



Phenotyping from a breeder's perspective

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Forschungszentrum Jülich, Germany
ICG-3: Phytosphere
Jülich Plant Phenotyping Centre (JPPC)
Website: <http://www.jppc.de>

<http://www.plantphenomics.com/phenotyping2009>



www.csiro.au

Phenotyping from a plant breeder's perspective

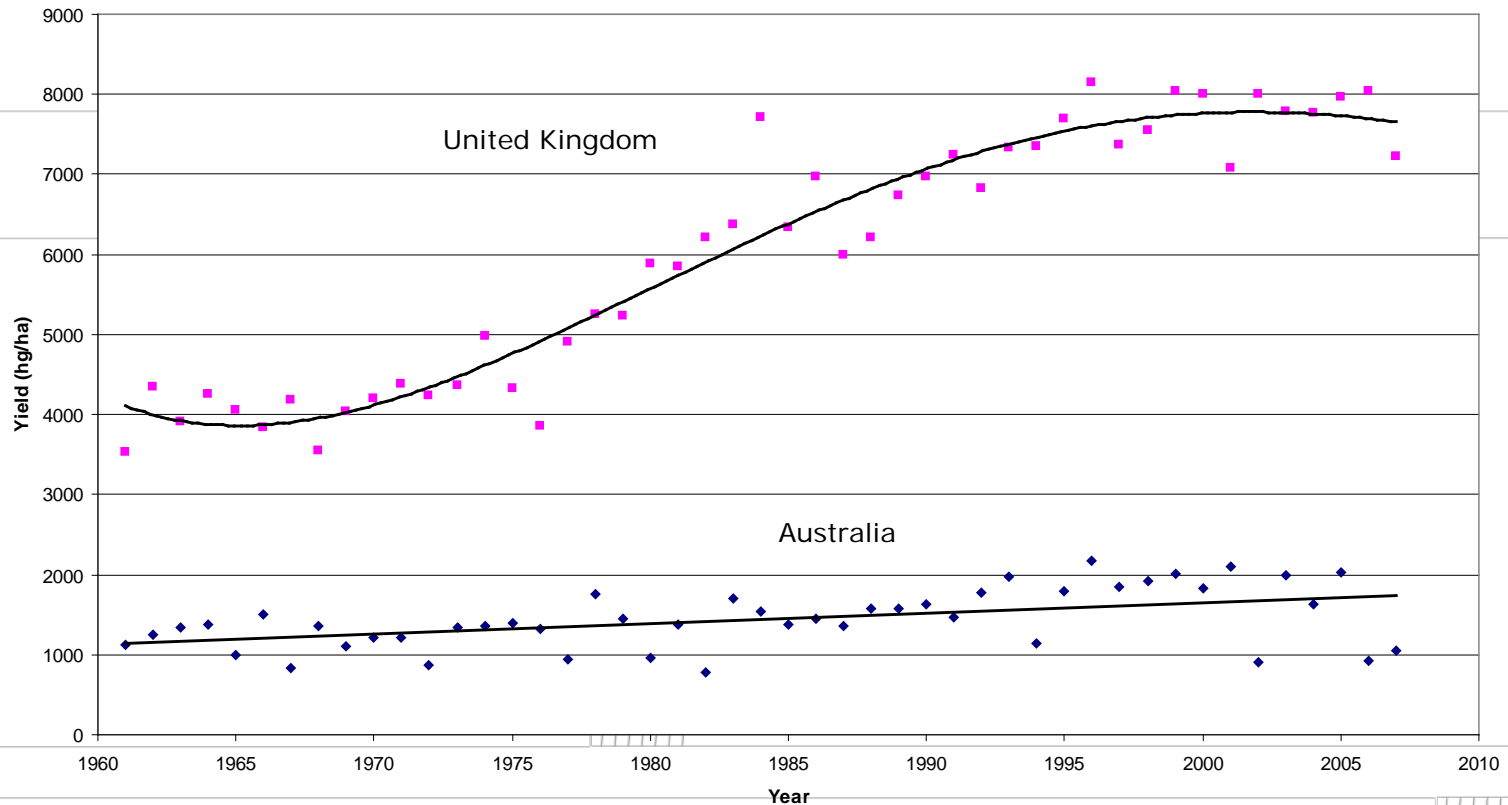
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**All the food produced today has
been developed using a
phenomics approach**

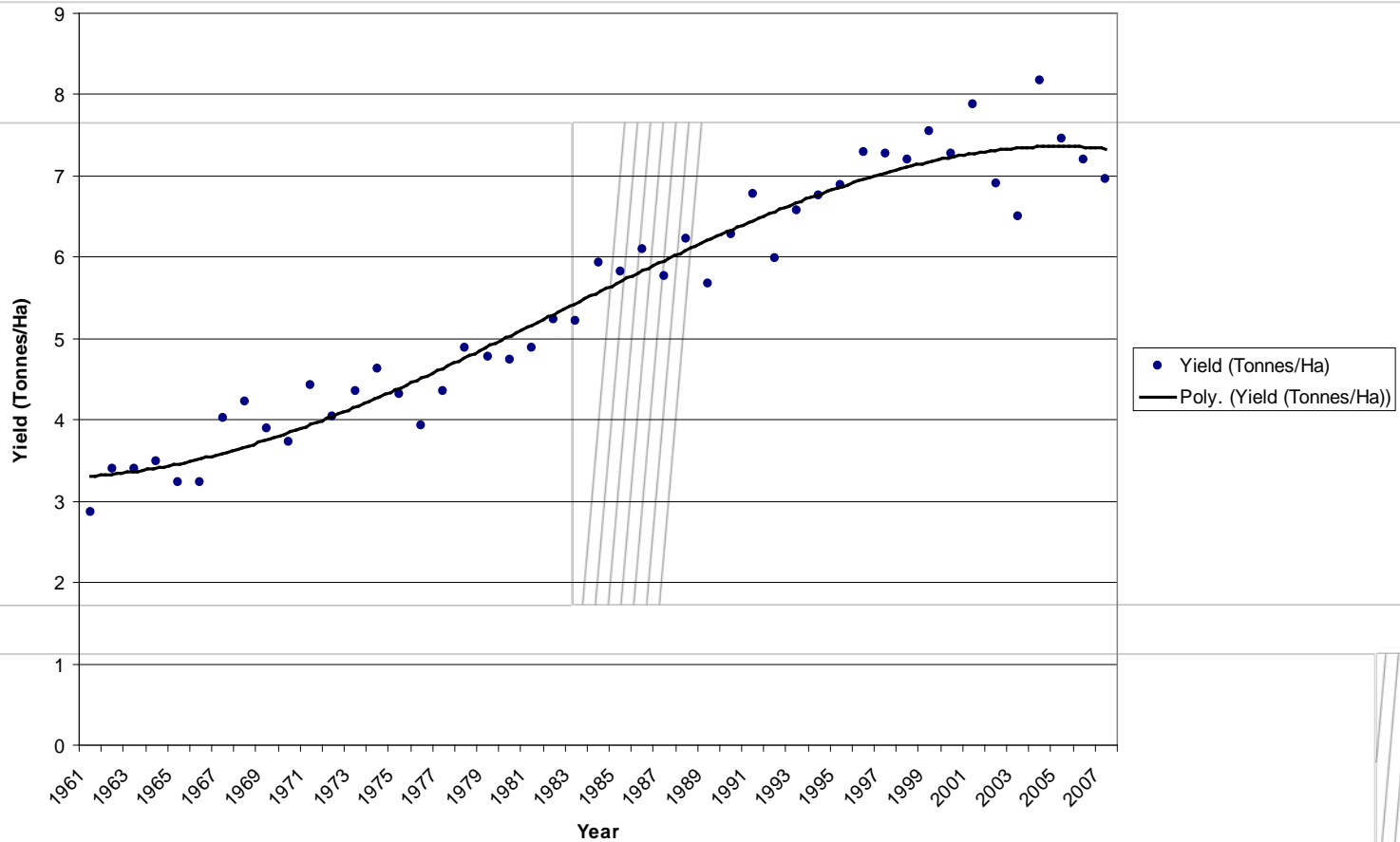
It is an amazing success story!

Wheat yield increase – progress over 60 years

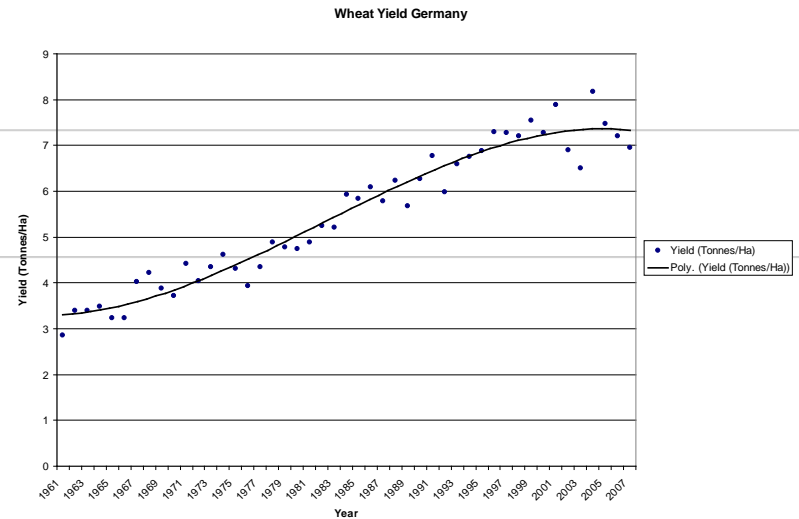
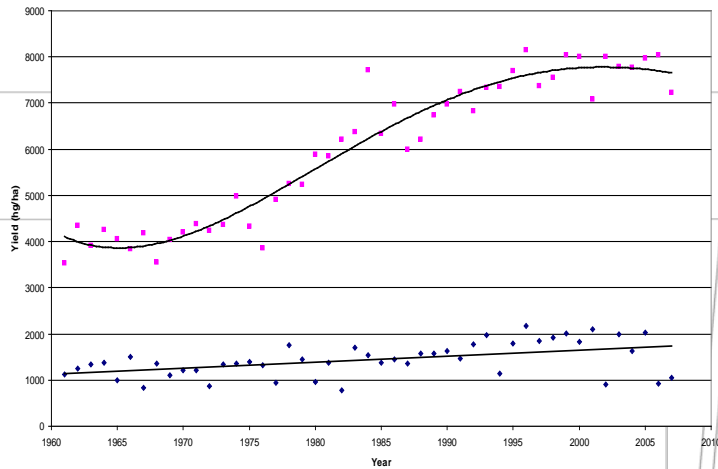


National average wheat yields from 1960 onwards for a country with plentiful rain and a mild climate (United Kingdom, ■) and for a country with a water-limited environment (Australia, ◆) (Source: FAOSTAT)

Wheat yields in Germany over 50 years



Towards smarter breeding



Australia

To increase yields in the future we have to be smarter

So far the recent –omics revolutions have not delivered to plant breeders!!!

CAN THE NEW PHENOMICS???



What do plant breeders select for?

- **Grain yield**
 - Traits that underpin yield
- **Performance under drought, acidity, salinity (abiotic stresses)**
- **Disease resistance**
- **Grain quality (eg oil%, protein content)**
- **Quality components (dough rheology, oil composition)**

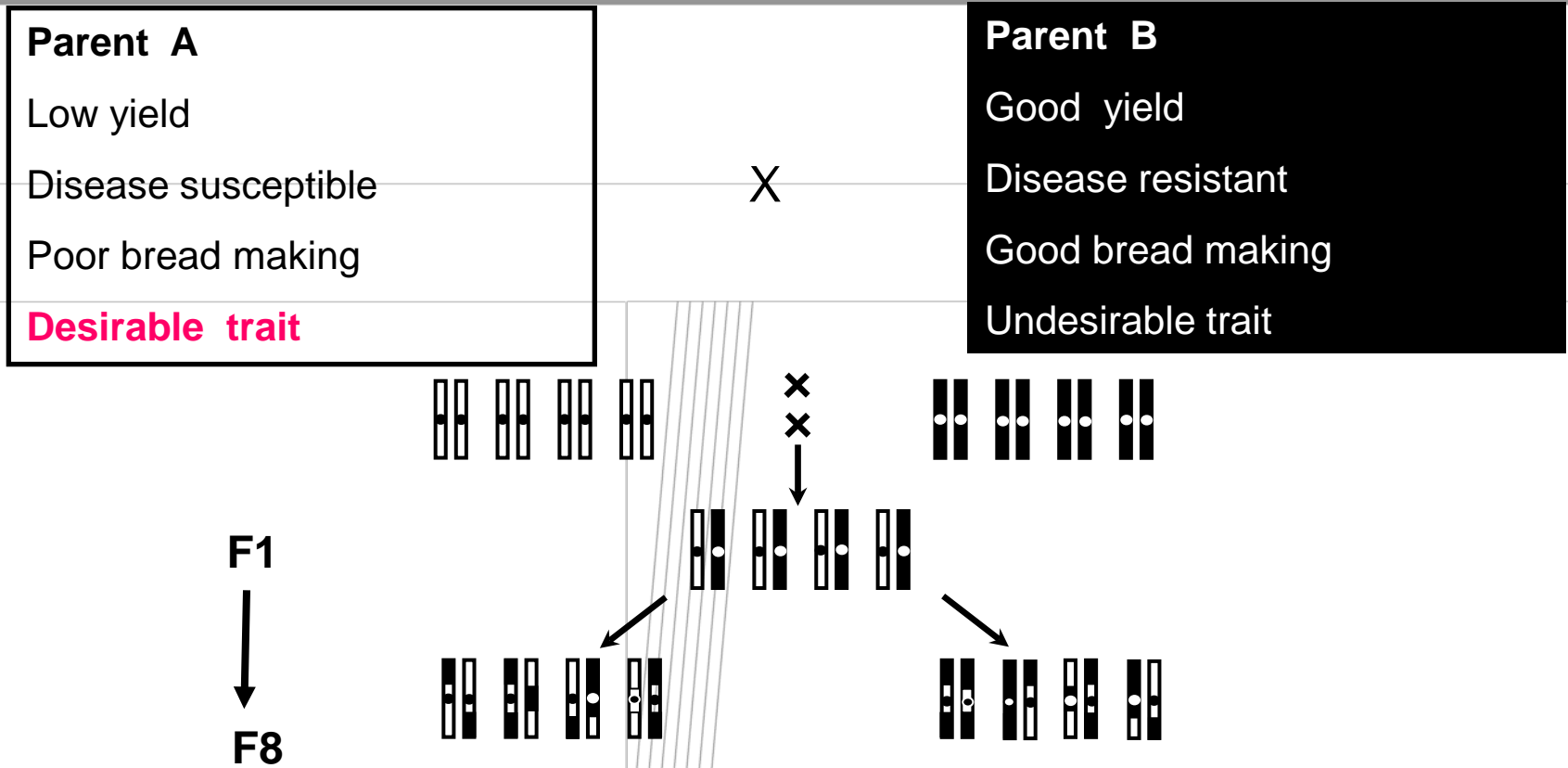
Breeders may have about 20 traits they select for

Breeding for improved yield

- direct selection for yield



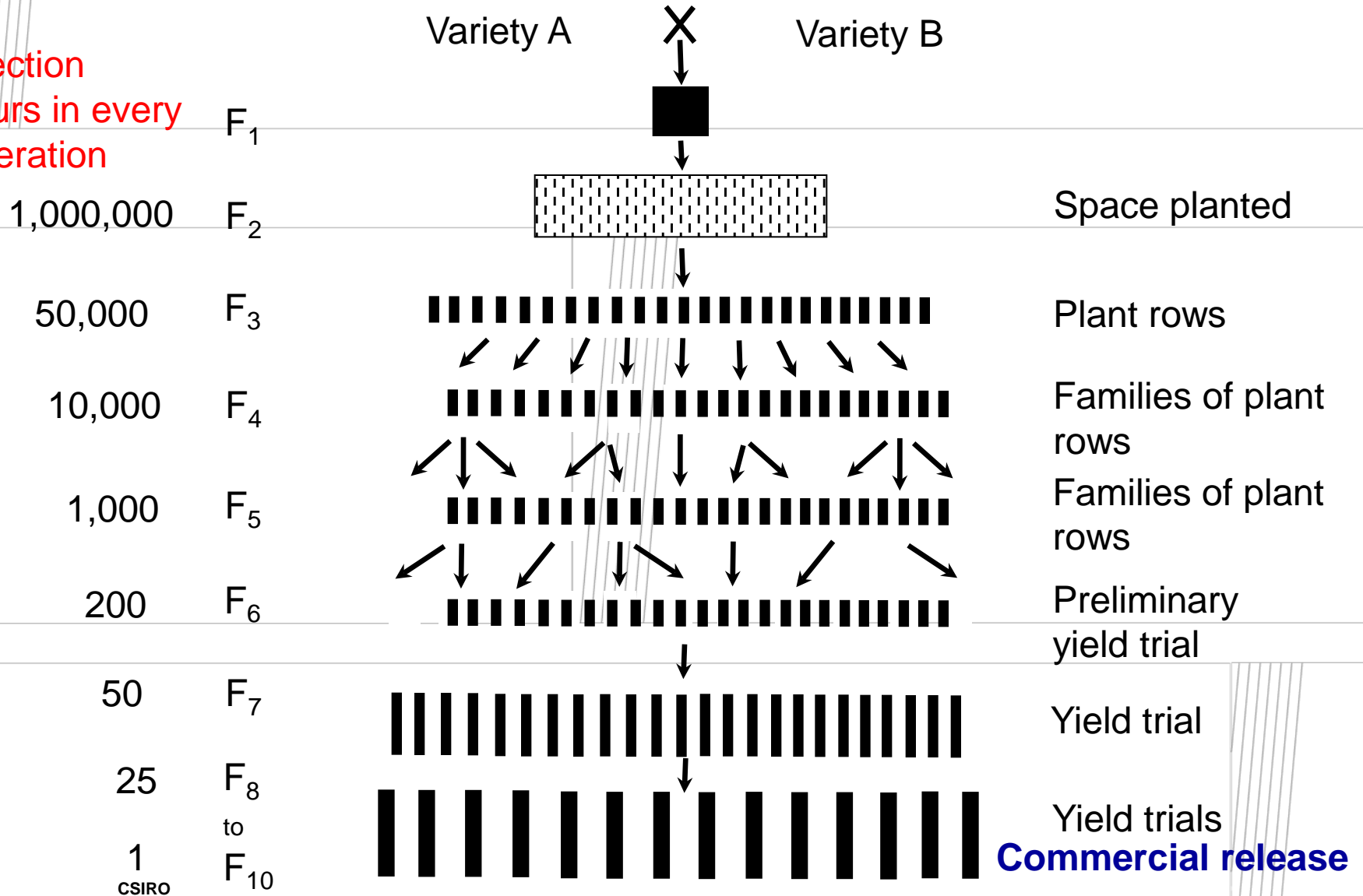
Selection for a desirable phenotype in a breeding program



And eventually a new variety with the desirable trait

A typical breeding program (eg wheat)

Selection occurs in every generation





**Can we select critical
underlying traits to improve
yield?**

Some of the advantages of designing crops for higher yields?

- **increase genetic variability for important traits**
- **faster gains in yield if the physiological trait has a higher heritability than yield**
- **more cost effective than yield evaluation**
- **out of season selection, ie more generations per year**
- **more amenable to marker-assisted selection**
- **lead to pyramiding multiple yield enhancing traits.**

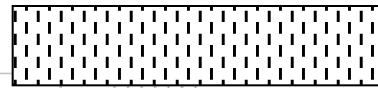
Selection for a desirable phenotype in a breeding program

Selection for a desirable phenotype in a breeding program

P is a desirable phenotype

Variety A +P X Variety B -P

Select for P F₂



Space planted

Select for P F₃



Plant rows

F₄



Families of plant rows

Select for P F₅



Families of plant rows

F₆



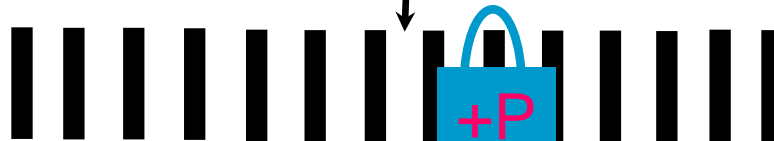
Preliminary yield trial

F₇



Yield trial

F₈



Yield trials

Commercial release

Some examples of trait selection

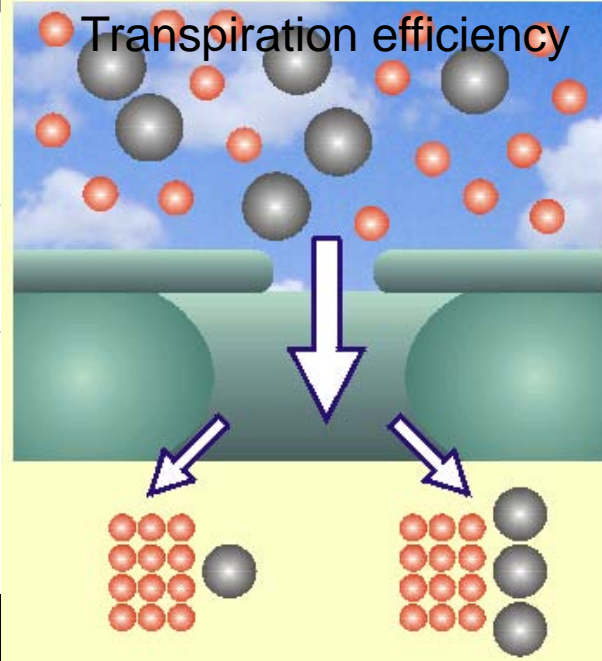
What are the most important traits to improve water productivity of cereals?

Traits for greater water – productivity (drought)

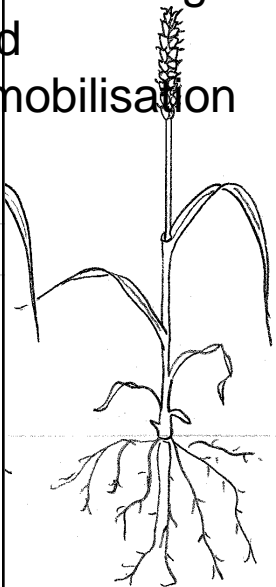
New dwarfing genes



Early vigour



CHO storage and remobilisation



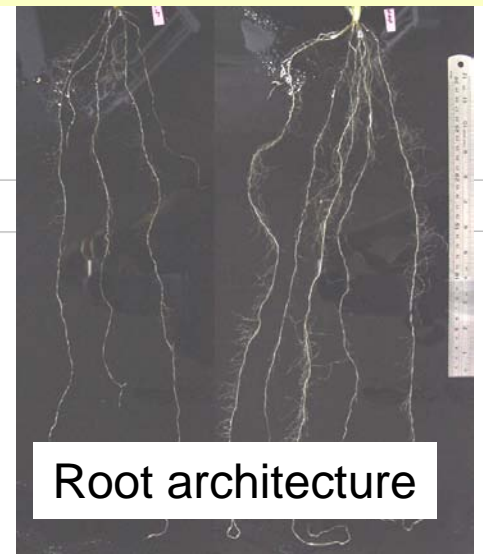
Tillering



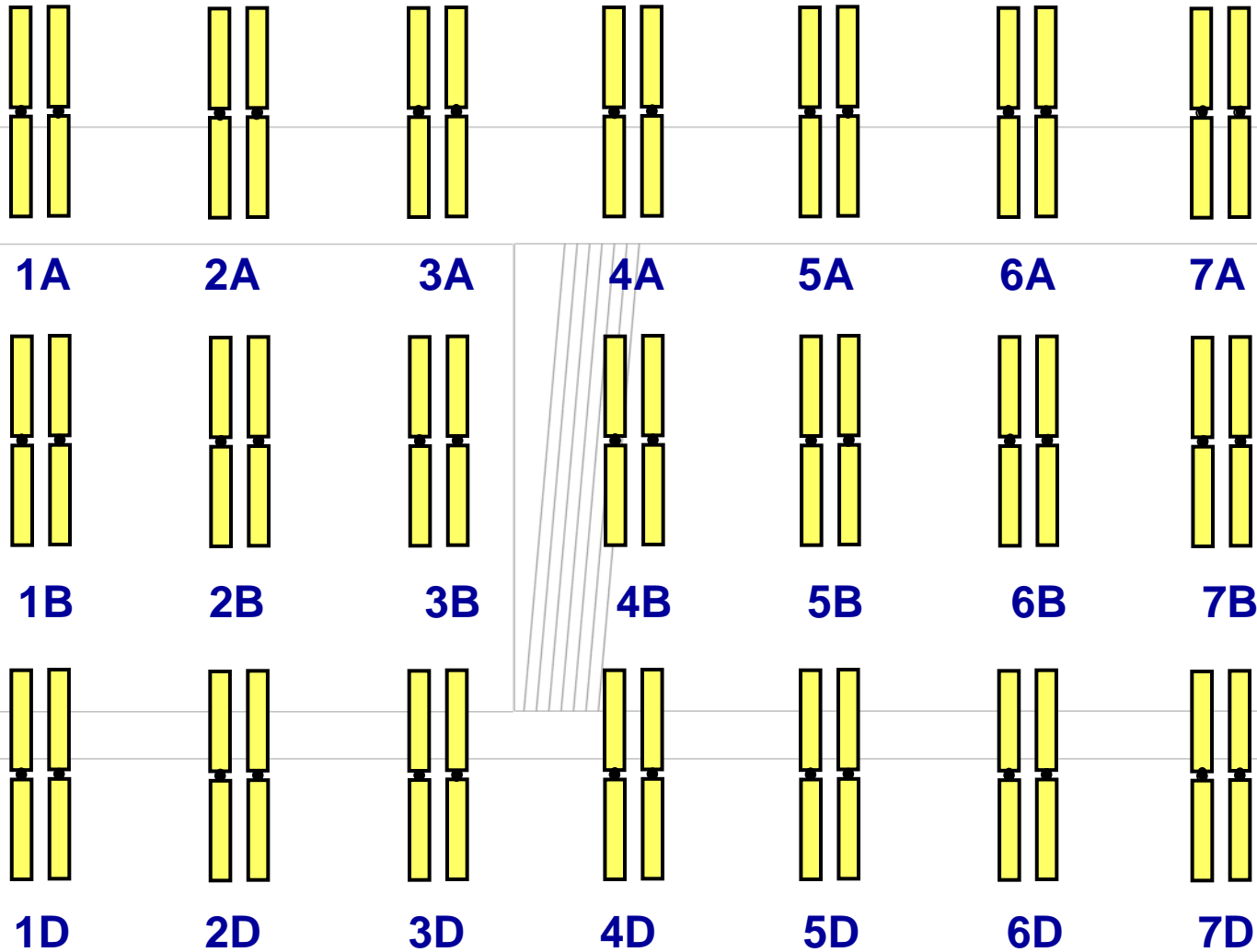
Glaucousness



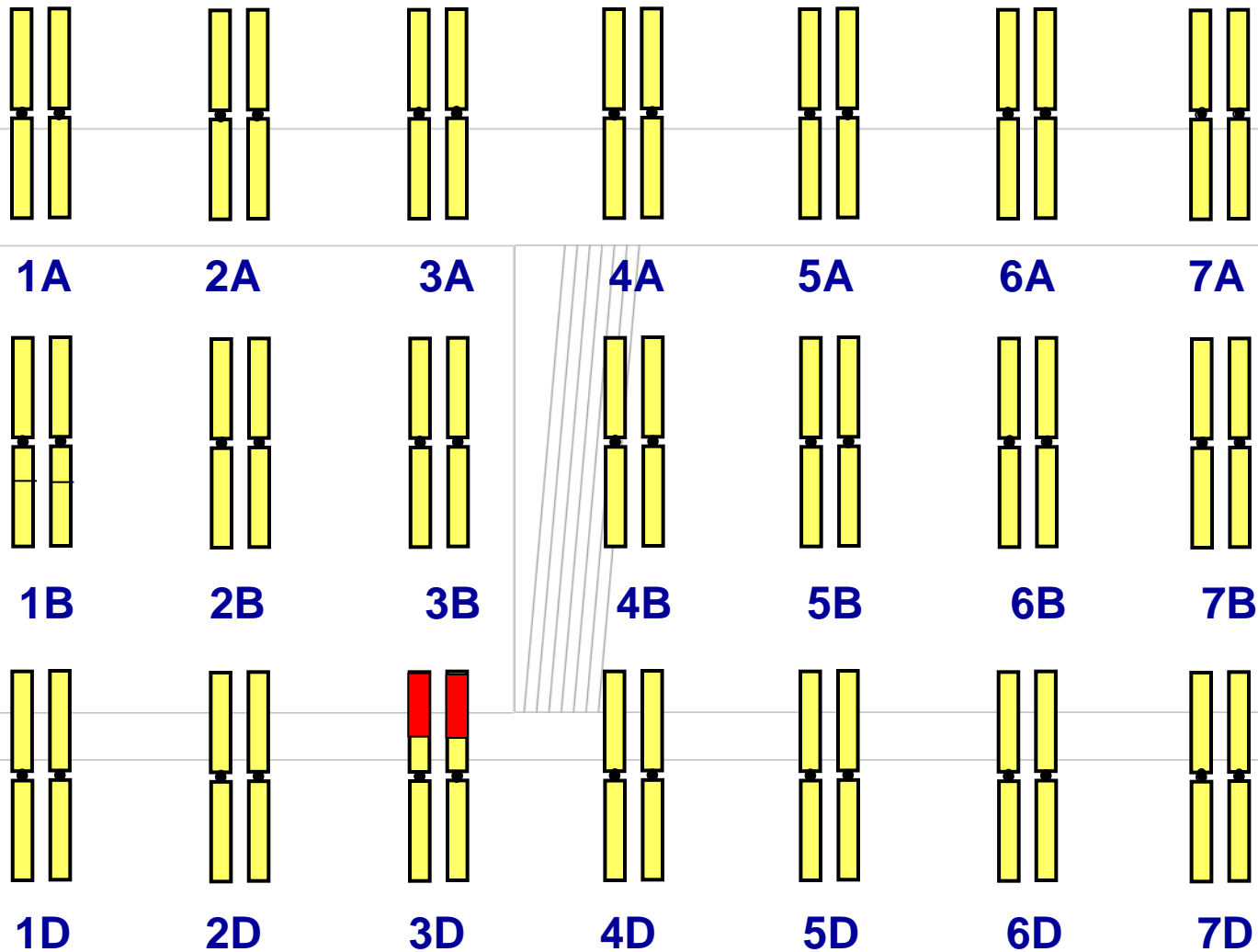
Root architecture



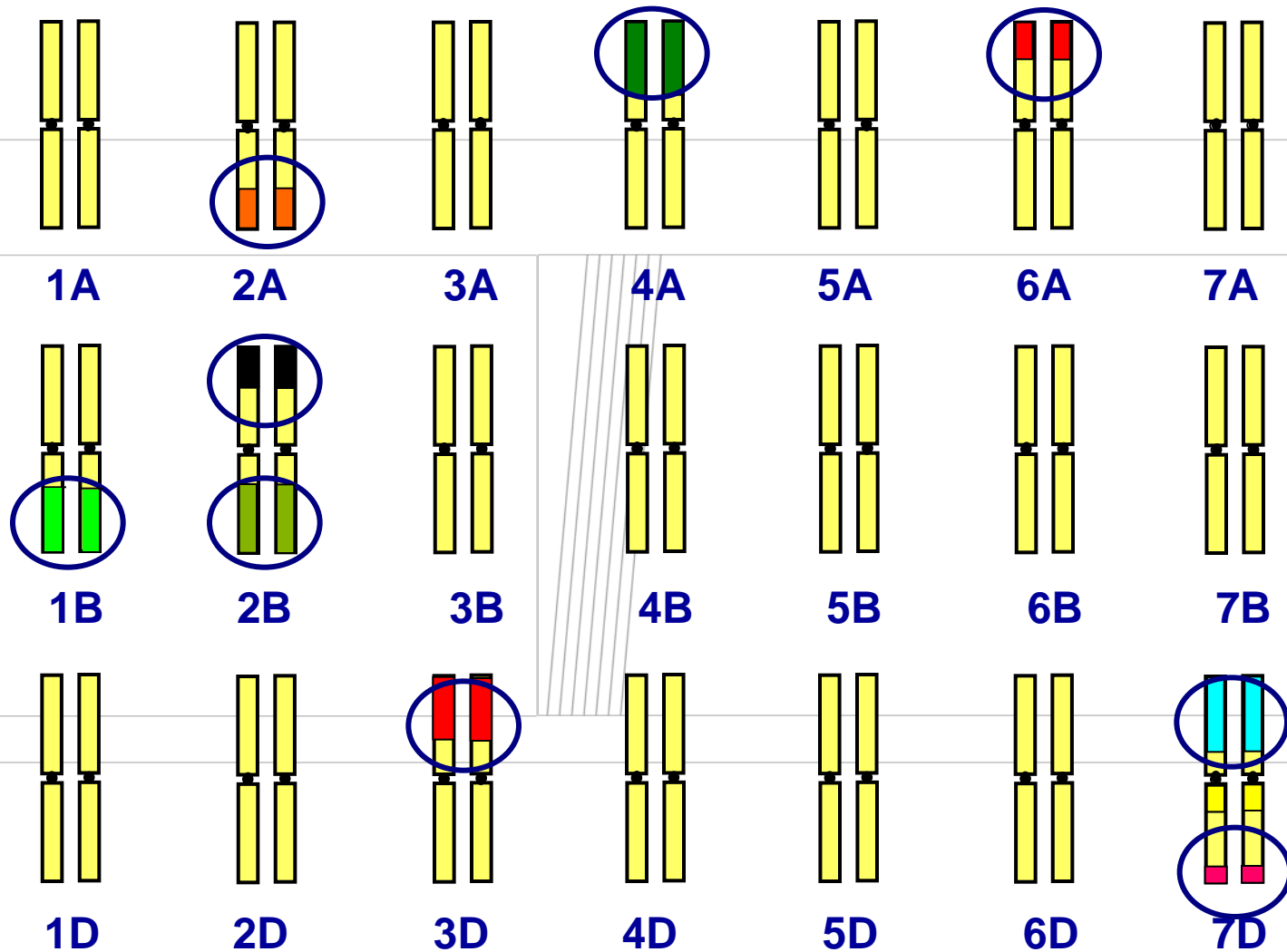
Genome of a bread wheat



Genome of a bread wheat showing a genomic region (molecular marker) for a new dwarfing gene



Genome of a bread wheat showing QTLs for a complex trait (eg transpiration efficiency)



Traits for improved performance under drought: Selection methods

Trait	Selection environment – favourable or droughted	Markers or genomic regions identified	Most efficient selection method
Seedling establishment			
Shoot vigour			
Root vigour			
Root length			
Transpiration efficiency (CID)			
Stem carbohydrates			
Tillering -HI			
Glaucousness			
Floret fertility			

Traits for improved performance under drought: Selection methods

Trait	Selection environment – favourable or droughted	Markers or genomic regions identified	Most efficient selection method
Seedling establishment	Favourable		
Shoot vigour	Favourable		
Root vigour	Favourable		
Root length	Favourable		
Transpiration efficiency (CID)	Favourable		
Stem carbohydrates	Favourable		
Tillering -HI	Favourable		
Glaucousness	Favourable		
Floret sterility	Non-droughted		

Traits for improved performance under drought: Selection methods

Trait	Selection environment – favourable or droughted	Markers or genomic regions identified	Most efficient selection method
Seedling establishment	Favourable	Yes	
Shoot vigour	Favourable	Yes	
Root vigour	Favourable	Yes	
Root length	Favourable	No (?)	
Transpiration efficiency (CID)	Favourable	Yes	
Stem carbohydrates	Favourable	Yes	
Tillering -HI	Favourable	Yes	
Glaucousness	Favourable	Yes	
Floret sterility	Non-droughted	No	

Traits for improved performance under drought: Selection methods

Trait	Selection environment – favourable or droughted	Markers or genomic regions identified	Most efficient selection method
Seedling establishment	Favourable	Yes	Phenotype and marker
Shoot vigour	Favourable	Yes	Phenotype
Root vigour	Favourable	Yes	Phenotype
Root length	Favourable	No	Phenotype
Transpiration efficiency (CID)	Favourable	Yes	Phenotype
Stem carbohydrates	Favourable	Yes	Phenotype
Tillering -HI	Favourable	Yes	Phenotype or marker
Glaucousness	Favourable	Yes	Phenotype
Floret sterility	Non droughted	No	Phenotype

Use of trait in the development of new varieties for dry environments

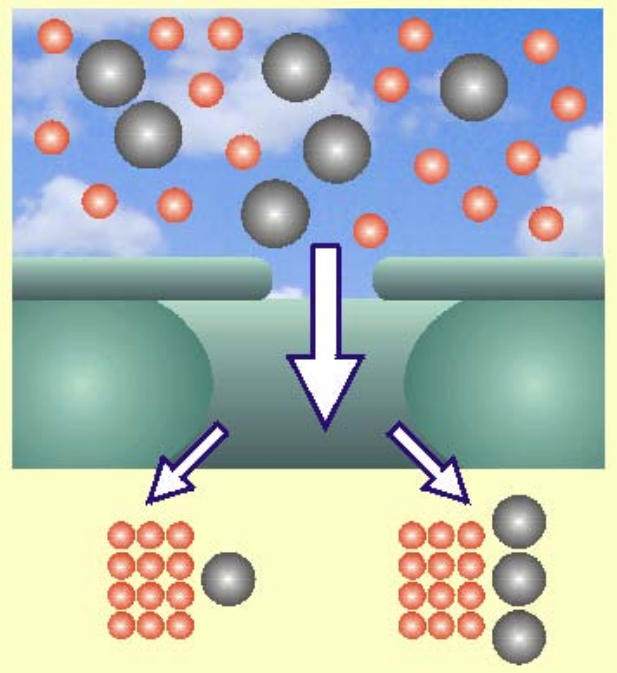


- Screening technique developed
- Genetic variability identified
- Validation of trait in different field environments continues

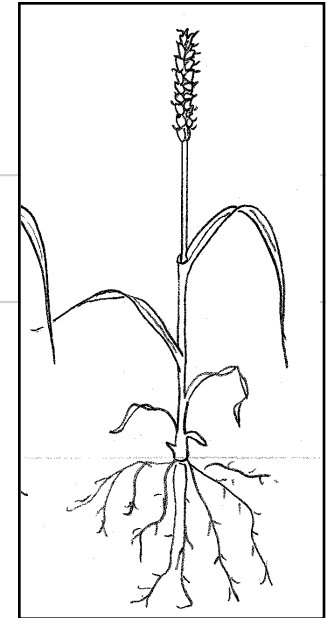
Ready for use in breeding programs



Use of trait in the development of new varieties for dry environments



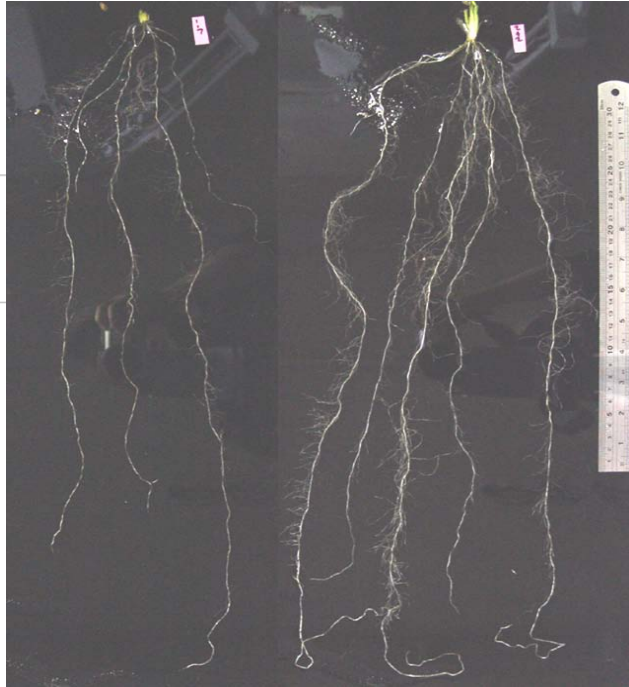
C^{13}/C^{12}



Stem CHO

- Screening technique developed but costly
- Genetic variability identified
- Validation of trait in different field environments continues
- **Faster, cost effective screening techniques required**

Use of trait in the development of new varieties for dry environments



- Screening techniques under development
- Genetic variability identified
- Validation of trait in different field environments required
- **Faster, cost effective screening techniques required**

Some interim comments

Everything hinges on accurate phenotyping

Important traits for crop improvement are complex and in many cases molecular markers or QTLs may not be very effective.

Validation in the field is critical. It is difficult, chancy and we underestimate the importance of it.

Do not expect rapid uptake by breeding programs!

Issues in applying phenomics to breeding

- **for a measurement to be used by breeders it must be:**

- An improvement on what currently is being used
- Repeatable
- Fast
- Inexpensive
- Applicable to their target region and crop

Issues in applying phenomics to breeding

Plant breeders are very inventive (i)



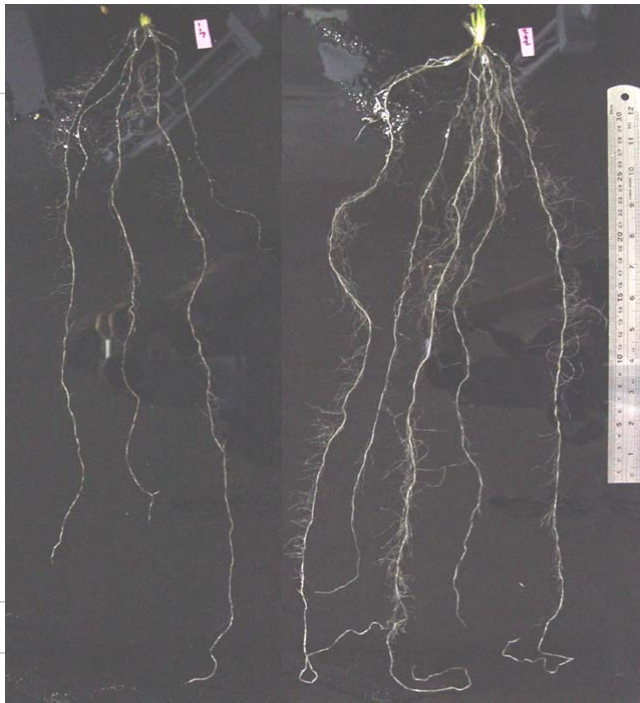
- Selection methodology for long coleoptile

Selection methodology for enhanced vigour



Issues in applying phenomics to breeding

Plant breeders are very inventive (ii)



Root systems in the lab

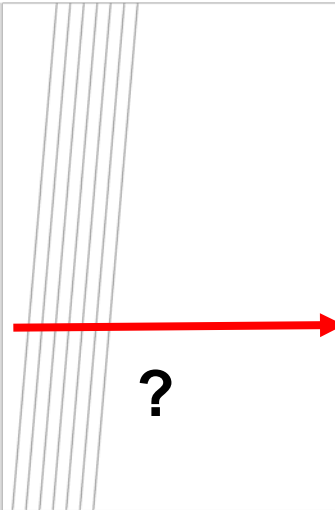


Root systems in the field

In the field we can measure roots to over 1.5m deep in 3 minutes!

Issues in applying phenomics to breeding

Do measurements on single plants in a glasshouse/phytotron correspond to plants in a community?



Some final comments

- **Do not expect uptake by breeders**
- **Engage with breeders in the early stages**
- **Everything hinges on accurate phenotyping**
 - Effective breeding
 - Trait discovery
 - Gene and marker discovery
 - New mechanisms and function
- **Make sure what ever you do has relevance**

Don't let the technology dominate

A final comment

Let us all ensure that the **next generation phenomics** is as successful as phenomics has been in the past.