 

# The CSIRO breeding program

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www.csiro.au

# The Australian cotton industry

**The average Australian cotton farm:**

- is family owned and operated
- is run by growers with an average age of 39
- grows 495 hectares (1200 acres) of cotton, comprising 17% of the total farm area
- supplements cotton with other crops including wheat, chickpeas and sorghum, and many Australian cotton farmers also graze sheep and cattle

- 30% is cotton is produced on corporate farms, the largest has 22,000 ha of irrigated cotton (54,000 acres).




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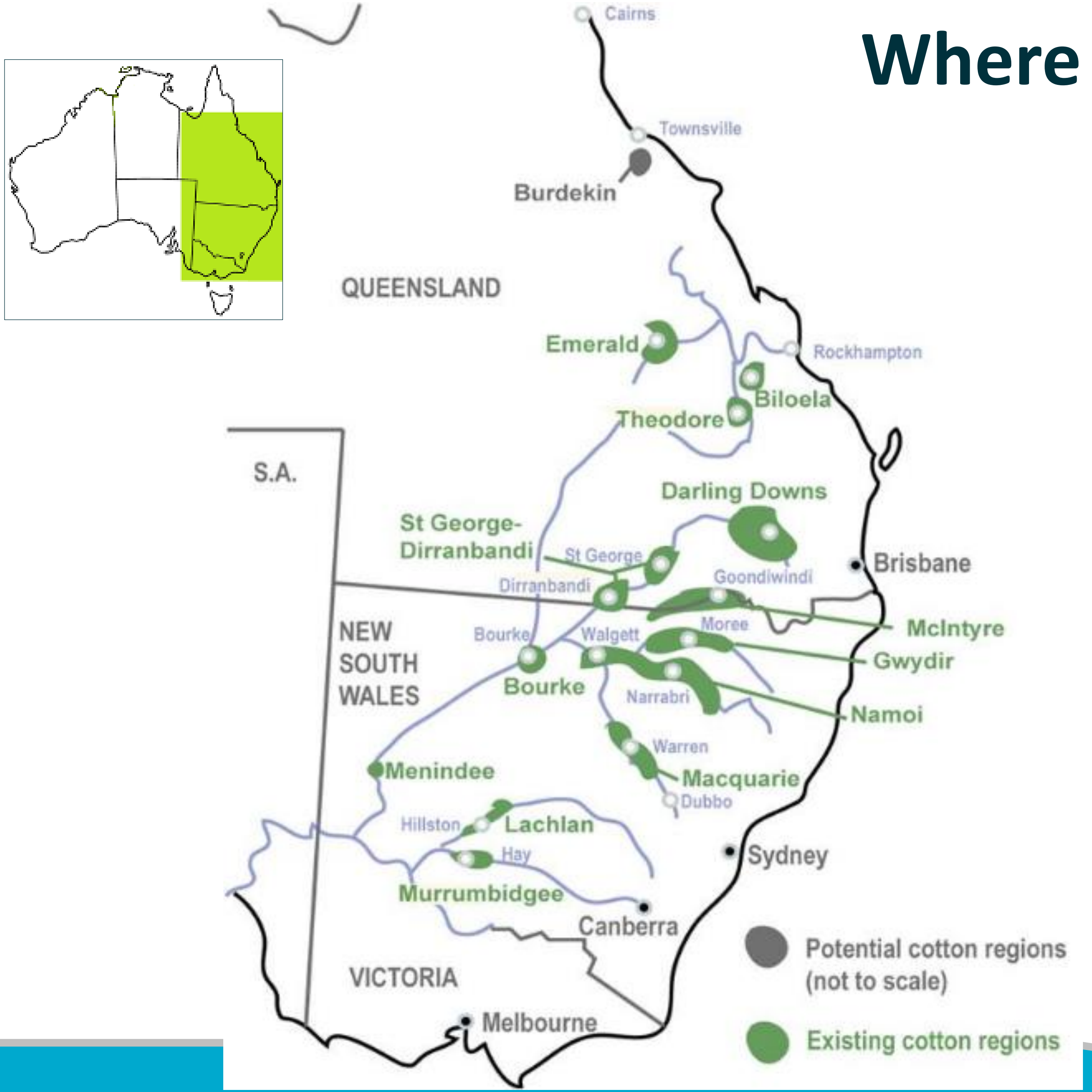
# The Australian cotton industry

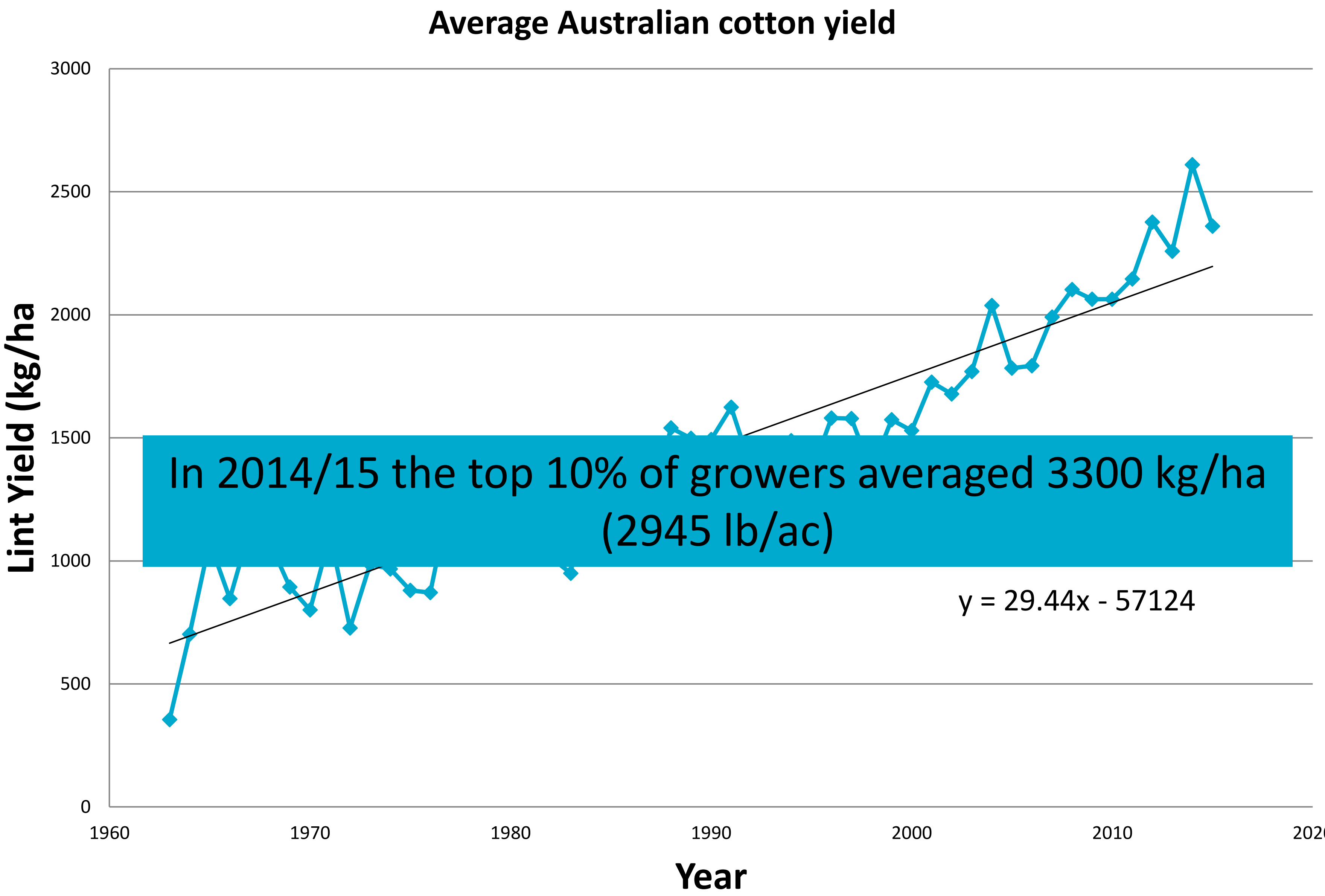
- There are only around 1500 cotton farms
- Total area between 200K and 600K ha (500K and 1.5M acres)
- 80% fully irrigated, 20% rainfed (dynamic)
- Average yield 2014/15 was 2610 kg/ha (2330 lb/ac)

**Characterised by:**

- Young industry (growers are second or third generation)
- High proportion of tertiary education
- Professional farmers that rapidly adopt new technology

# Where is cotton grown?

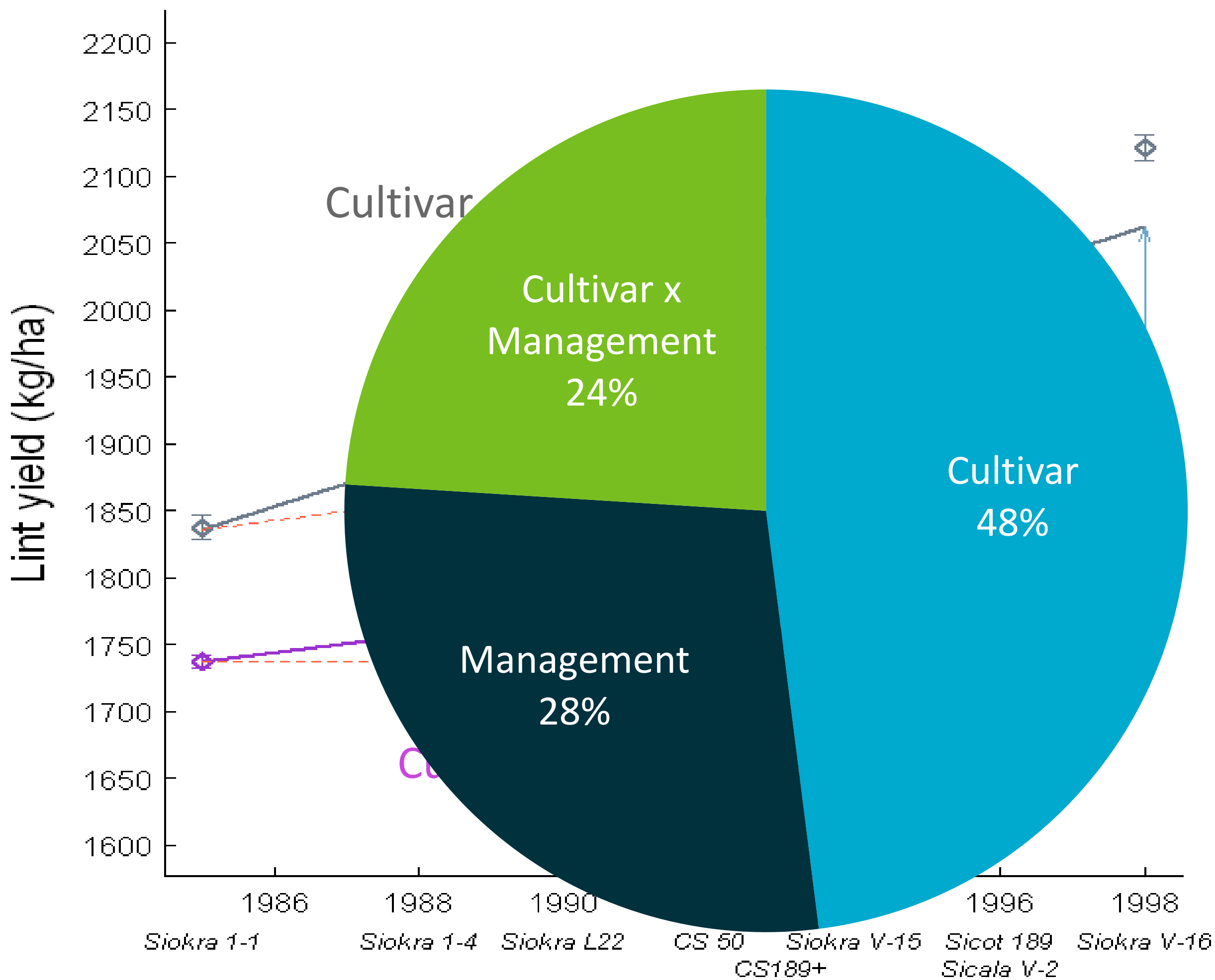



Average Australian cotton yield
3000
2500
2000
1500
1000
500
0
1960
1970
1980
1990
2000
2010
2020
Lint Yield (kg/ha)
Year
y = 29.44x - 57124
In 2014/15 the top 10% of growers averaged 3300 kg/ha (2945 lb/ac)

# Other facts

- Since the mid 2000's, all cotton grown in Australia is GMO
  - ~95% was Bollgard 3/RRF in 2016/17
- Since 2009 all cotton grown in Australia has been bred by CSIRO

# Yield gain due to variety, management & their interaction




# Cotton Breeding – Objectives

**Through novel research and applied plant breeding develop Australian cotton varieties with the package of:**

- increased yield
- fibre quality preferred by international spinners
- resistance to all important diseases
- widely adapted
- with GM traits of importance.

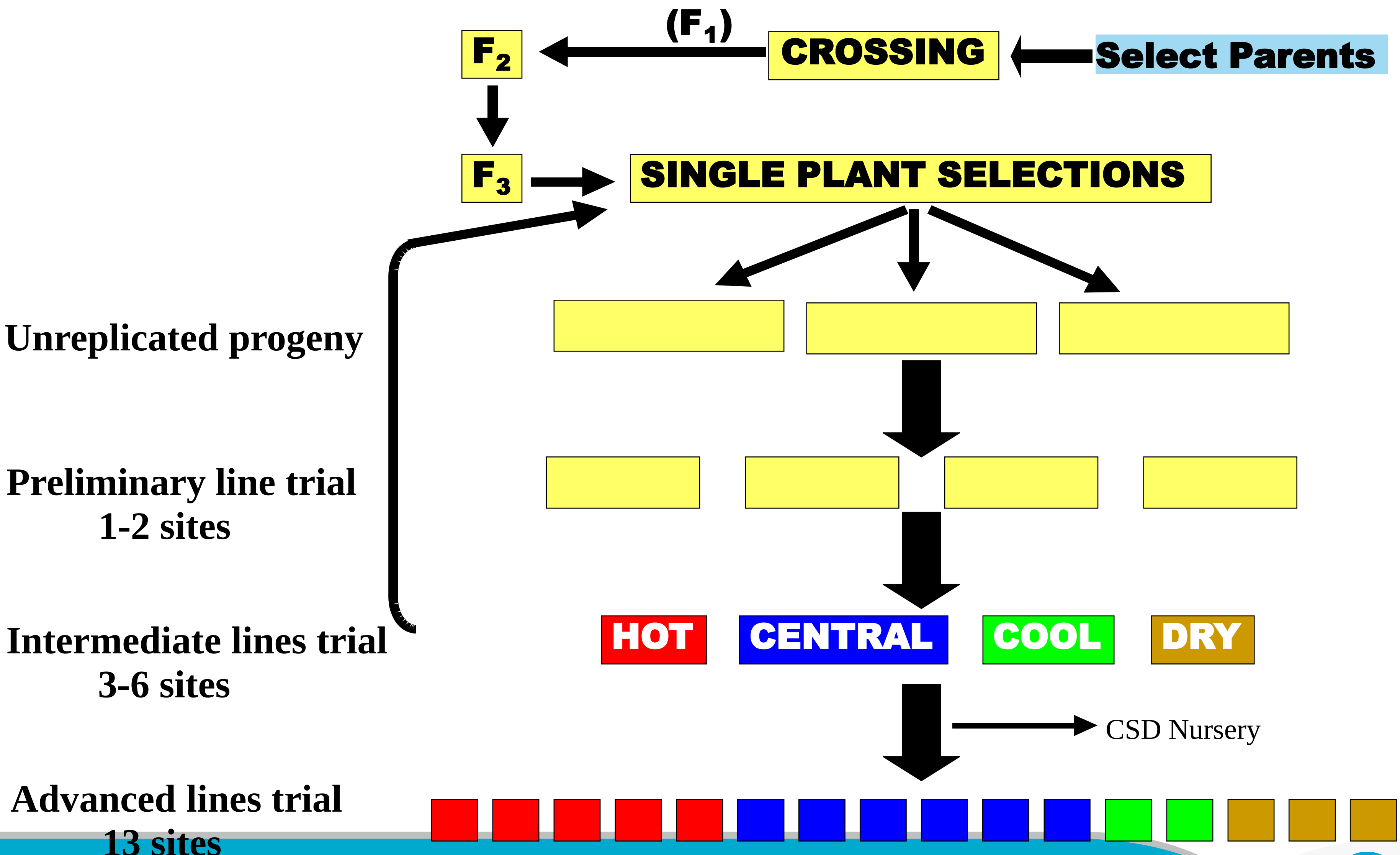
**Achieved through the integration of traditional breeding and modern tools**

# Trial sites, area and technology


| Site | B3XF | B3F | RRF | Conv | Total |
|---|---|---|---|---|---|
| Coleambally | | 1.7 | | 1.2 | 2.9 |
| Hillston | | 2.7 | 1 | 7.2 | 10.9 |
| Warren | | 2.7 | | | 2.7 |
| Moree Norwood | | 3.6 | 0.4 | 4.4 | 8.4 |
| Goondiwindi | 1.1 | 3.6 | 1 | 7.5 | 13.2 |
| CSD Farms | | | 1 | 3.2 | 4.2 |
| Maules Ck Verticillium | | | | | |
| Locharba | 0.2 | | | | 0.2 |
| ACRI | | 7 | 1 | 19.5 | 27.5 |
| Field L2 (Leitch) | 4.2 | 2.7 | 0.7 | 20.9 | 28.5 |
| Total | 6.6 | 36.1 | 6.4 | 77.9 | 127 |

**40,000 plots plus 25,000 single plants each season**

# Breeding method (Pedigree)



# CSIRO cotton: a fully integrated continuum

**Time to delivery as fixed variety**

Basic research → Applied research → Variety delivery

| Fibre biol/traits | Markers | Host Plant Res | CBT marker | Breeding |
|---|---|---|---|---|
| ***MYB*** | Genomics | **Abiotic stress** | Trait screen | *Yield* |
| ***PME*** | Sequencing | **Yield/quality** | | *Disease res* |
| ***NAC*** | | Low fibre attachm't | Input of third party traits | *Quality* |
| ***Designer fibre*** | | Disease resistance | | |
| ***Fibre mutants*** | | Sodic v nutrition | | |
| | | Herbicide res mutants | | |
| | | Introductions | | |
| | | Breeding methods and practices | | |

Strategic ideas →

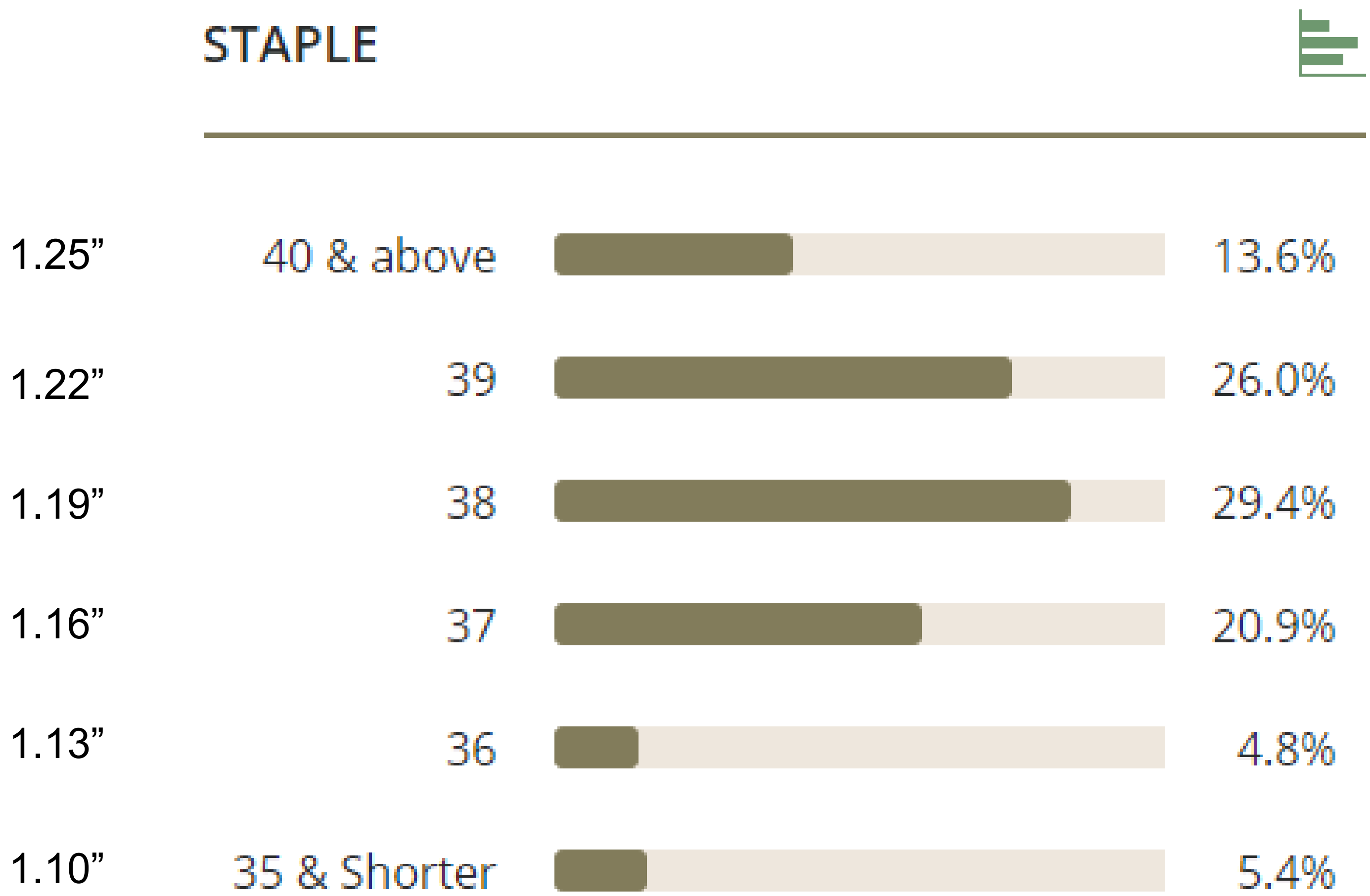
← Strategic ideas

**Collaboration with crop management and post harvest research groups**

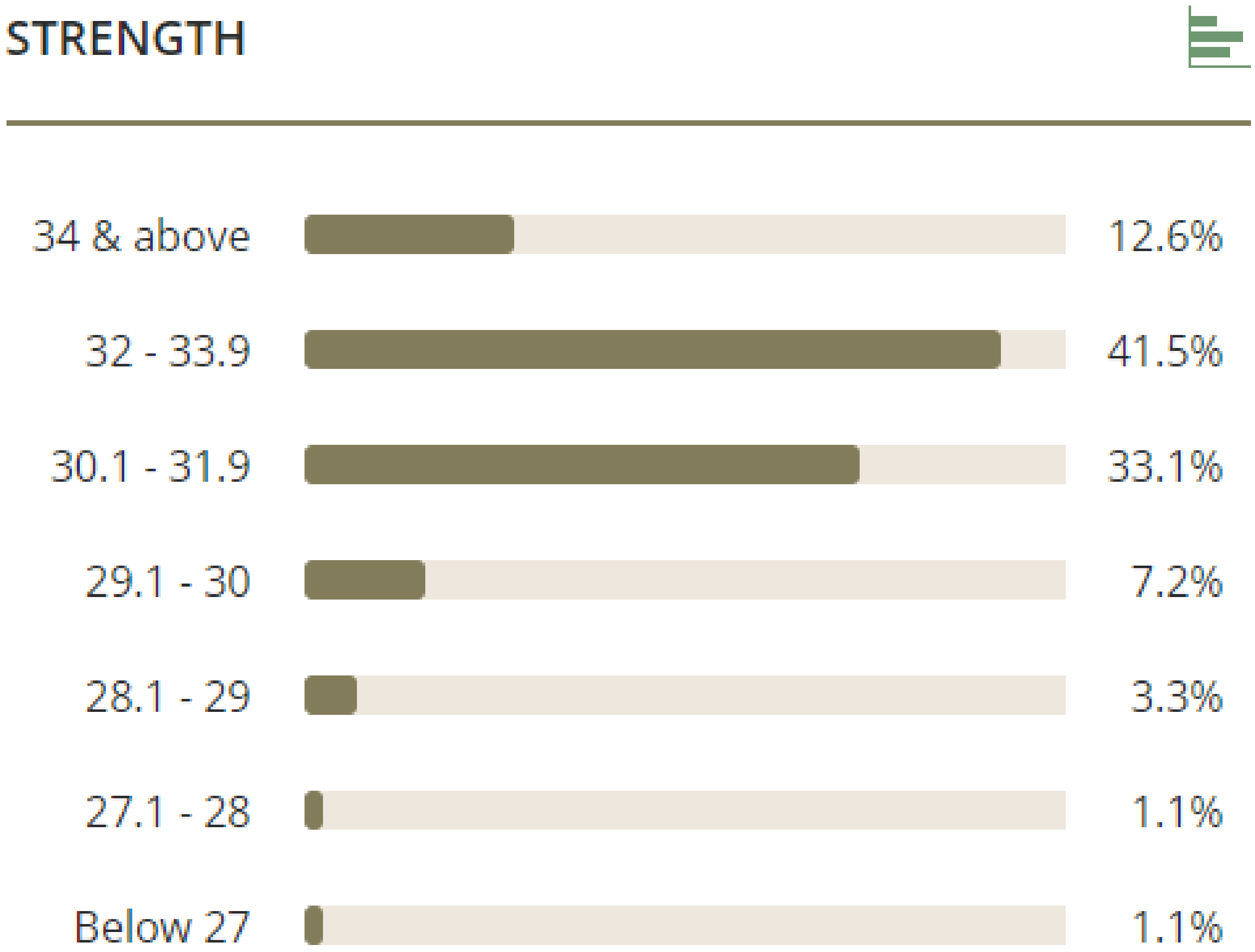
# Current activities

- Yield improvement
- Fibre quality
- Host Plant resistance
  - Disease resistance (Fusarium wilt, Verticillium wilt, Cotton Bunchy Top, Black Root Rot)
  - Two spotted spider mite, Silverleaf Whitefly
- Abiotic stress tolerance

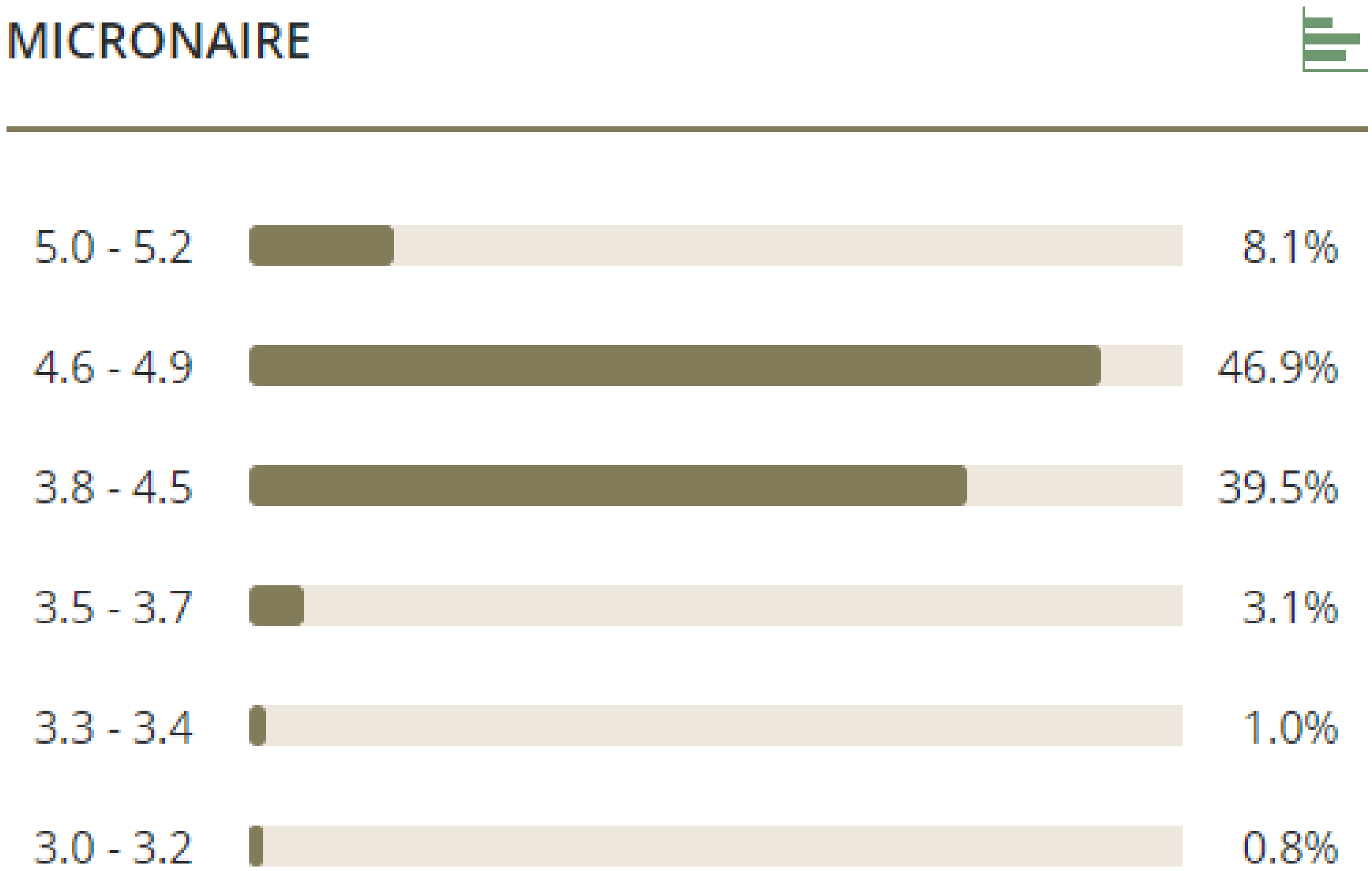
# Staple length 2016/17



# Strength 2016/17



# Micronaire 2016/17



# Fusarium wilt

# Verticillium wilt



# Black Root Rot

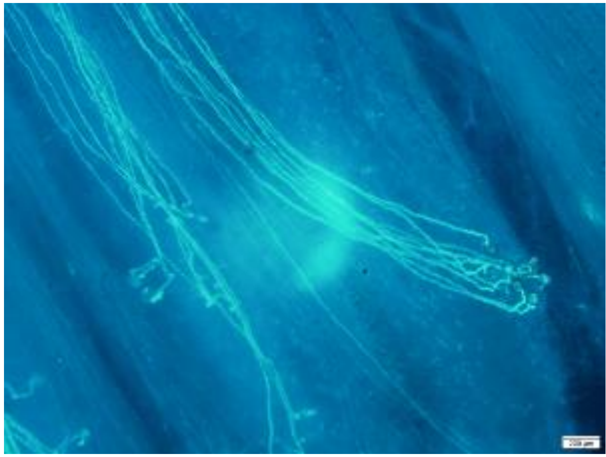
# Abiotic Stress

- Assays developed for pollen viability, fruit set & retention under heat stress
- Validate and refine the use of the canopy temperature for assessing crop water use
- Phenotype diverse cotton collection for heat tolerance

# Pollen viability studies

- Few studies have focused on cotton reproductive characteristics as a mechanism for stress tolerance, despite direct impact on fruit.

- *In vivo* study- method
  - Sicot 746B3F
    - Irrigated and rainfed water treatment
    - Elevated and ambient temperature
  - 0 DPA flowers (on four occasions)
    - Collected for microscopic analysis
    - Tagged to assess boll components

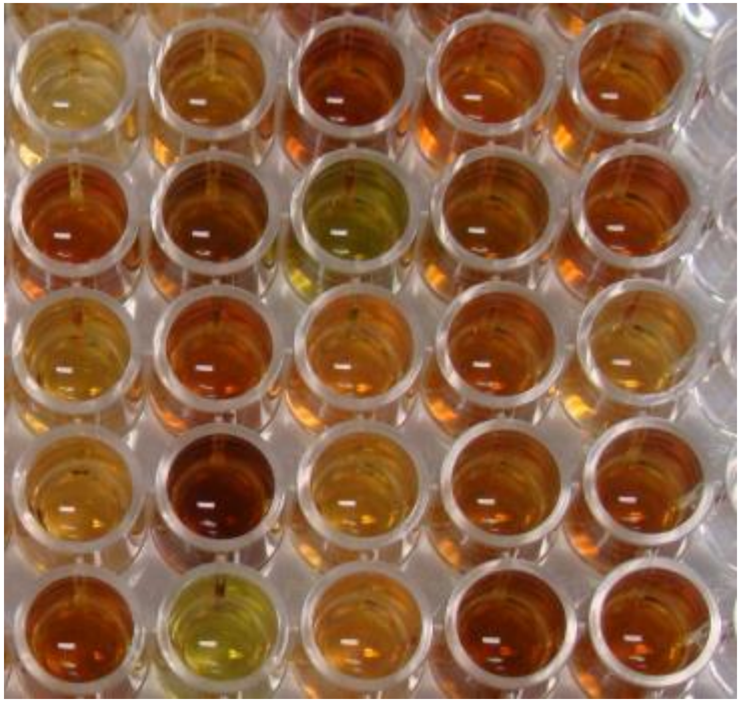


# Canopy temperature phenotyping

- Water-use efficiency measurements
  - Physiological: slow, laborious, low heritability (G x E interactions)
  - Crop level: inferred by soil water or weather data.
- No suitable indirect screening method has been developed for assessing the response of large populations of breeding material to water limited conditions.
- On an agronomic level, canopy temperature has been shown to relate to crop water use

# Heat tolerance assay

- Biochemical assay developed based on cell viability following an *in vitro* heat stress
- When live cells come in contact with a triphenyl tetrazolium chloride (TTC) solution, the TTC undergoes a chemical reduction producing a red product
- A higher absorbance value reflects more functional cells, thus the higher the tolerance of the plant to the stress.



# Rainfed breeding protocol

- Variable rainfall environment, opportunistic rainfed industry
  - Disconnect between target and testing environments, plus trial variability.
- Developed a Managed Stress Environment (MSE) protocol where a furrow irrigation is applied in years that testing environment does not match target environment
  - Based on crop simulation modelling and field validation
- Since 2015, selection under MSE at one location combined with offsite multi-location testing

# Keys to success

- Characterise the target environment
- Understand the marketplace
  - What do growers want/need
  - Academic studies are limited to those that contribute to variety development
- Long term view
  - Ensure what you are doing is important, then focus on it.
- Collection of accurate and reliable data

- Always look for efficiencies – smarter often beats bigger
- Nothing can substitute for hard work
- Engage with industry



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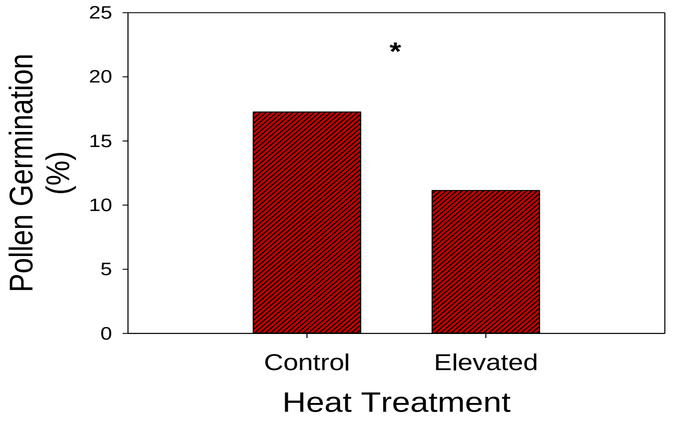
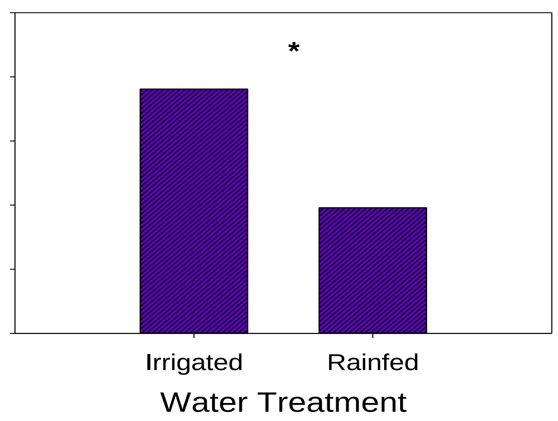
# Thank you

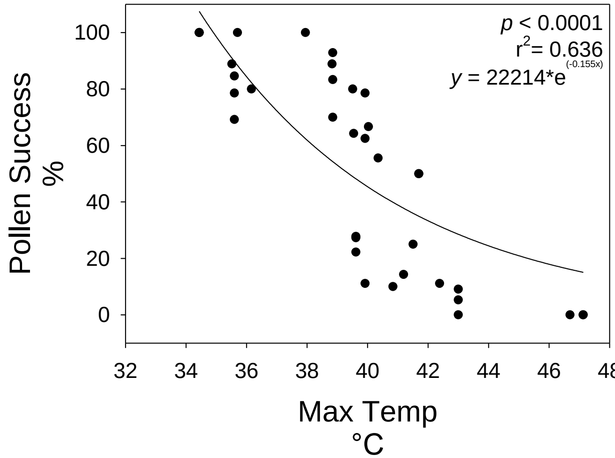
Dr Warwick Stiller
CSIRO Agriculture and Food

# Pollen viability studies

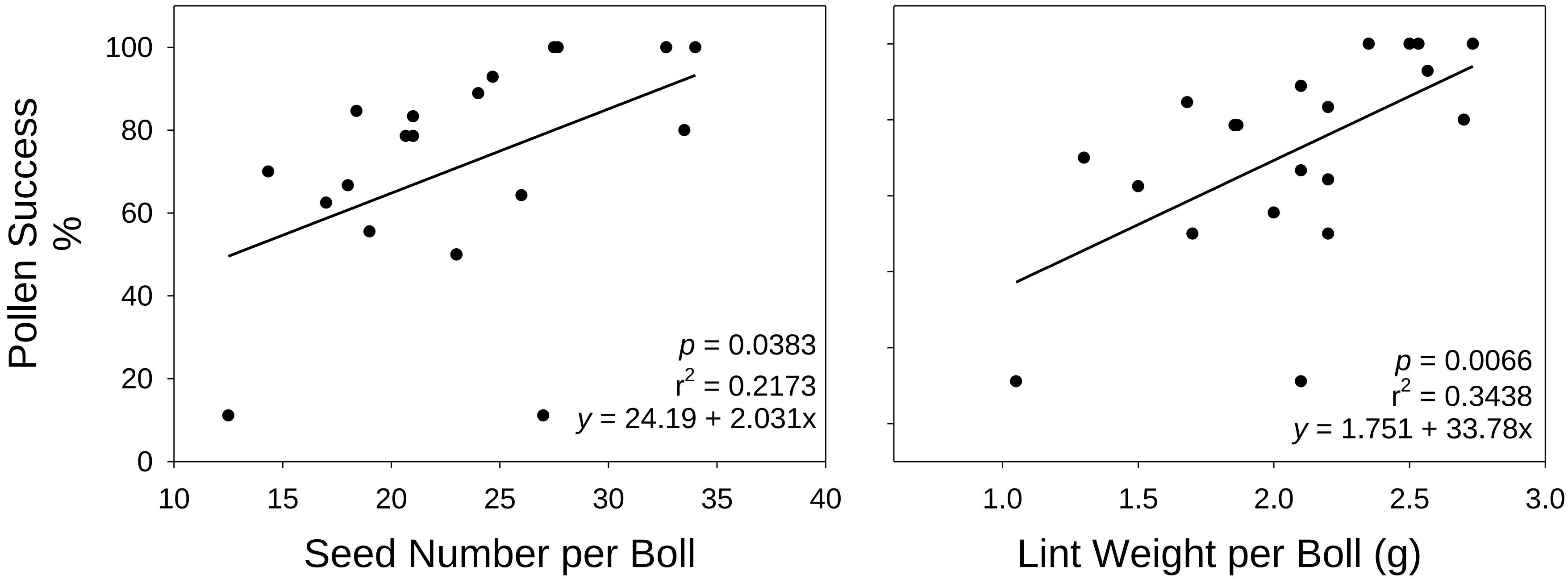
- Results (3 measurement dates)
- Temperature and water treatment significant
  - Elevated temperature reduced pollen germination ($p=0.021$) and water stress reduced pollen germination ($p<0.001$)
  - No temperature x water interaction
- Relationship observed between $T_{max}$ and VPD and likelihood floral stigma has germinated pollen
- Relationship between pollen viability and seed number / lint weight per boll



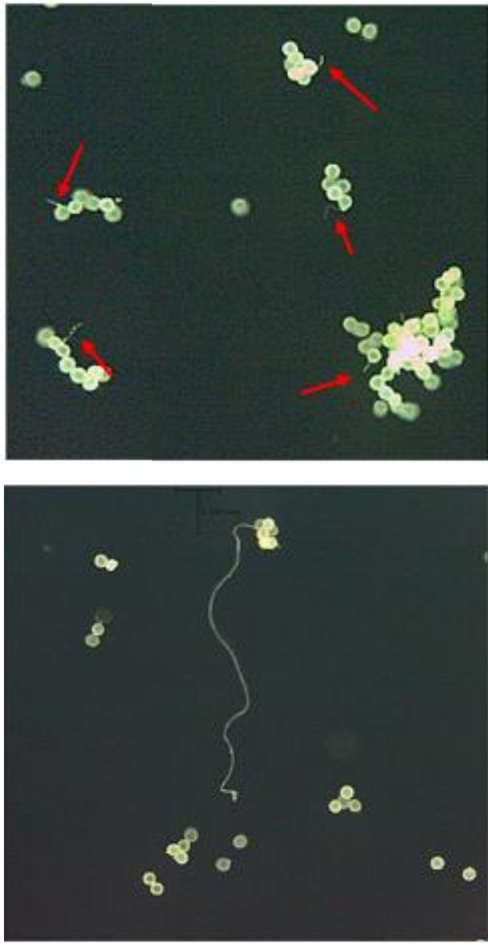



# Pollen vs. yield components



# Pollen viability studies

- *In vitro* study
- Refine media cocktail for pollen germination and growth, based on Kakani *et al.*, 2005.
  - Examples of a pollen tubes and differences in growth due to media cocktail.
    - Short pollen tubes (highlighted by red arrows; top)
    - Long pollen tube (bottom)
- Experimental phase will expose pollen on artificial media from a range of germplasm to elevate the effect of heat and humidity.



# Heat tolerance assay

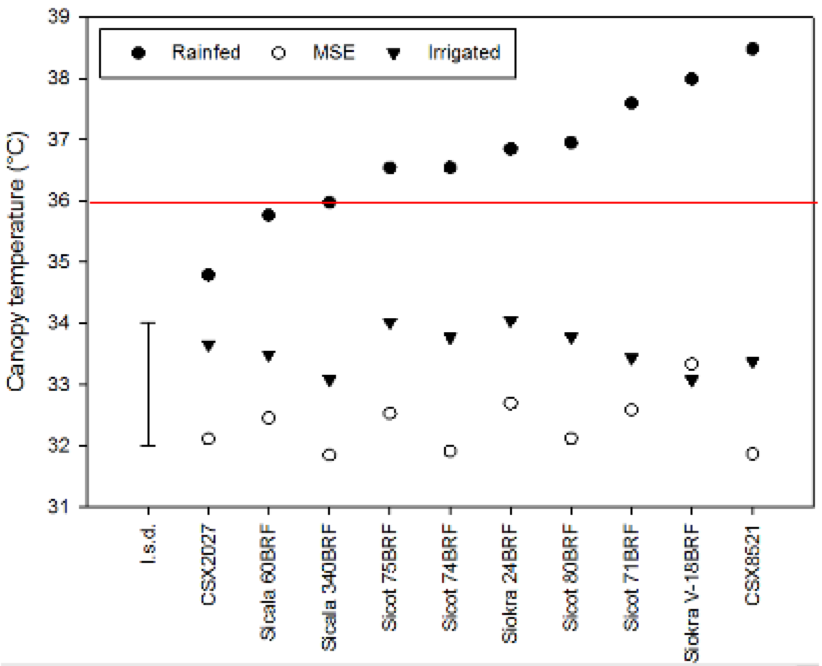
- Glasshouse study to assess assay:
  - 30 diverse genotypes of 4 species
  - 32/18°C; 5d heat wave 42/28°C
  - Study was replicated three times

| | P value | var. explained |
|---|---|---|
| Genotype | <0.001 | 0.56 |
| G x Experiment | <0.001 | 0.07 |
| G x Measurement | <0.001 | 0.13 |
| G x Temperature | <0.001 | 0.06 |

| Genotype | Abs40 | Rank Abs40 | RelAbs40 | Rank RelAbs40 | | 80:20 | 70:30 | 60:40 | 50:50 |
|---|---|---|---|---|---|---|---|---|---|
| Sicot 80 | 0.268 | 2 | 83.9 | 2 | | 1 | 1 | 1 | 1 |
| Acala Maxxa | 0.247 | 3 | 82.3 | 3 | | 2 | 2 | 2 | 2 |
| VH8-4602 (*G. barb*) | 0.213 | 10 | 91.4 | 1 | | 7 | 5 | 4 | 3 |
| CS 50 | 0.241 | 4 | 78.5 | 8 | | 3 | 3 | 3 | 4 |
| STV 825 | 0.219 | 9 | 80.4 | 5 | | 8 | 6 | 6 | 5 |
| DP 5415 | 0.240 | 5 | 78.1 | 10 | | 5 | 4 | 5 | 6 |
| Namcala | 0.209 | 12 | 81.6 | 4 | | 12 | 11 | 7 | 7 |
| Sicala V-2 | 0.211 | 11 | 78.9 | 6 | | 10 | 10 | 8 | 8 |
| Siokra L23 | 0.233 | 7 | 76.5 | 13 | | 9 | 9 | 9 | 9 |
| Sicot 53 | 0.239 | 6 | 73.9 | 15 | | 6 | 8 | 10 | 10 |
| Siokra V-16 | 0.208 | 13 | 78.3 | 9 | | 13 | 13 | 12 | 11 |
| Sicot 730 | 0.203 | 14 | 77.9 | 11 | | 14 | 14 | 14 | 12 |
| BM13H (*G. arboreum*) | 0.282 | 1 | 65.0 | 25 | | 4 | 7 | 11 | 13 |
| 64224-212 | 0.225 | 8 | 71.0 | 19 | | 11 | 12 | 13 | 14 |
| Pima A-8 (*G. barb.*) | 0.180 | 20 | 78.8 | 7 | | 17 | 16 | 15 | 15 |
| SG125 | 0.184 | 19 | 77.2 | 12 | | 18 | 18 | 17 | 16 |
| Sicala 40 | 0.203 | 15 | 71.7 | 18 | | 15 | 15 | 16 | 17 |
| CIM 496 | 0.202 | 16 | 72.1 | 17 | | 16 | 17 | 18 | 18 |
| Ersan92 | 0.175 | 21 | 74.7 | 14 | | 20 | 20 | 20 | 19 |
| CIM448 | 0.200 | 17 | 69.5 | 20 | | 19 | 19 | 19 | 20 |
| Sicala 45 | 0.149 | 27 | 72.4 | 16 | | 25 | 24 | 22 | 21 |
| SG248 | 0.174 | 22 | 68.5 | 22 | | 22 | 22 | 21 | 22 |
| ST474 | 0.157 | 24 | 66.7 | 23 | | 24 | 23 | 24 | 23 |
| YZ (*G. arboreum*) | 0.198 | 18 | 56.5 | 30 | | 21 | 21 | 23 | 24 |
| DP5111 | 0.171 | 23 | 61.5 | 26 | | 23 | 25 | 25 | 25 |
| Simian 3 | 0.146 | 28 | 69.1 | 21 | | 28 | 28 | 27 | 26 |
| Sicot 71 | 0.150 | 26 | 65.4 | 24 | | 27 | 26 | 26 | 27 |
| STV468 | 0.156 | 25 | 60.7 | 27 | | 26 | 27 | 28 | 28 |
| BA119 | 0.132 | 29 | 59.1 | 28 | | 29 | 29 | 29 | 29 |
| *G. herbaceum* | 0.125 | 30 | 58.7 | 29 | | 30 | 30 | 30 | 30 |

# Canopy temperature

- CT-Multiscan platform




# Highlights and challenges

- An increased understanding of the effect of temperature and VPD on *in vivo* pollen viability, and its relationship to yield components. This provides a basis of the potential development of genotypes with thermotolerant pollen.
- Successful development of an *in vitro* heat tolerance pollen assay medium. Once optimisation of the media are completed, genotypes will be screened for pollen germination thermotolerance.
- Experimentation has validated the reproducibility and assisted in the interpretation of the heat tolerance assay data.

**Challenges:**

- Inconsistent results in measured canopy temperature phenotypes with the CT-multiscan. No genotype differences observed in UAV thermal imagery data from 2015.
- The high ambient temperatures experienced in the 2016/17 season affected the quality of experimental data collected, as non-stressed (control) comparisons cannot be made.
- The effect of early season glyphosate drift on the MSE and heat tolerance experiments has limited the results obtained in the 2016 season.