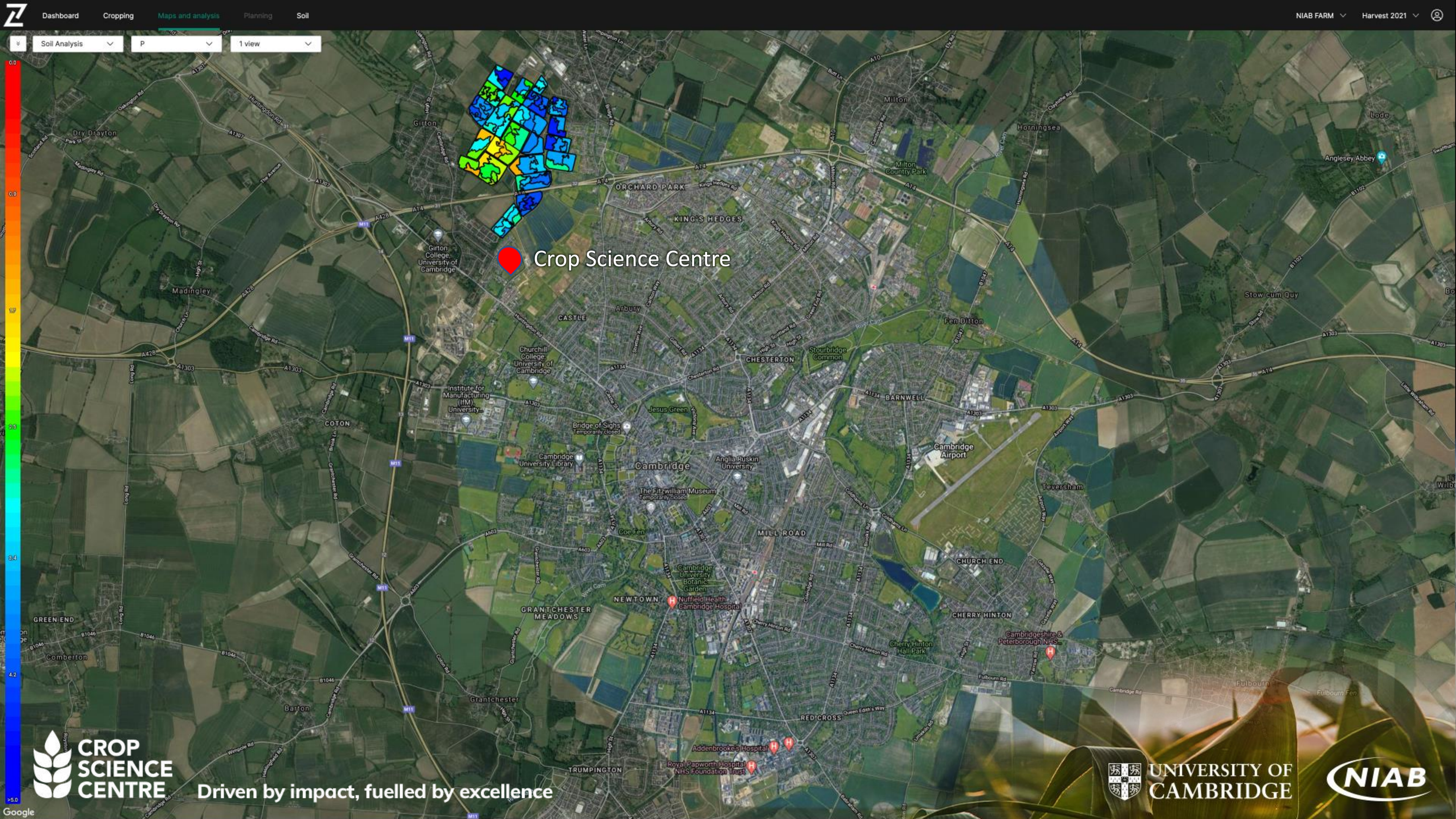


Translation

Sustainability

Equity

Zipfel and Oldroyd, 2017


Dashboard
Cropping
Maps and analysis
Planning
Soil
NIAB FARM
Harvest 2021
Soil Analysis
P
1 view
Crop Science Centre
Girton
Orchard Park
King's Hedges
Madingley
Castle
Chesterton
Barnwell
Cambridge
Cambridge Airport
Mill Road
Newtown
Cherry Hinton
Trumpington
Grantchester
Coton
Milton
Fen Ditton
Stow cum Quy
Teversham
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Google

Replacing inorganic fertilisers

Enhancing photosynthesis

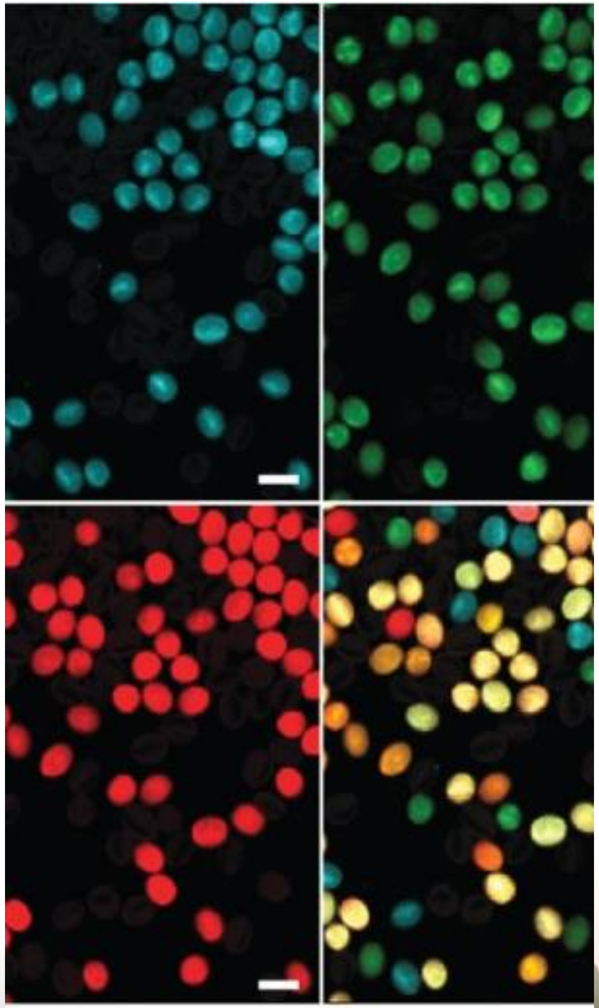
Reducing losses from pests and pathogens

Replacing inorganic fertilisers

Enhancing photosynthesis

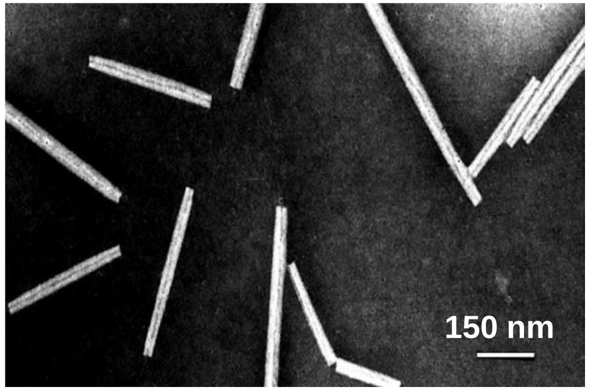
Reducing losses from pests and pathogens

Breeding Technologies



My Background: Plants and Plant Viruses

Moscow State University



Barley stripe mosaic virus

Barley

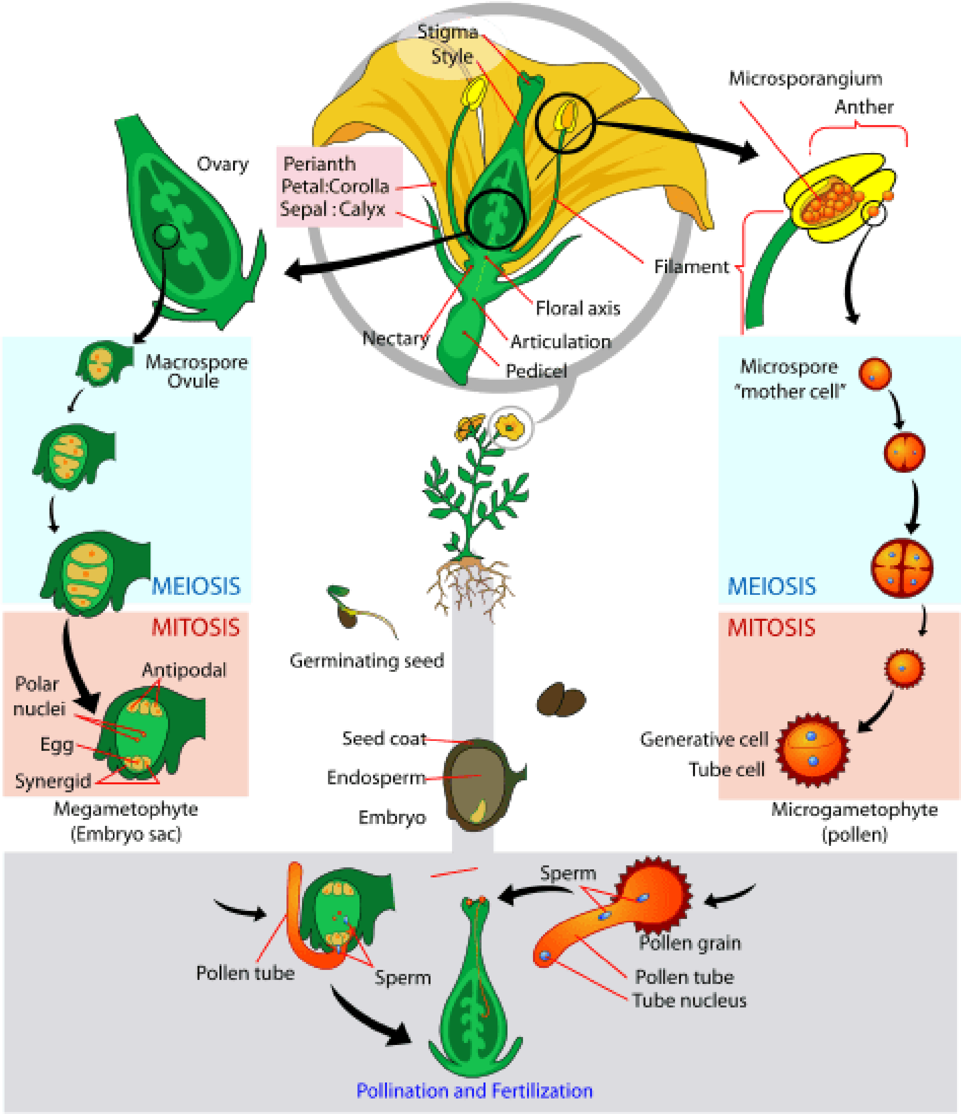
Virus infection: Plant fights back, virus suppresses plant's response

Just one virus protein

Strong virus infection, strong plant response, plant recovers

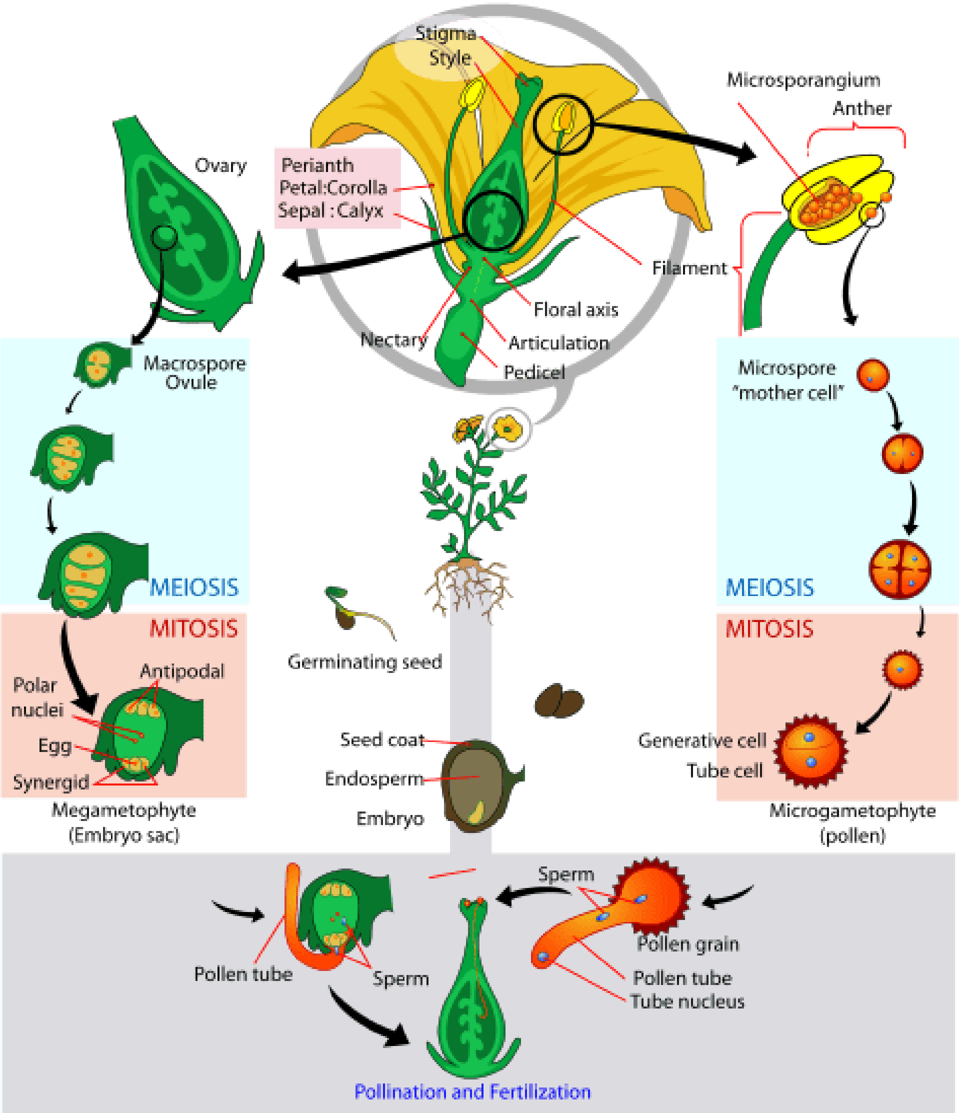
My Background: Plant Reproduction

Department of Plant Sciences, Cambridge, UK

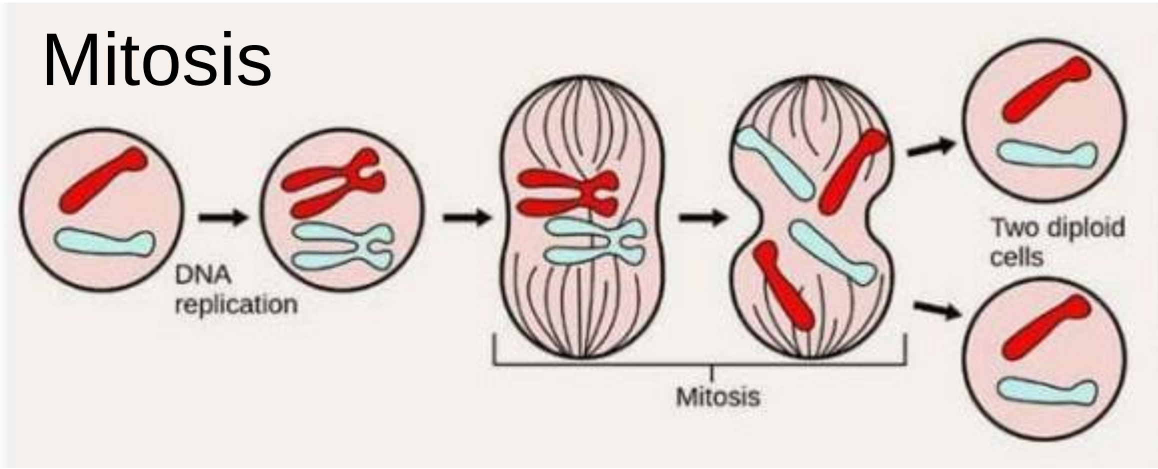


Judd et al. 1999. Plant Systematics: A Phylogenetic Approach

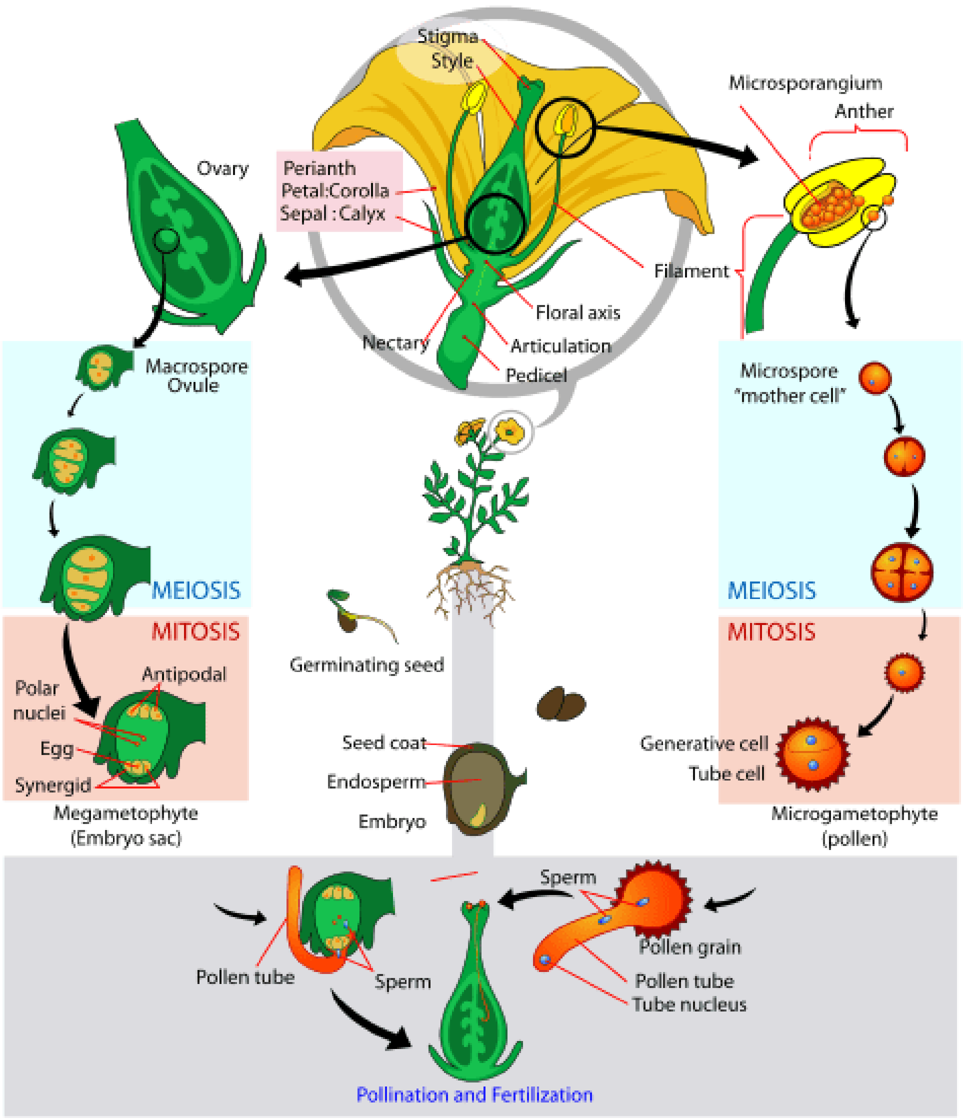
My Background: Plant Reproduction



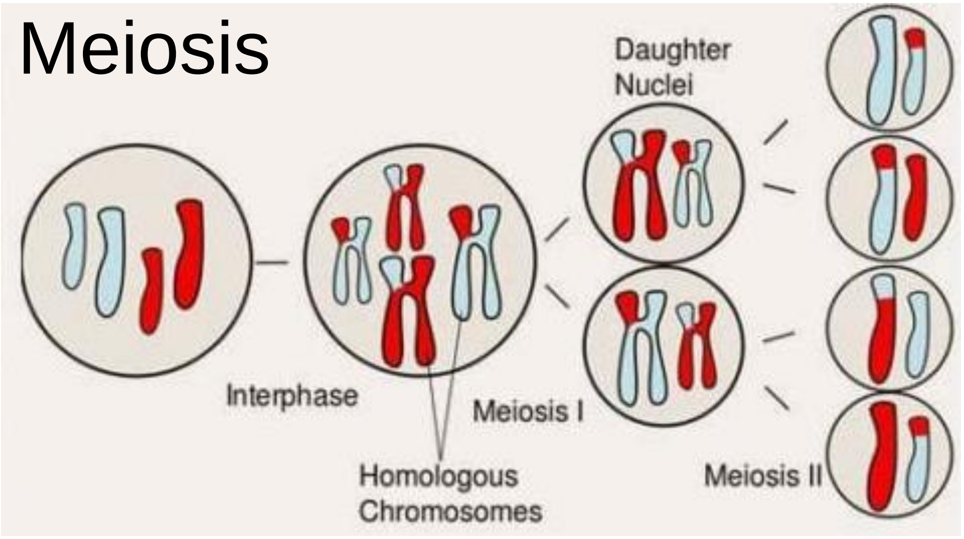
Judd et al. 1999. Plant Systematics: A Phylogenetic Approach



My Background: Plant Reproduction



Judd et al. 1999. Plant Systematics: A Phylogenetic Approach

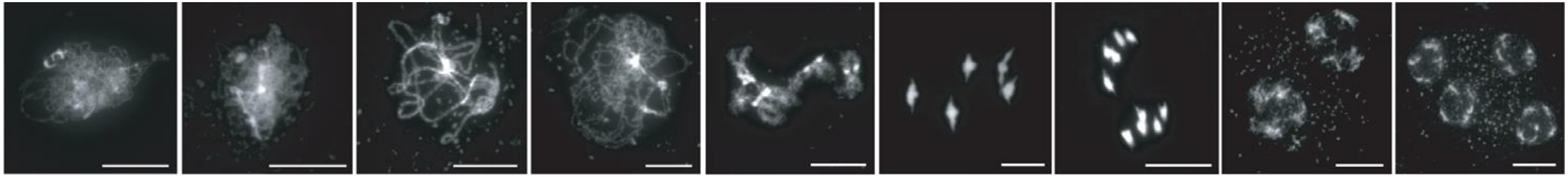


4 haploid gametes

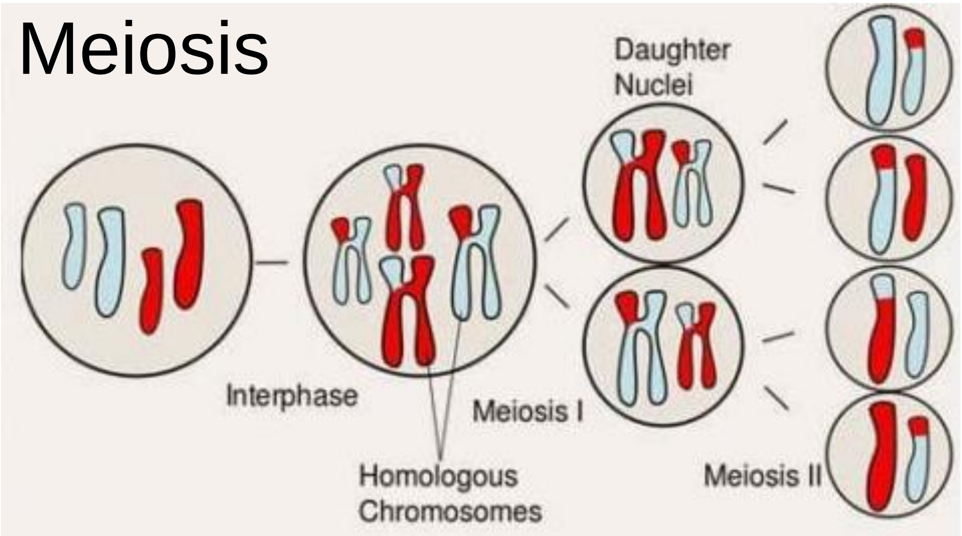
Meiosis Is Complex…

Meiosis progression

2n → n

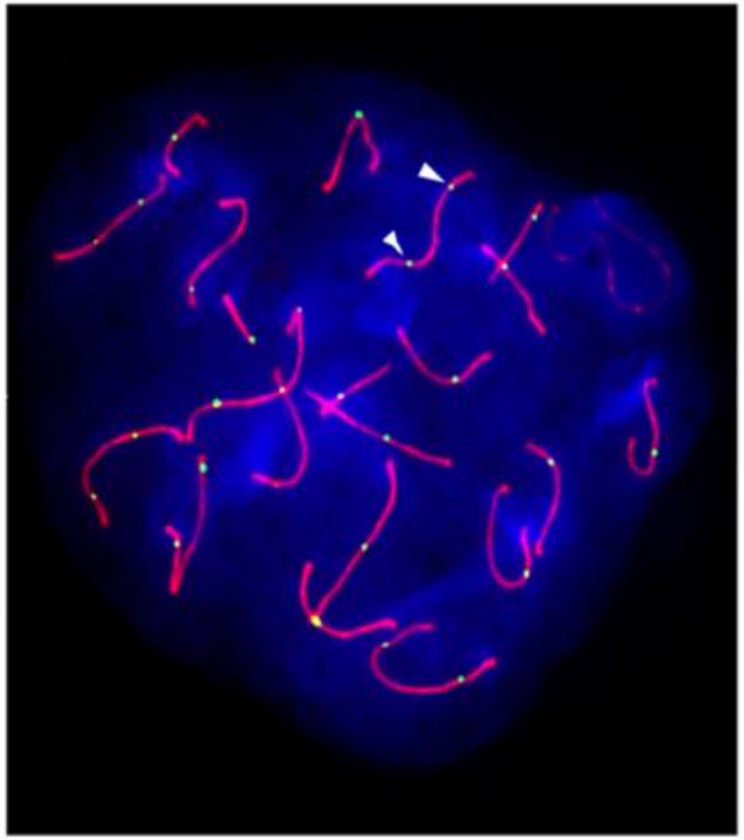


Yelina et al. 2012

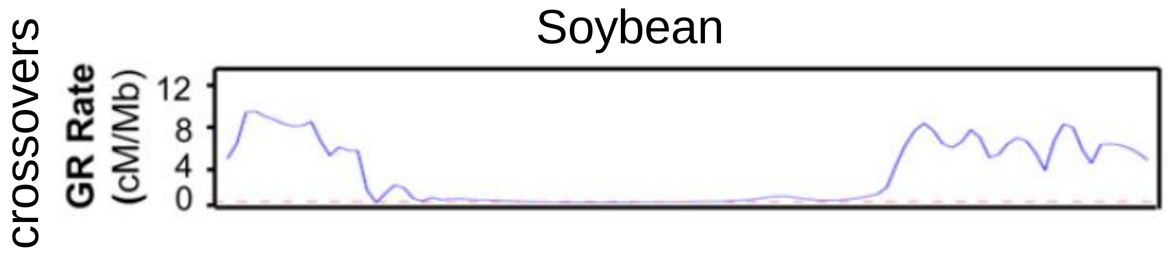


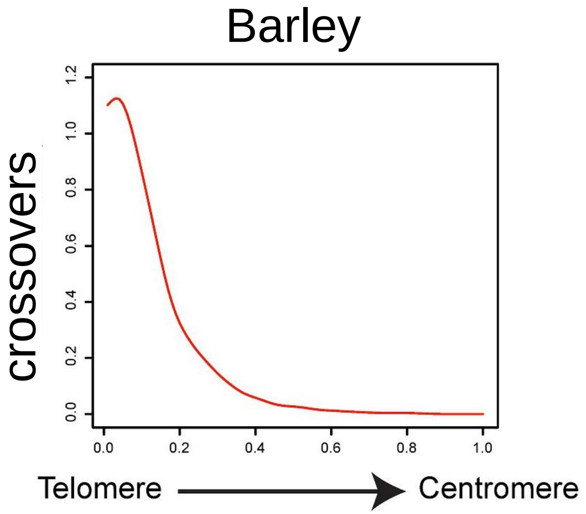
4 haploid gametes

… and Extremely Important For Crop Breeding



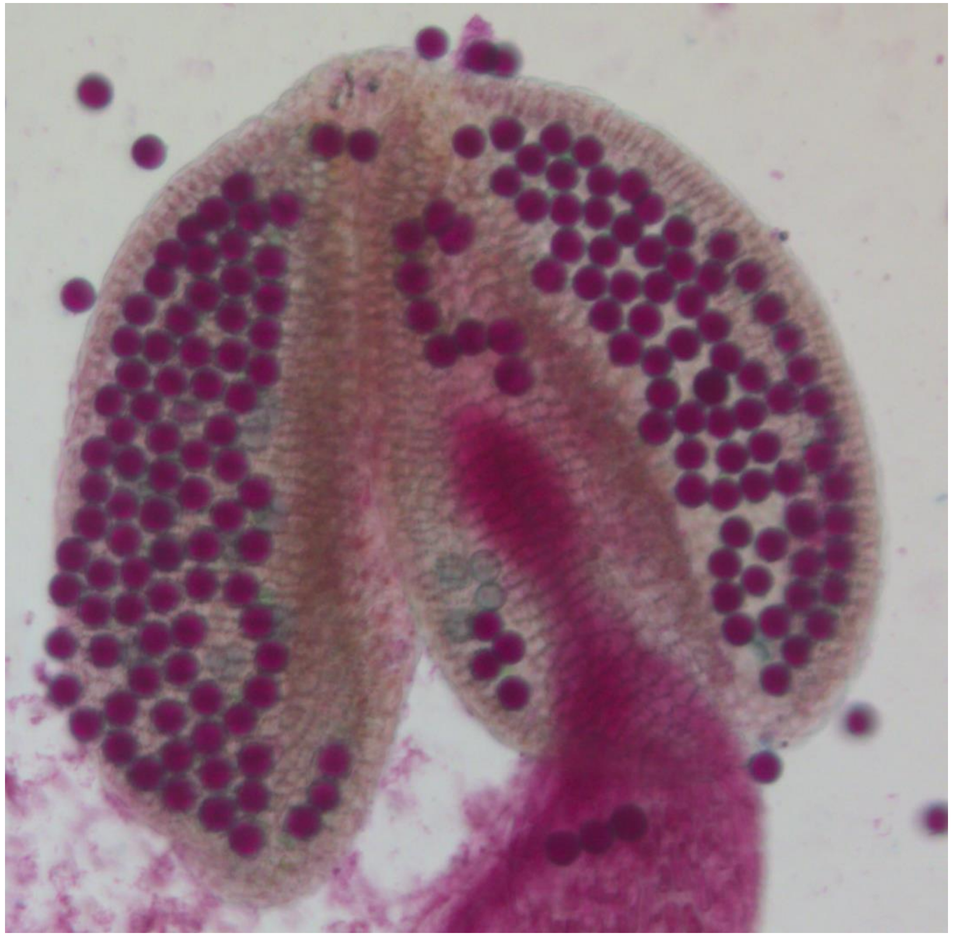
Thacker et al. 2009



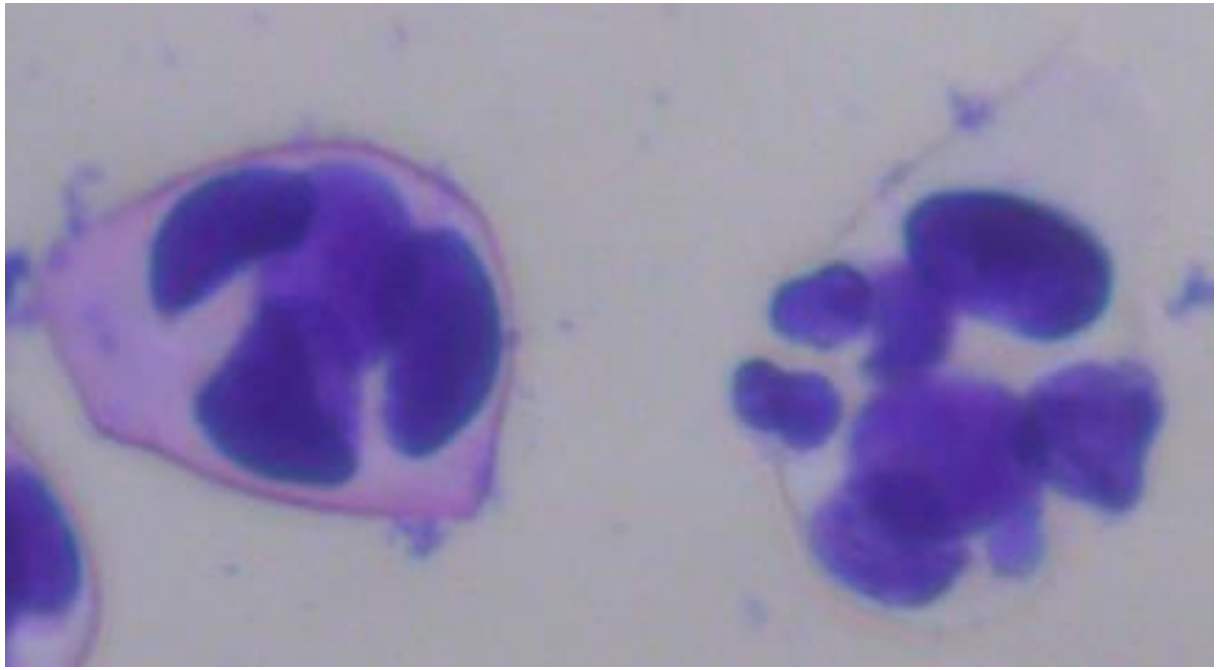


Schmutz et al. 2010
Du et al. 2012
Darrier et al., 2017
Kuo et al., 2021

… and Extremely Important For Crop Breeding

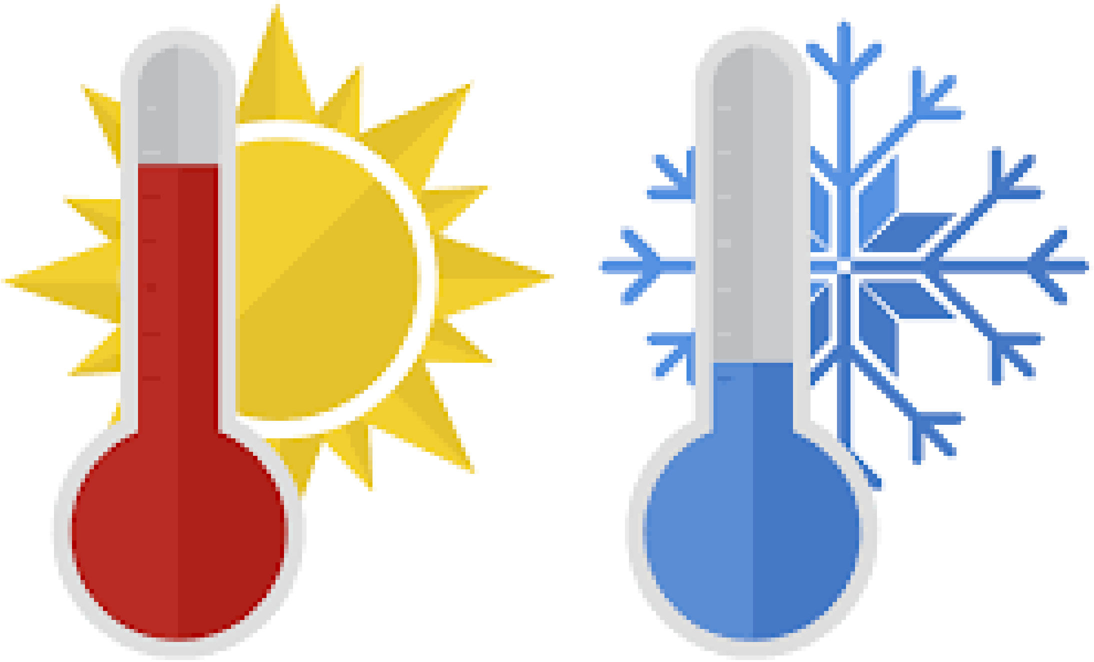


Alexander staining for pollen viability

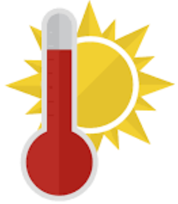


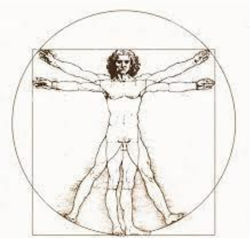
Toluidine blue staining for aneuploidy

Yelina et al. unpublished

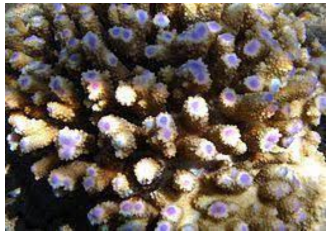


Examples: Fertility Affected by Temperature




Homo sapiens


Mus musculus


Acropora digitifera


Tribolium castaneum


Bos taurus


Poecilia reticulata


Sus species


Taeniopygia guttata


Grapholita molesta


Gallus gallus domesticus


Chickpea


Pea


Cowpea

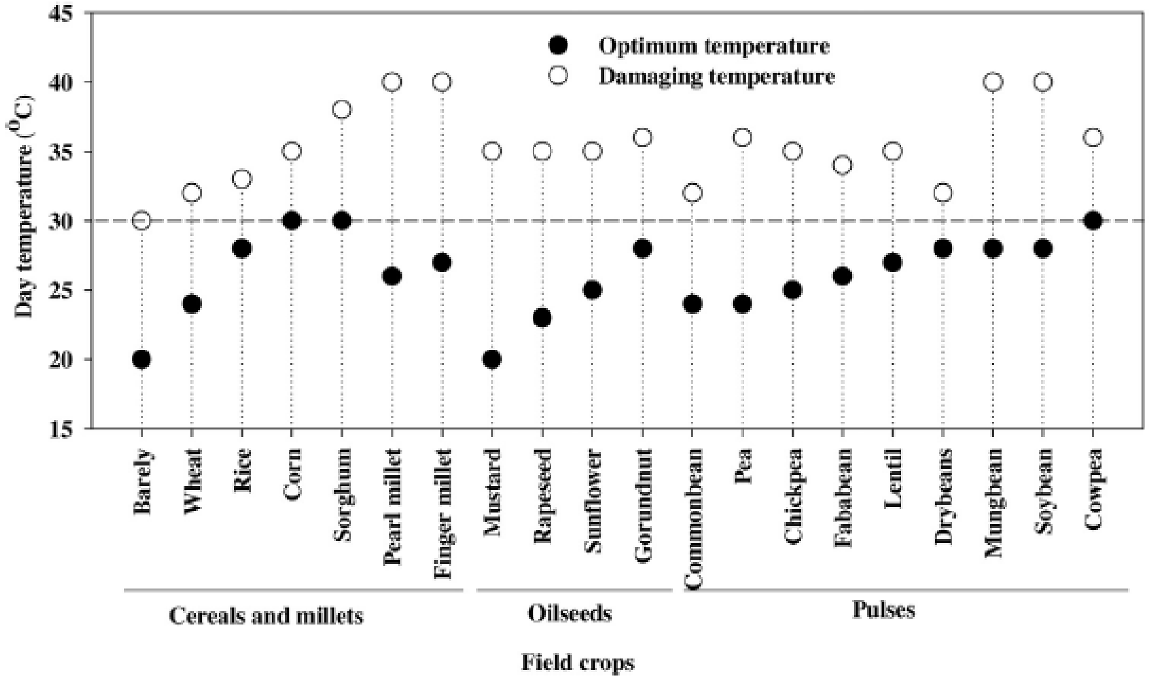

Rice


Barley


Wheat


Tomato

Examples: Fertility Affected by Temperature



Prasad et al. 2016

Chickpea

Pea

Cowpea

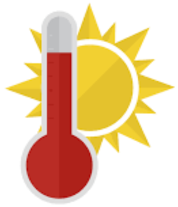
Rice

Barley

Wheat

Tomato

Examples: Fertility Affected by Temperature



Crop species	Stress	Yield losses (%)	Reference
Maize (*Zea mays* L.)	Drought	63–87	Kamara et al., 2003
	Heat	42	Badu-Apraku et al., 1983
Wheat (*Triticum aestivum* L.)	Drought	57	Balla et al., 2011
	Heat	31	Balla et al., 2011
Rice (*Oryza sativa* L.)	Drought	53–92	Lafitte et al., 2007
	Heat	50	Li et al., 2010
Chickpea (*Cicer arietinum* L.)	Drought	45–69	Nayyar et al., 2006
Soybean (*Glycine max* L.)	Drought	46–71	Samarah et al., 2006
Sunflower (*Helianthus annuus* L.)	Drought	60	Mazahery-Laghab et al., 2003

Fahad et al. 2017

Why Legumes?

Intercropping

Smaller carbon footprint

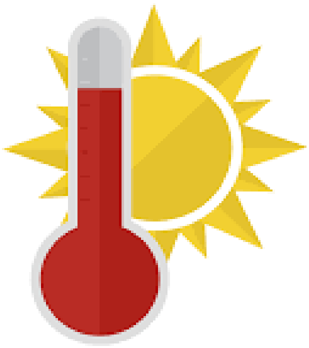
N_2 fixing

Water efficiency

Genetic diversity
Climate resilience

Dietary benefits

Questions:



Why is Fertility Affected By Temperature?

How Can We Reduce Crop Losses Due To Heat Stress During The Reproductive Stage?

The Plant Cell, Vol. 27: 1857–1874, July 2015, www.plantcell.org

Genome-Wide Association Mapping of Fertility Reduction upon Heat Stress Reveals Developmental Stage-Specific QTLs in *Arabidopsis thaliana*

Johanna A. Bac-Molenaar,[a,b] Emilie F. Fradin,[a,b] Frank F.M. Becker,[b] Juriaan A. Rienstra,[a] J. van der Schoot,[a] Dick Vreugdenhil,[a] and Joost J.B. Keurentjes[b,1]

Developing Climate-Resilient Chickpea Involving Physiological and Molecular Approaches With a Focus on Temperature and Drought Stresses

*Anju Rani[1], Poonam Devi[1], Uday Chand Jha[2], Kamal Dev Sharma[3], Kadambot H. M. Siddique[4] and Harsh Nayyar[1]**

Food Legumes and Rising Temperatures: Effects, Adaptive Functional Mechanisms Specific to Reproductive Growth Stage and Strategies to Improve Heat Tolerance

Kumari Sita[1], Akanksha Sehgal[1], Bindumadhava HanumanthaRao[2], Ramakrishnan M. Nair[2], P. V. Vara Prasad[3], Shiv Kumar[4], Pooran M. Gaur[5], Muhammad Farooq[6,7,8], Kadambot H. M. Siddique[7], Rajeev K. Varshney[5,7] and Harsh Nayyar[1]**

Scientia Agricola

DOI: http://dx.doi.org/10.1590/1678-992X-2018-0233

ISSN 1678-992X

Research Article

Influence of high temperature on the reproductive biology of dry edible bean (*Phaseolus vulgaris* L.)

Daiana Alves da Silva[1]*, Cecília Alzira Ferreira Pinto-Maglio[2], Érica Cristina de Oliveira[2], Raquel Luiza de Moura dos Reis[1], Sérgio Augusto Morais Carbonell[1], Alisson Fernando Chiorato[1]

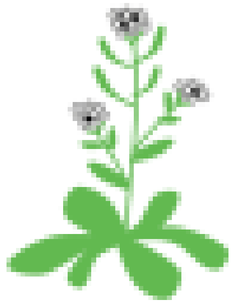
Theoretical and Applied Genetics (2020) 133:809–828
https://doi.org/10.1007/s00122-019-03508-9

ORIGINAL ARTICLE

Dmc1 is a candidate for temperature tolerance during wheat meiosis

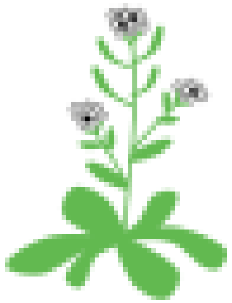
Tracie Draeger[1] · Azahara C. Martin[1] · Abdul Kader Alabdullah[1] · Ali Pendle[1] · María-Dolores Rey[2] · Peter Shaw[1] · Graham Moore[1]

What Can Be Done Using Model Plants



135 Mb genome
Ideal for forward
genetic mutagenesis
screens

What Can Be Done Using Model Plants



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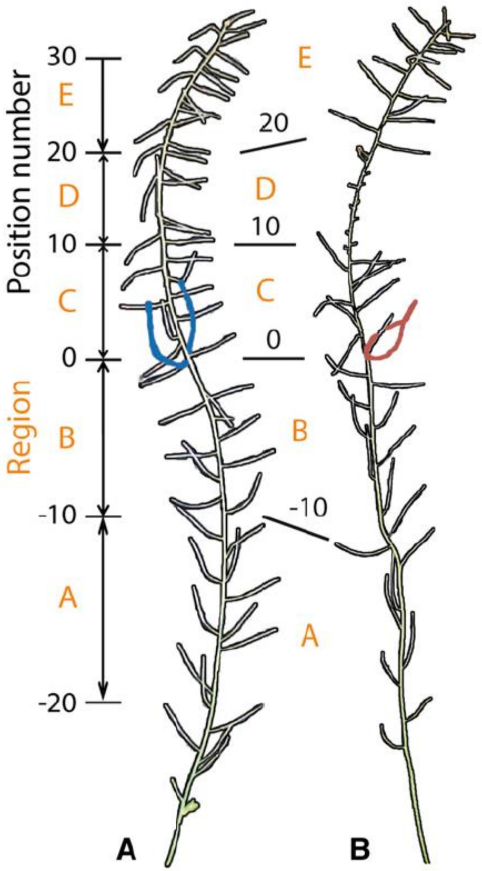
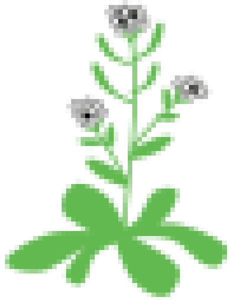


Bac-Molenaar et al. 2015

What Can Be Done Using Model Plants



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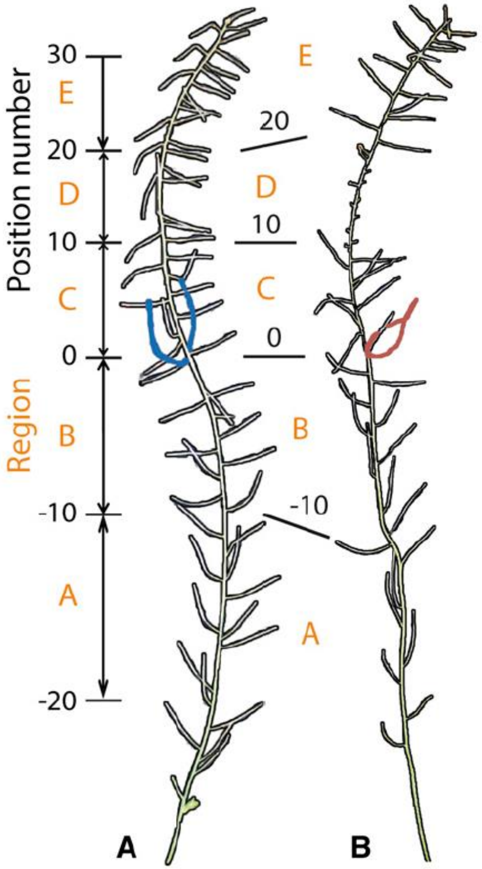
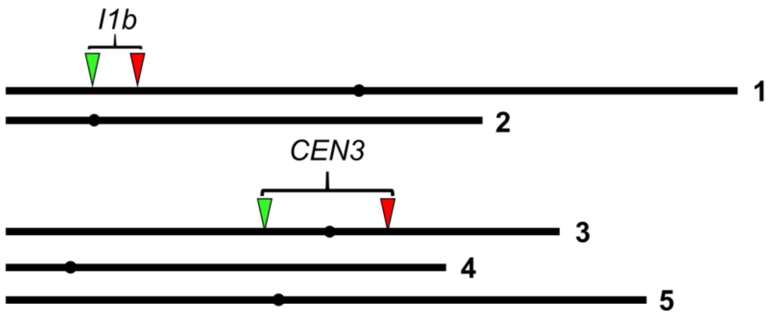
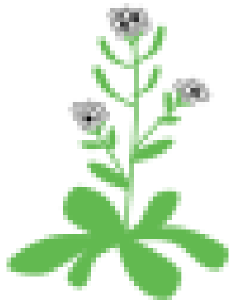


Bac-Molenaar et al. 2015

Look for mutants that retain fertility despite heat stress

What Can Be Done Using Model Plants

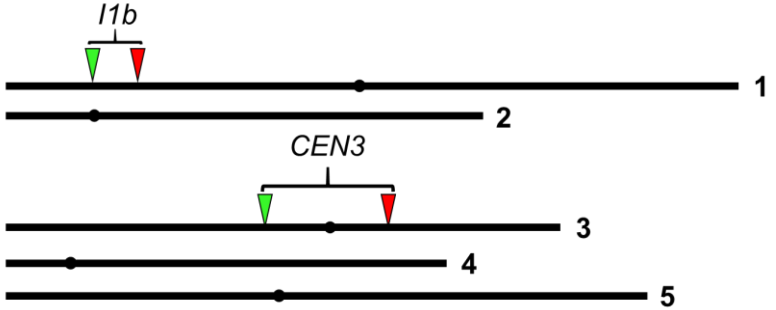


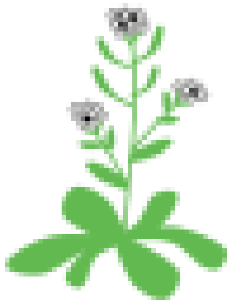


135 Mb genome
Ideal for forward genetic mutagenesis screens

Fluorescent pollen markers developed by Prof Greg Copenhaver's lab

What Can Be Done Using Model Plants





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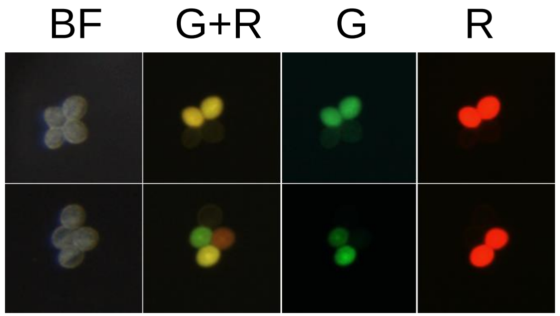
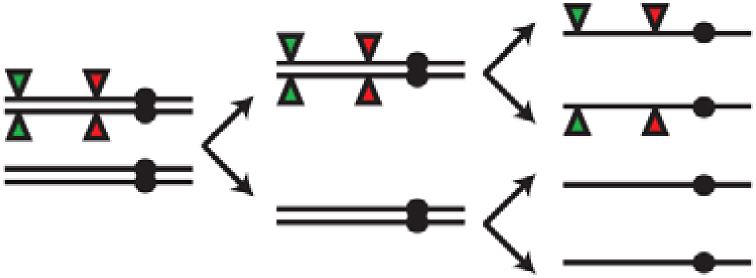
Ideal for forward genetic mutagenesis screens

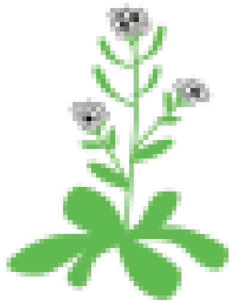


pollen



Yelina et al. 2012

What Can Be Done Using Model Plants



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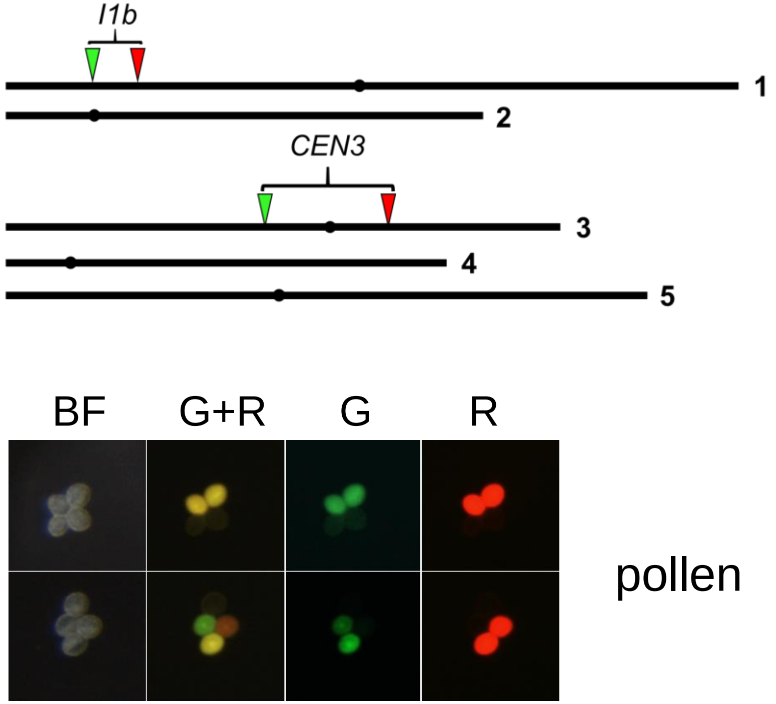
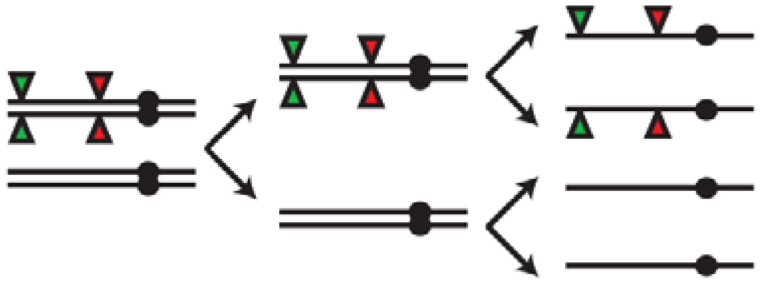
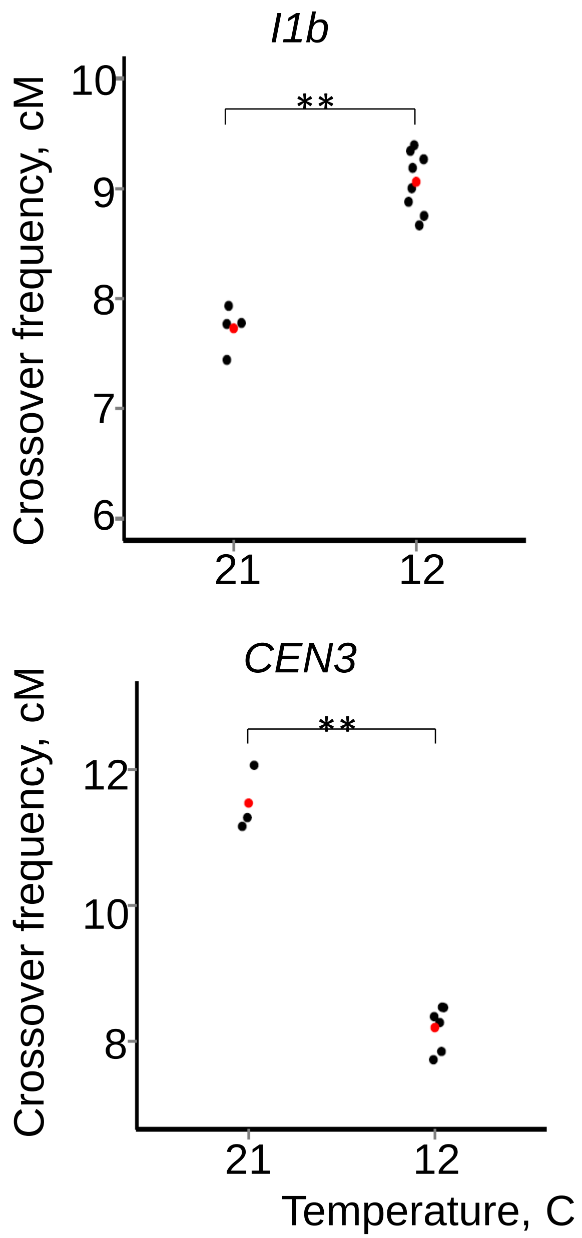


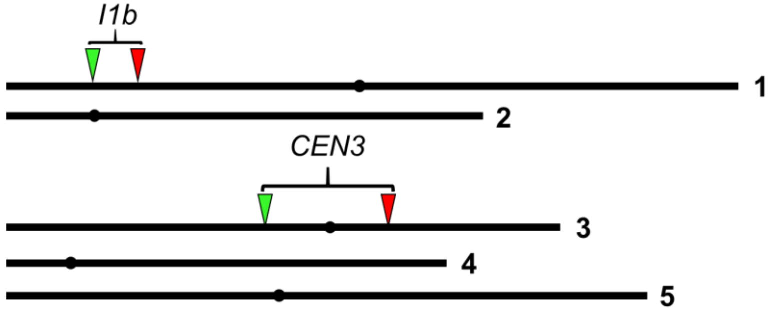


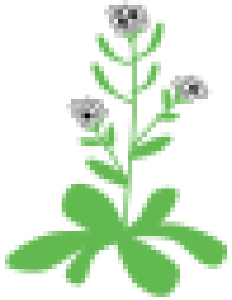


Lloyd et al. 2018
Modliszewski et al. 2018

Yelina et al. 2012

What Can Be Done Using Model Plants





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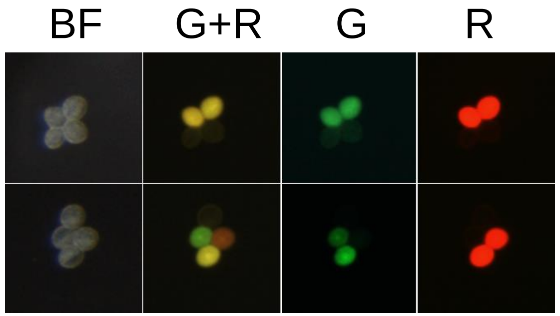
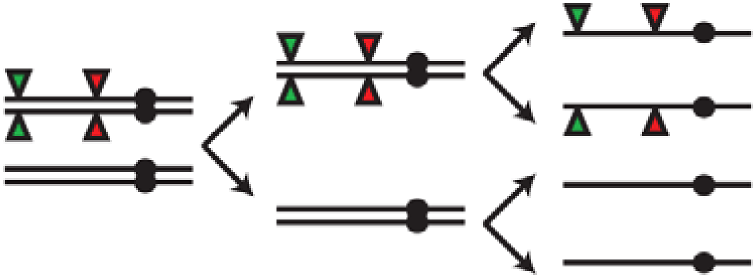


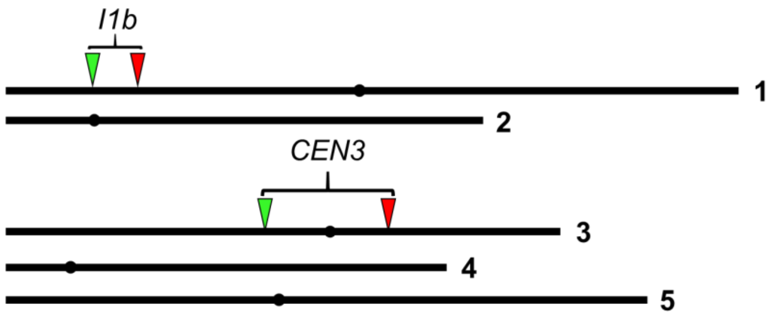
pollen

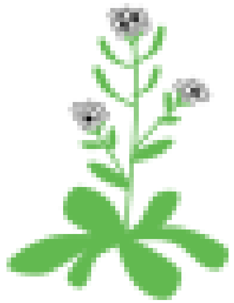
Identify mutants where crossovers are insensitive to temperature changes



Yelina et al. 2012

What Can Be Done Using Model Plants





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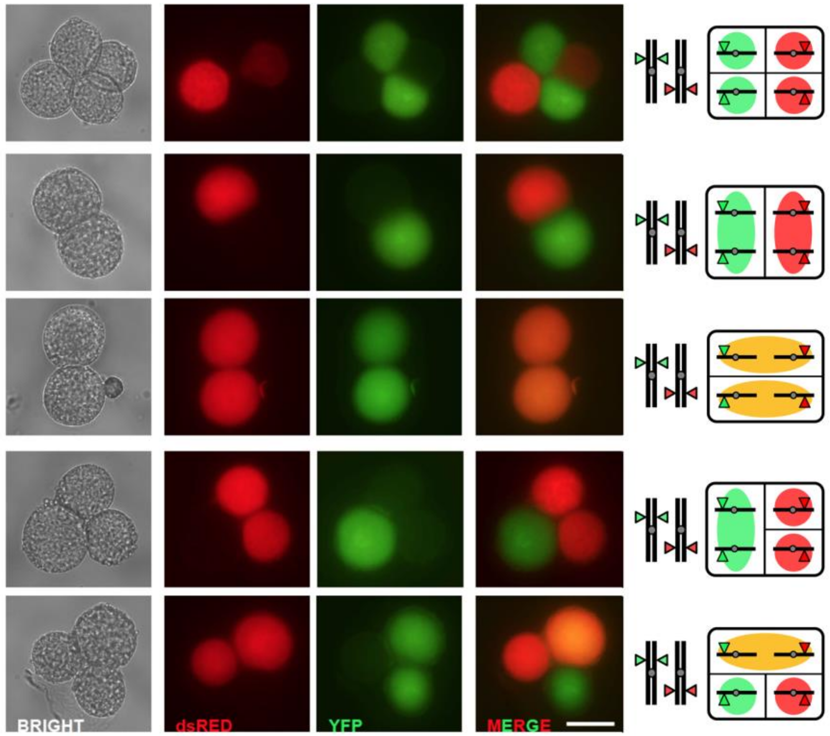
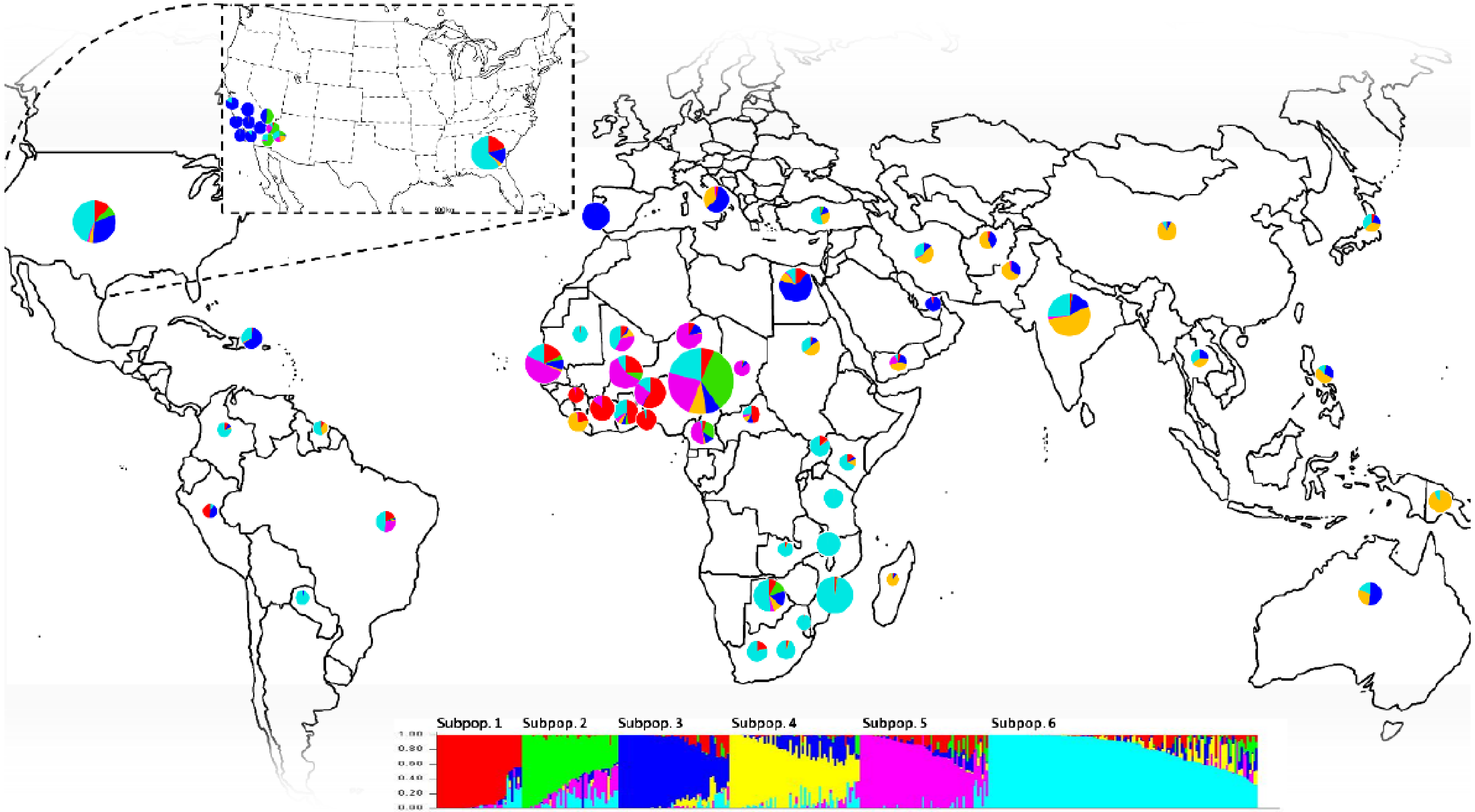


Storme and Geelen 2020

Identify mutants that do not have abnormalities in cell divisions and ploidy

What Can Be Done Exploiting Natural Variation



Understand molecular mechanisms of natural adaptation to heat stress during reproduction

Muñoz-Amatriaín et al. 2021

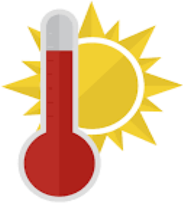
Overarching aim:

Understand mechanisms

Use this knowledge to engineer resilient crops

Address food security

Summary



- Fertility is affected by temperature in many species
- Meiosis defects contribute to infertility due to temperature stress
- Reduced fertility due to temperature stress has direct relevance for agriculture
- Forward genetics and natural variation studies are powerful approaches to understand and engineer crop resilience