The Challenges of [high-throughput] Phenotyping

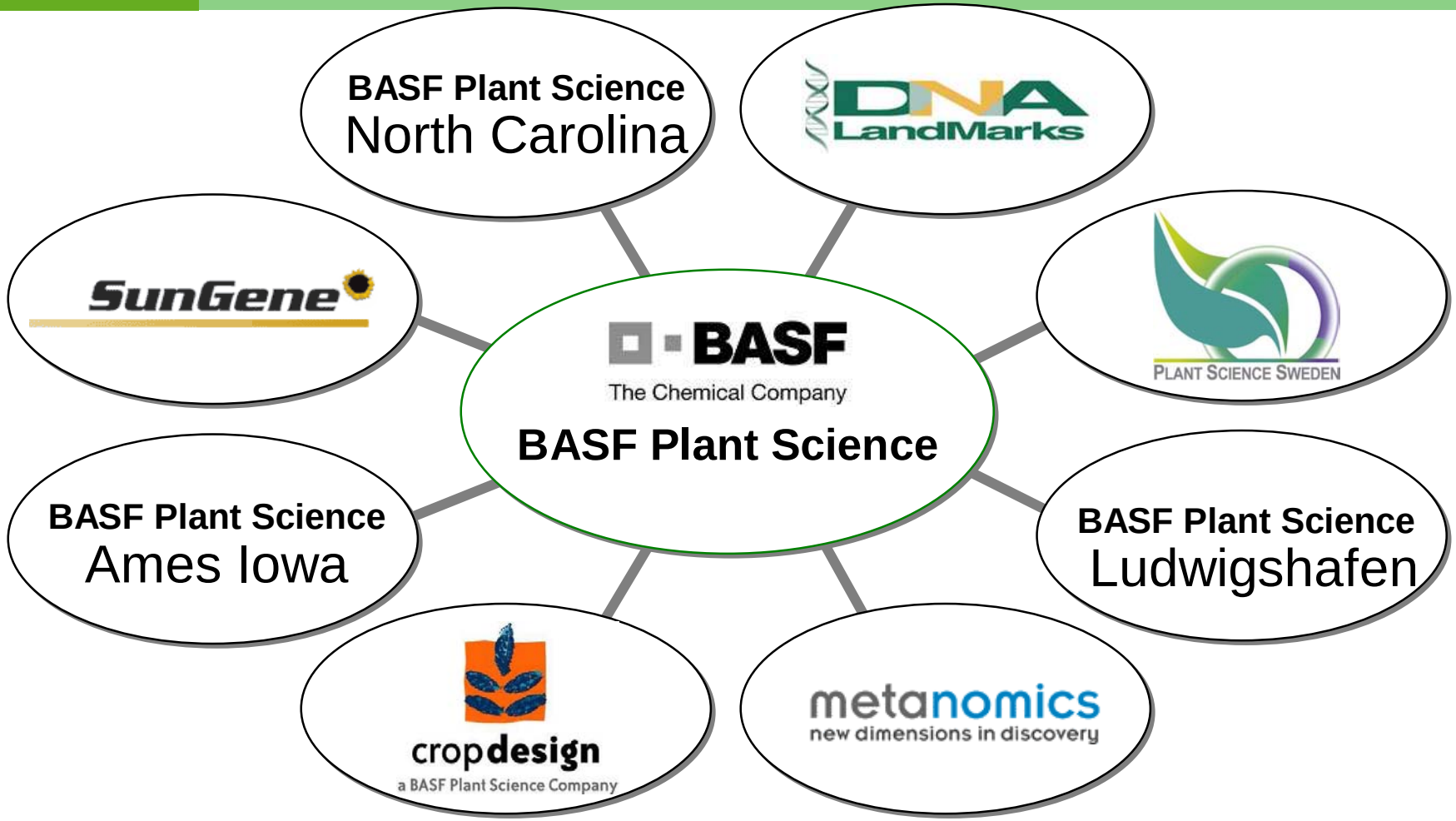
Mount Hood - sept 2008

Topics

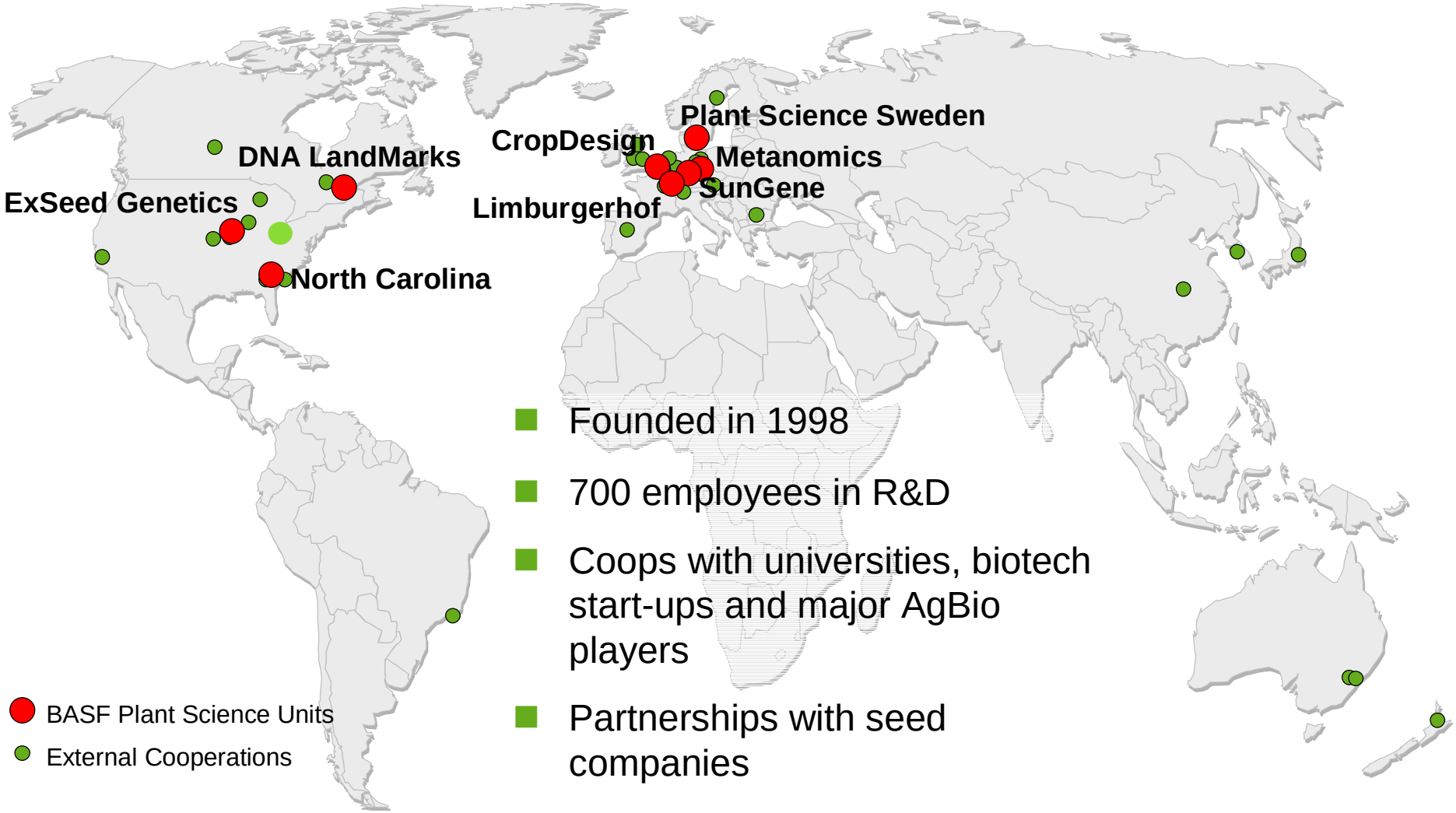
cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping
  - ⇨ The TraitMill example
- What is the output?
  - ⇨ Some lead examples
- Future developments

BASF Plant Science: a Global Technology Platform



Global R&D Platform



- Founded in 1998
- 700 employees in R&D
- Coops with universities, biotech start-ups and major AgBio players
- Partnerships with seed companies

CropDesign at a Glance

cropdesign
a BASF Plant Science Company

- **Headquartered in Gent, Belgium; 90 employees**
- **Founded in 1998 as a spin-off from VIB, acquired in June 2006 by BASF Plant Science**
- **Focus on the development of high productivity traits by operating a unique rice-based trait discovery platform**
- **Focus on rice as a commercial crop opportunity and as a model for corn**

The BASF approach to gene discovery: unique technology platform

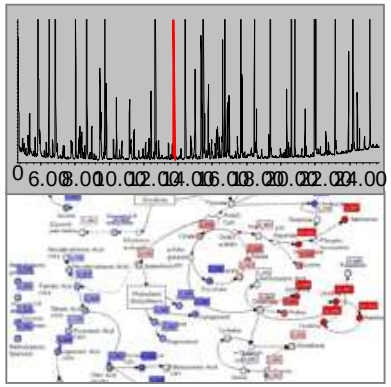
Crop yield improvement

CropDesign

Look at plant

BASF Plant Science

Look inside



metanomics

Unique and synergistic platform for gene function discovery

Combines visual plant screening & metabolic profiling for gene function analysis

High throughput at 5,000 to 10,000 genes tested per year

cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping
  The TraitMill example
- What is the output?
  Some lead examples
- Future developments

Trends driving demand for agricultural products

Food & Feed

- UN estimate* on word population:
  9.2 billion people for 2050
- Rising social standards drive global demand
  for more processed food (meat consumption in Asia)

Biofuels**

- Worldwide: Programs to support bio-fuel projects
- EU biofuel target:
  10% of total transportation fuel by 2020:
  → 55% of total agricultural land needed to reach the target (in canola)

- **To meet the demand we have to double productivity within the next 20 years**

*Published in May 2007 by the UN;
** EU-Directive, March 2007

BASF
The Chemical Company

Our Projects

Traits

Novel Agronomic specialty traits	Enhanced feed traits	Specialty food traits	Industrial traits
- Yield - Stress tolerance - Fungal resistance	- NutriDense - Phytate reduction - Amino acid enhancement	- PUFAs	- Modified starch - Increased Oil - Biofuels

Basic Technologies

Enabling **Genomics** **Bioinformatics**

cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping
  The TraitMill example
- What is the output?
  Some lead examples
- Future developments

What are the challenges?

cropdesign
a BASF Plant Science Company

- High Throughput
- Low costs

  - Efficient logistics
  - Automation

- Early discovery
- Predictability

  - Model plants
  - Screening strategy
  - Traits

- Organize the data flow

  - LIMS
  - Productivity tools

Key traits

cropdesign
a BASF Plant Science Company

- Seed yield
- Seed number
- Grain filling rate
- 1000 seed weight
- Harvest index
- Heading time
- Development rate
- Root biomass
- Root shoot ratio

- **Seed yield**
- **Seed number**
- **Grain filling rate**
- **1000 seed weight**
- **Harvest index**
- **Heading time**
- **Development rate**
- **Root biomass**
- **Root shoot ratio**

- Leafy biomass
- Plant height
- Development rate
- Oil content
- Rooty biomass
- Root thickness
- Root shoot ratio

cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping:
  ⇨ The TraitMill example
- What is the output?
  Some lead examples
- Future developments

TraitMill™ : Trait Development for Different High-Value Opportunities

cropdesign
a BASF Plant Science Company

TraitMill™ by cropdesign

Product leads

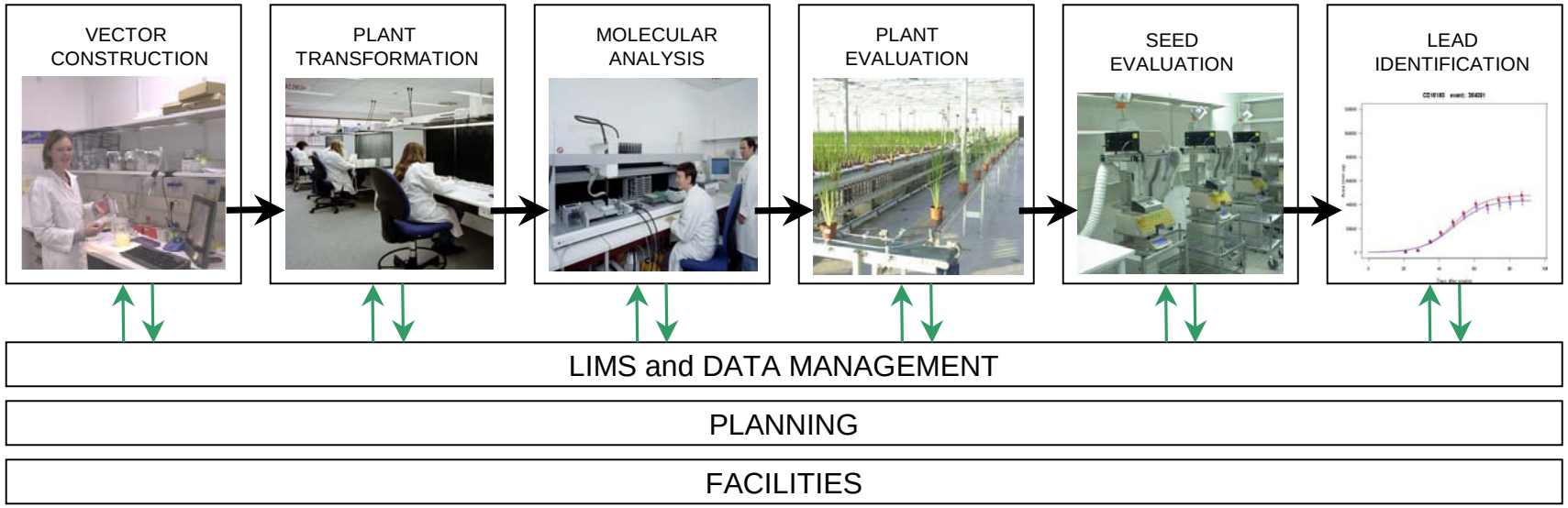
- Patent filing
- Data mgt & analysis
- Plant phenotyping
- Molecular analysis
- Plant transformation
- Vector construction
- Gene selection

Genes

Annual throughput
>60 validated leads
10s of terrabytes
140,000 plants
300,000 PCRs
>75,000 transformants
1300 constructs
2,000 genes

The TraitMill pipeline

cropdesign
a BASF Plant Science Company

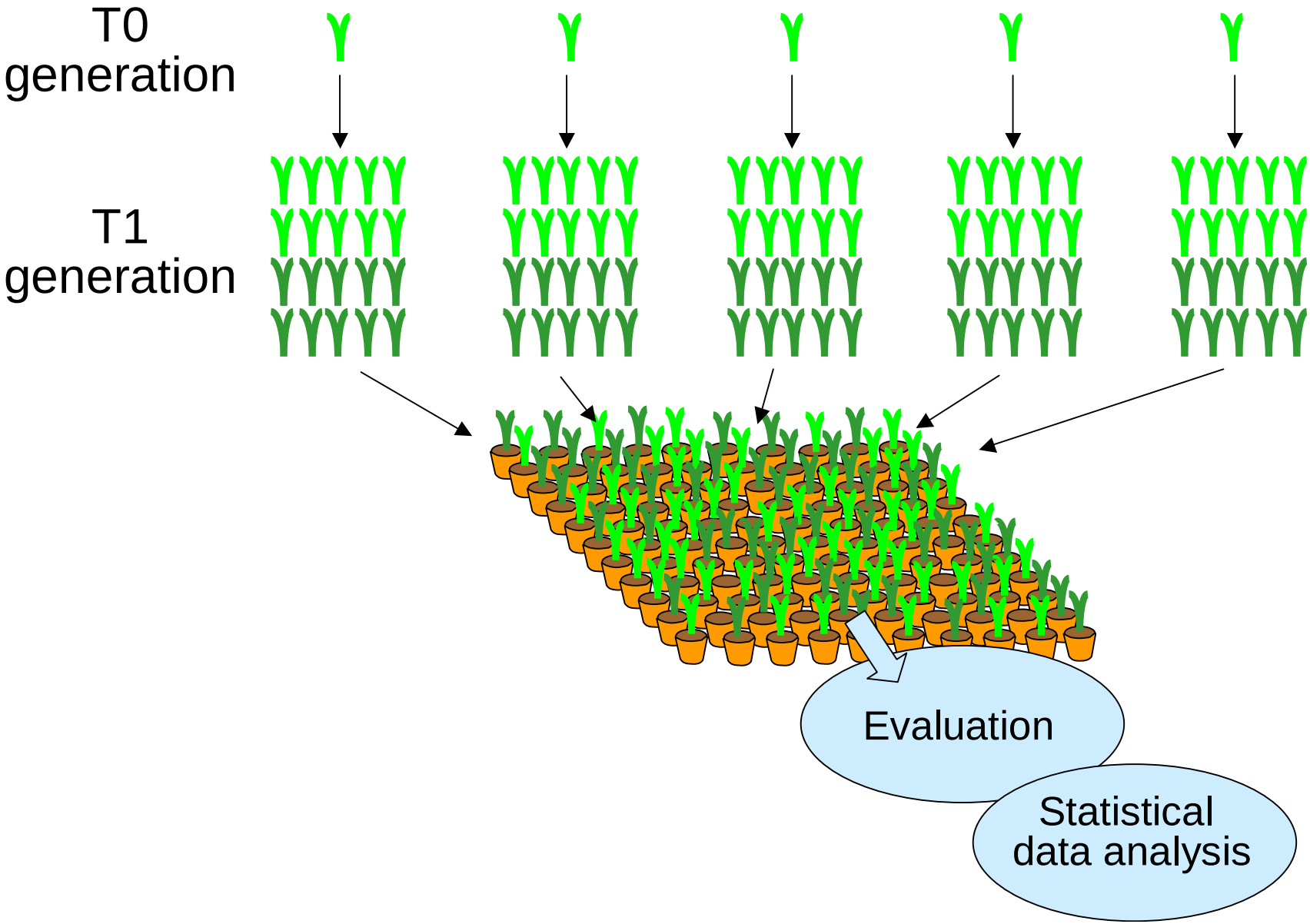


HTP plant evaluation

cropdesign
a BASF Plant Science Company

Evaluation set up

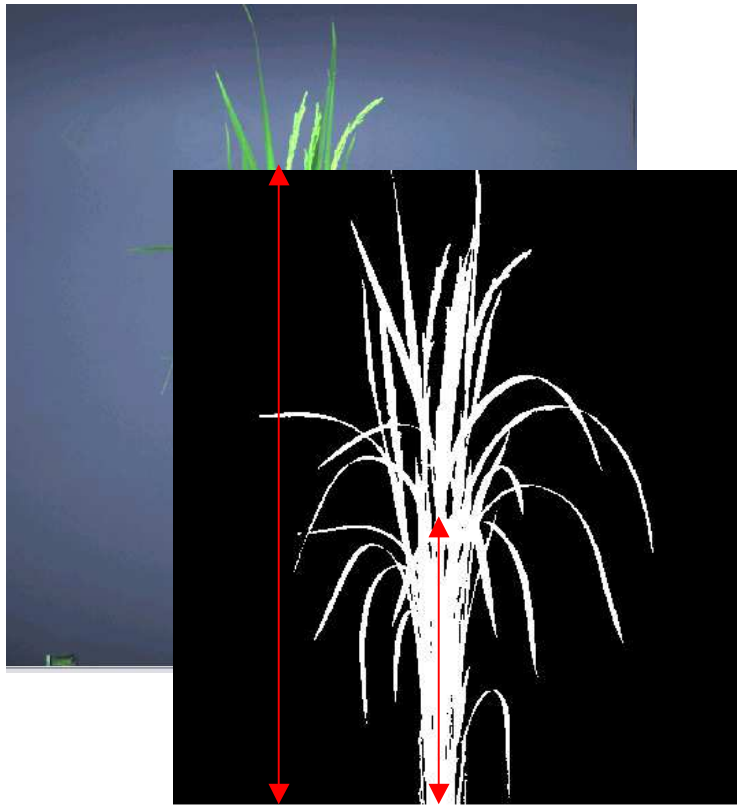
cropdesign
a BASF Plant Science Company



Green biomass

cropdesign
a BASF Plant Science Company

Green biomass



Leaf area

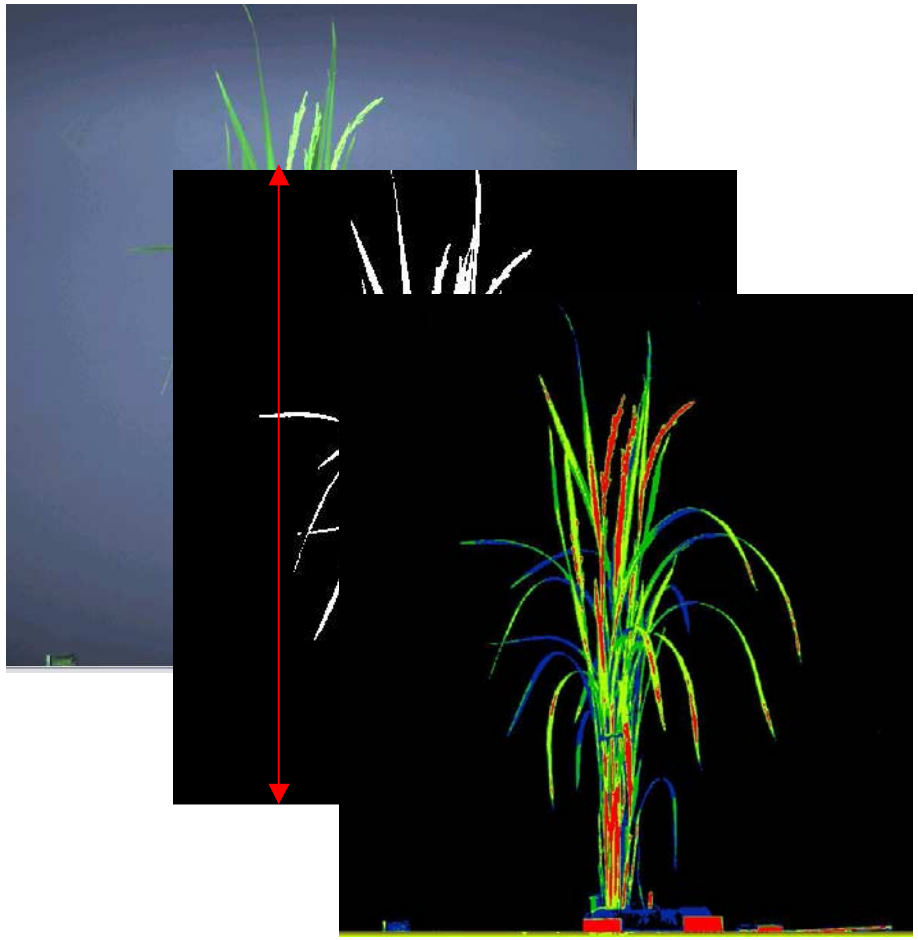
Early vigour
Max leaf area
After drought

Height

Maximum
Gravity centre

Green biomass

cropdesign
a BASF Plant Science Company



Leaf area

Early vigour
Max leaf area
After drought

Height

Maximum
Gravity centre

Greenness index

Before flowering
After drought

Green biomass

cropdesign
a BASF Plant Science Company

Leaf area

Early vigour
Max leaf area
After drought

Height

Maximum
Gravity centre

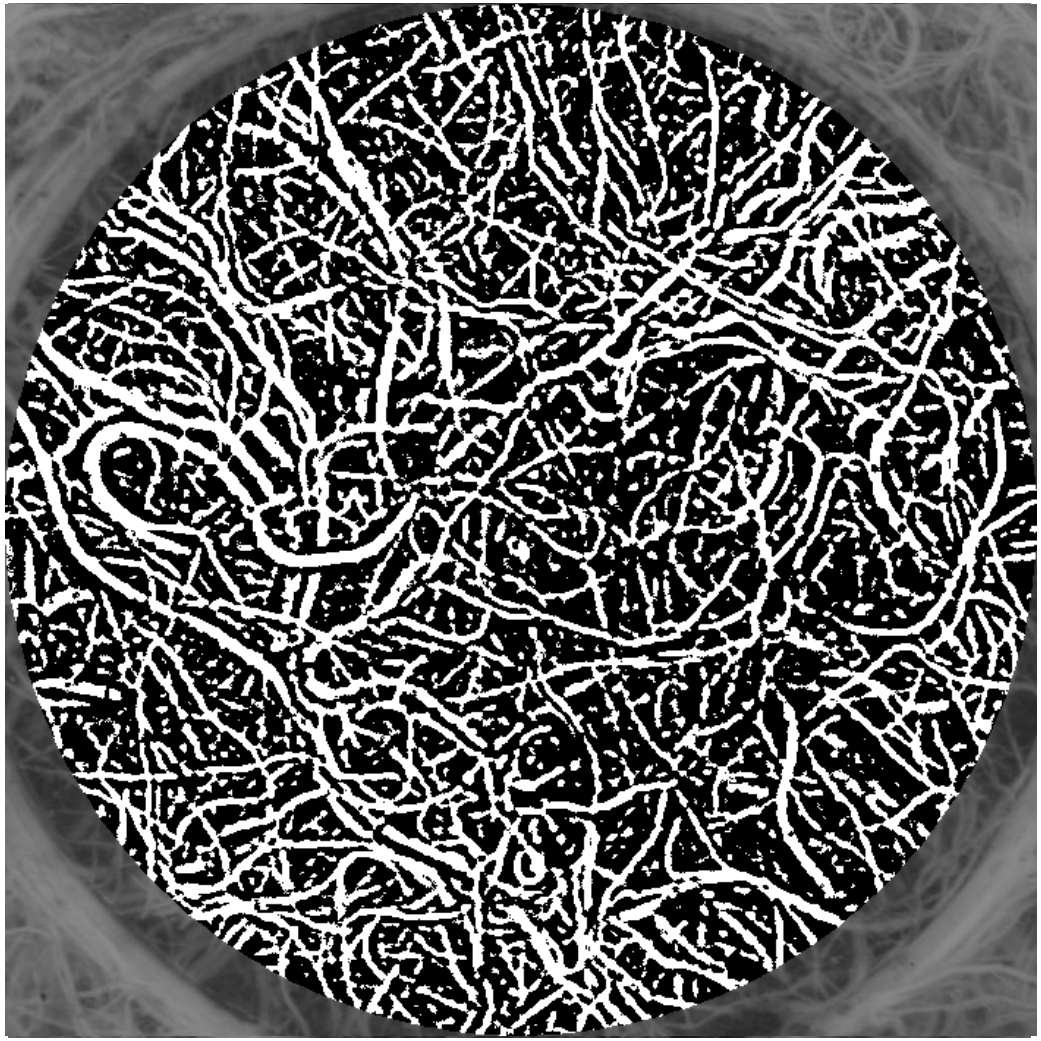
Greenness index

Before flowering
After drought

Days to flowering

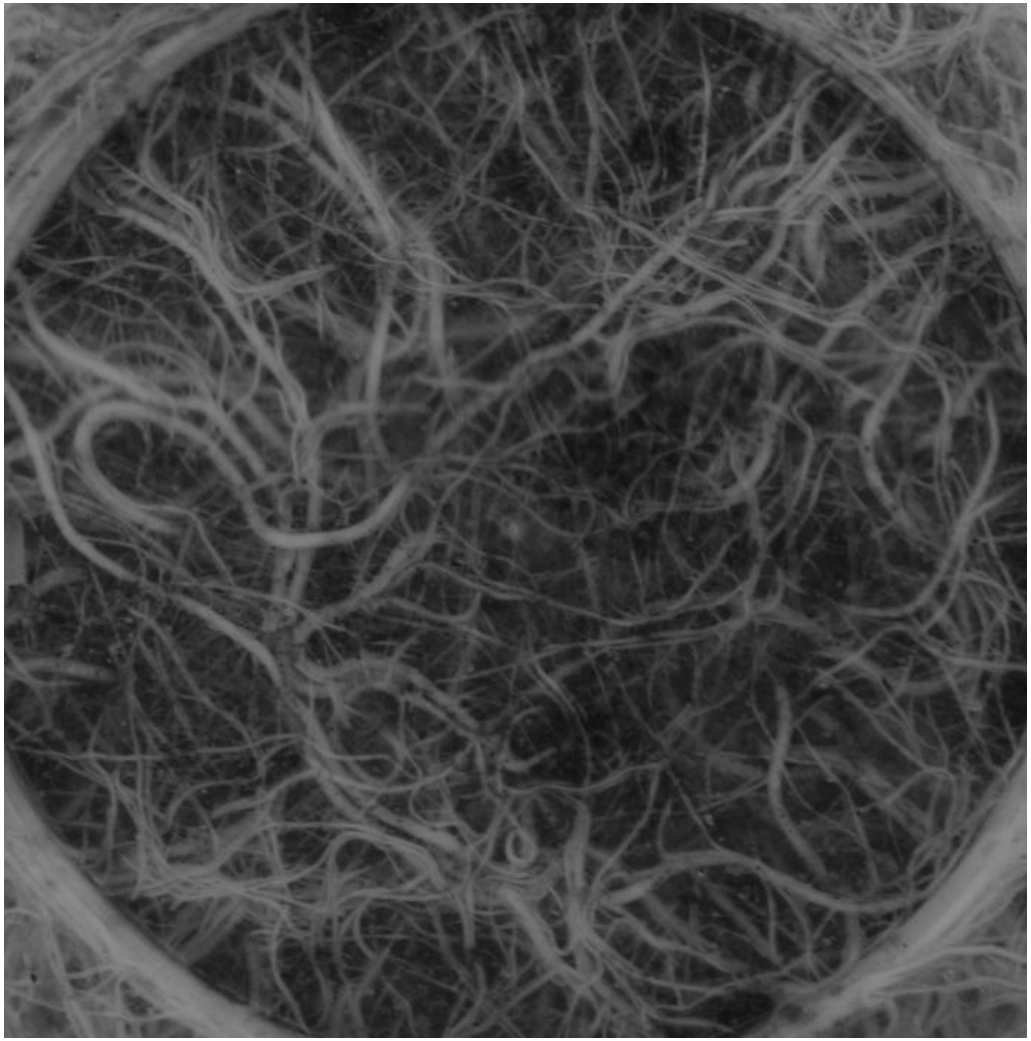
Root biomass

cropdesign
a BASF Plant Science Company



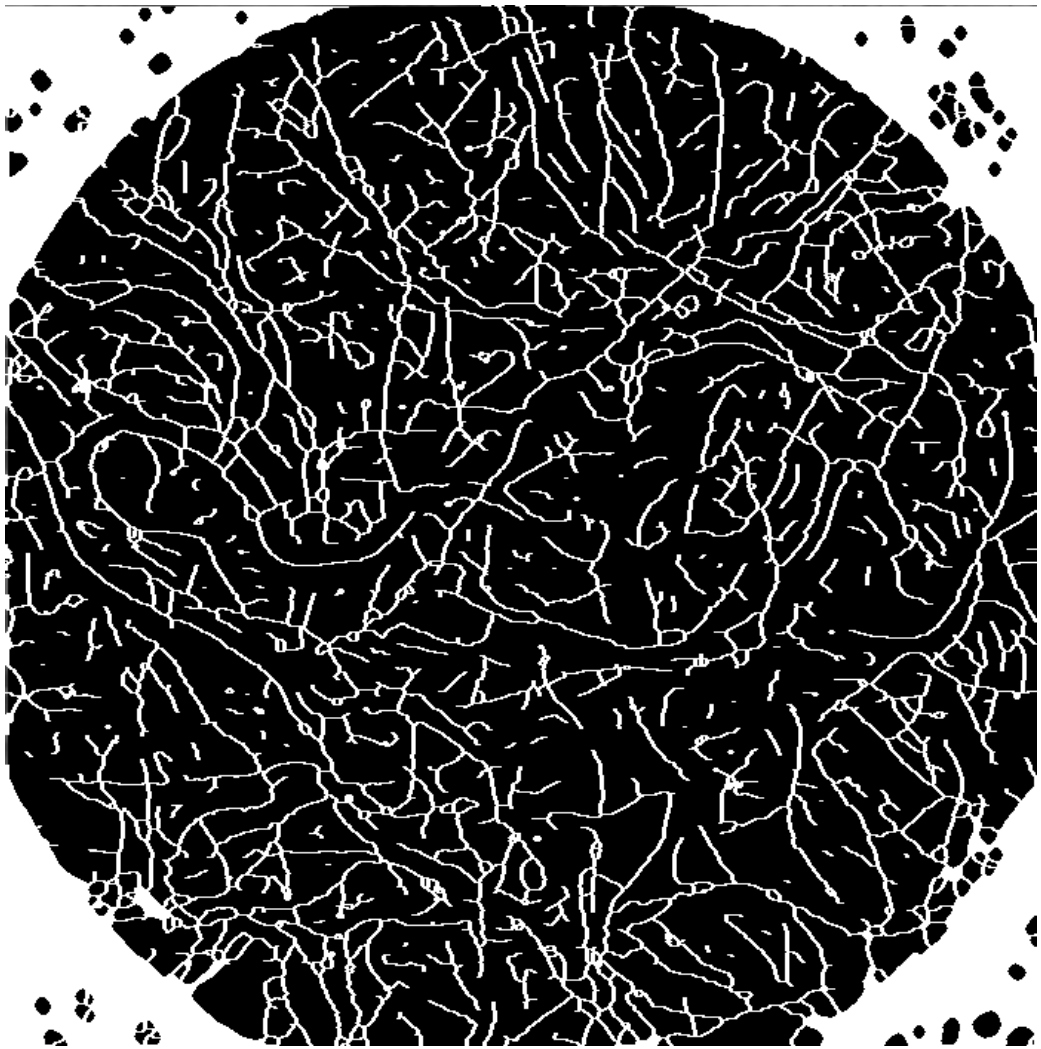
Root biomass

cropdesign
a BASF Plant Science Company



Root biomass

cropdesign
a BASF Plant Science Company



⇨ **Area**

⇨ **Length**
⇨ **Thickness**
⇨ **Branching**

⇨**Shoot/Root**

Yield components

cropdesign
a BASF Plant Science Company

Number of panicles

Yield components

cropdesign
a BASF Plant Science Company

Number of panicles

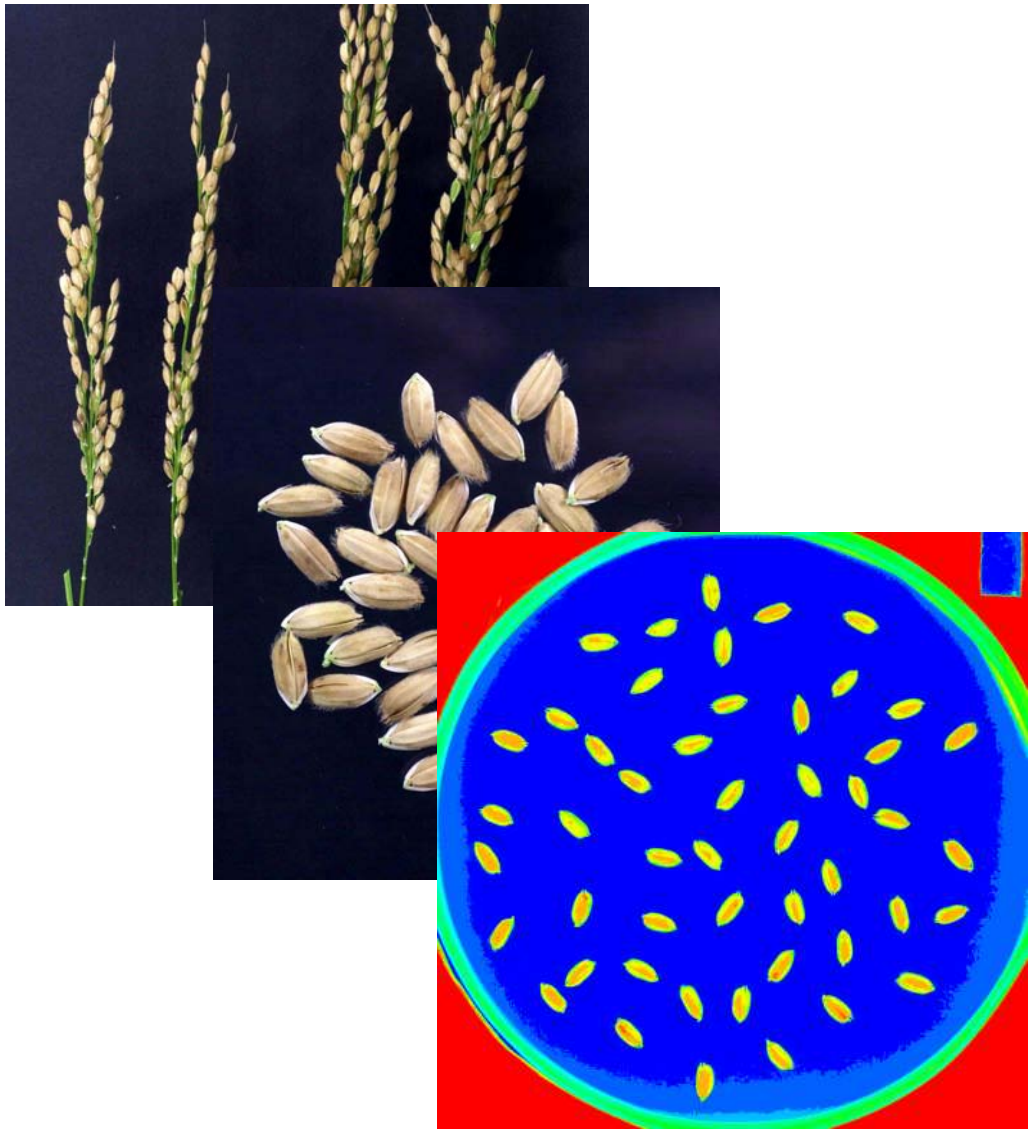
Total number of seeds
Flowers per panicle

Number of filled seeds
Fertility ("fill rate")

TKW

Total seed yield
Harvest index

Yield components



Number of panicles

Total number of seeds
Flowers per panicle

Number of filled seeds
Fertility ("fill rate")

TKW

Total seed yield
Harvest index

Seed dimensions
- *Width*
- *Length*
- *Area*

Materials tracking

cropdesign
a BASF Plant Science Company

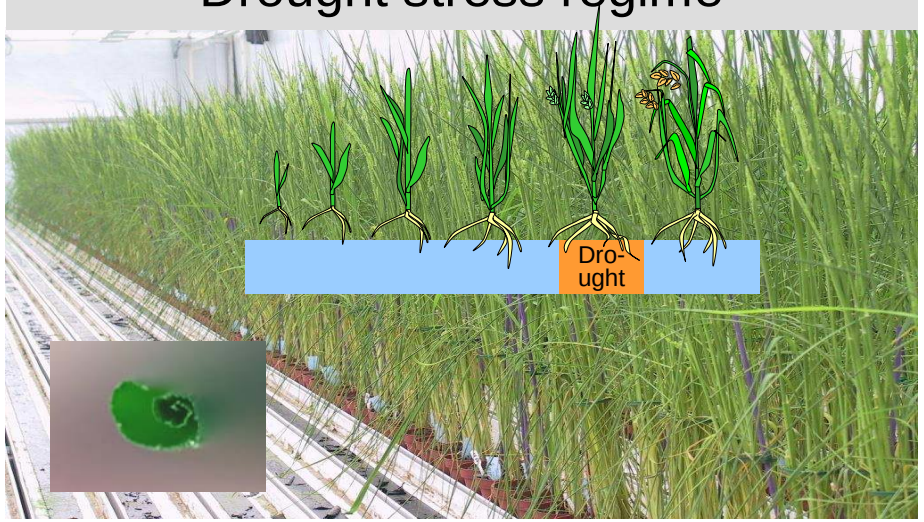
Screening strategies

cropdesign
a BASF Plant Science Company

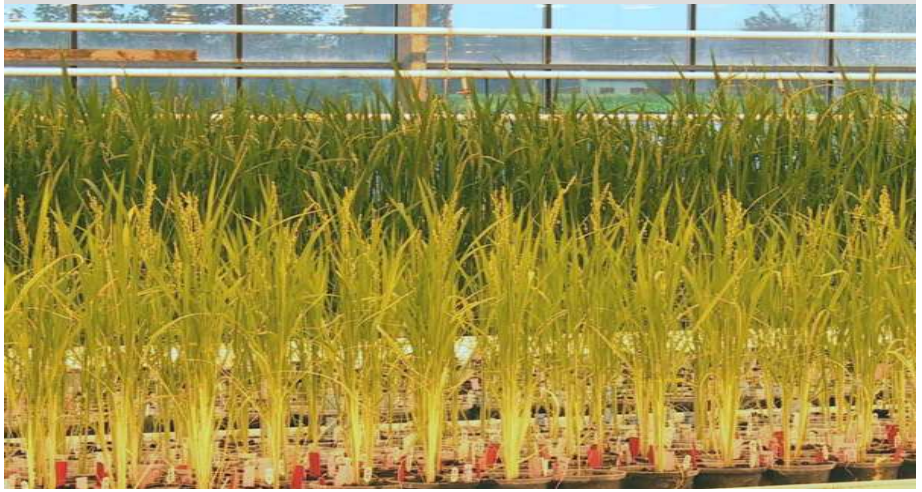
Optimal regime

Salt stress regime

Drought stress regime



Nitrogen limitation regime

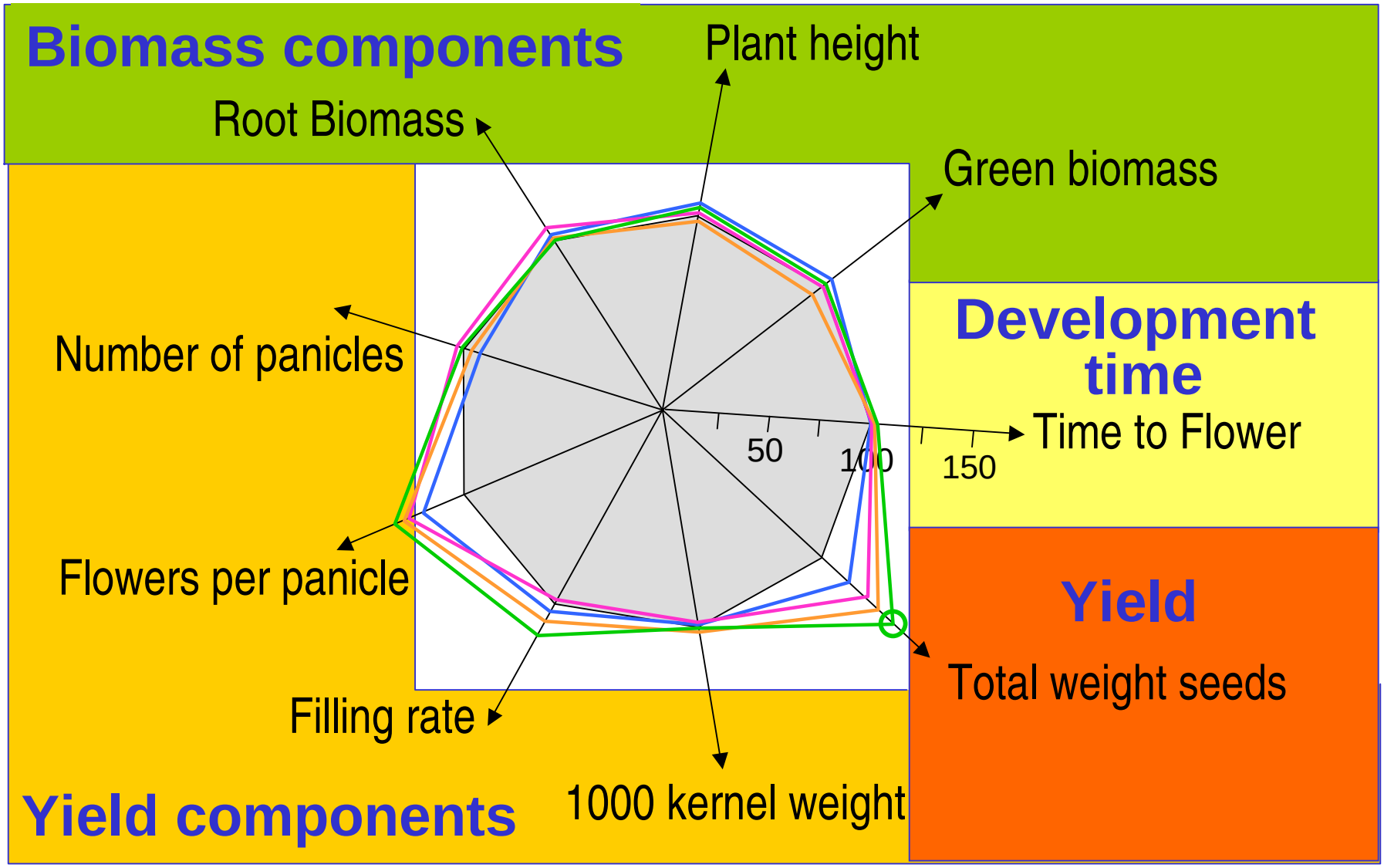


cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping
  The TraitMill example
- What is the output?
  ⇨ Some lead examples
- Future developments

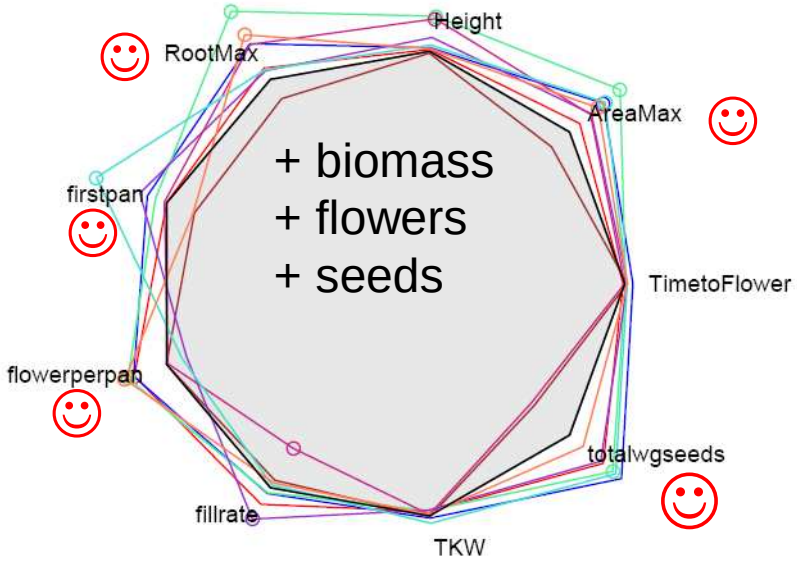
Gene selection targets different yield components

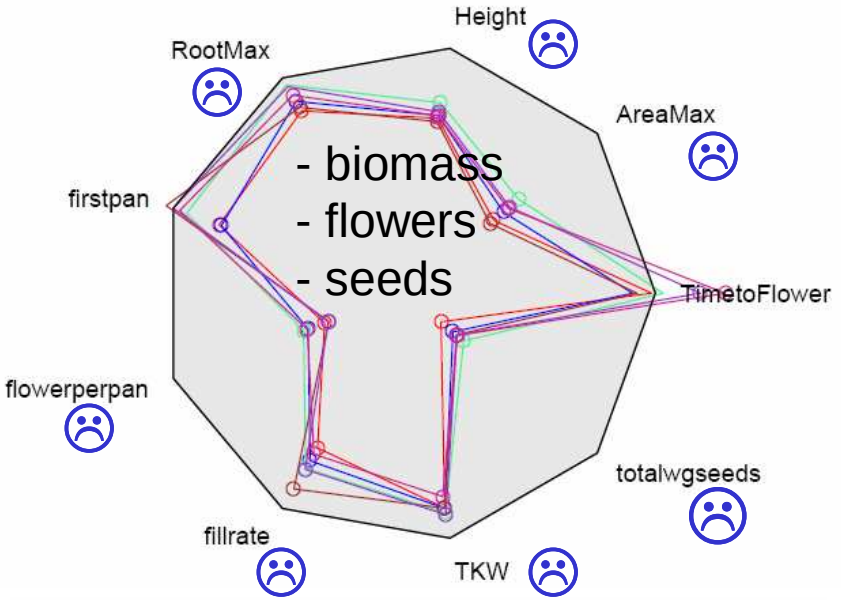
cropdesign
a BASF Plant Science Company

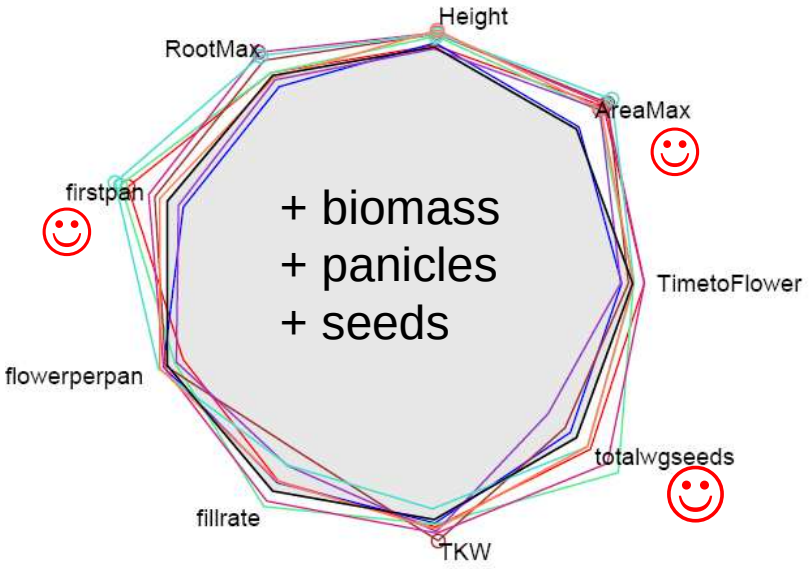


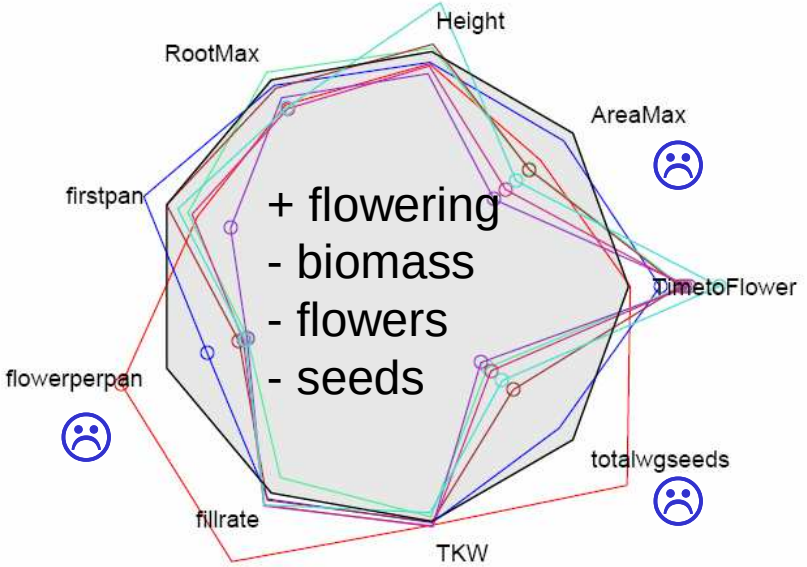
A “Phenotype tool kit”

cropdesign
a BASF Plant Science Company



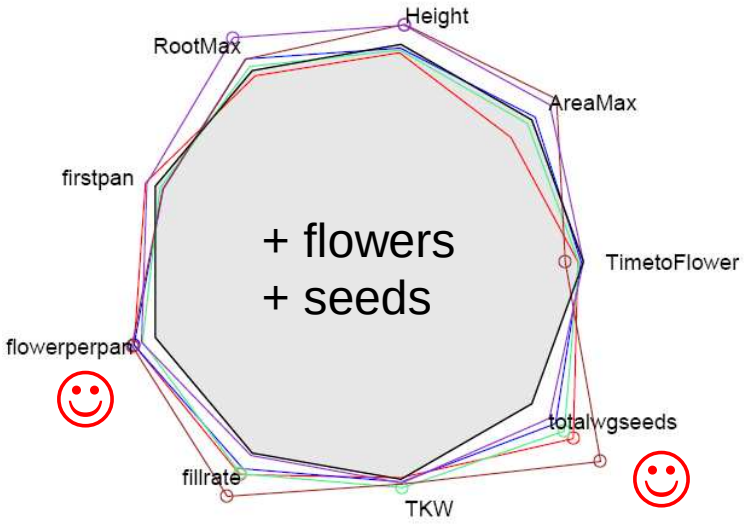


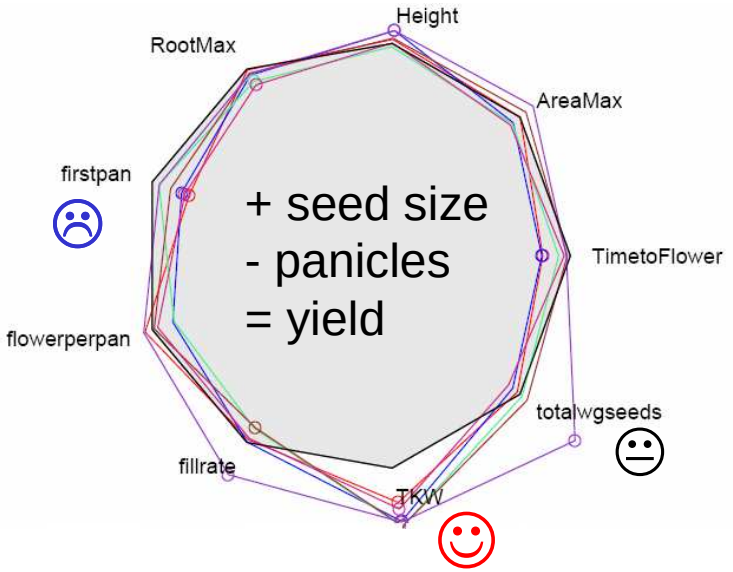


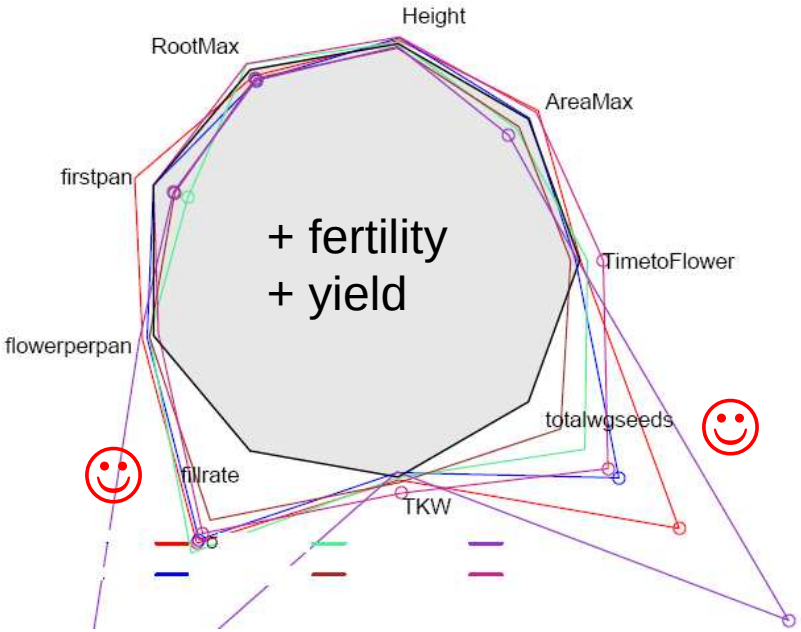


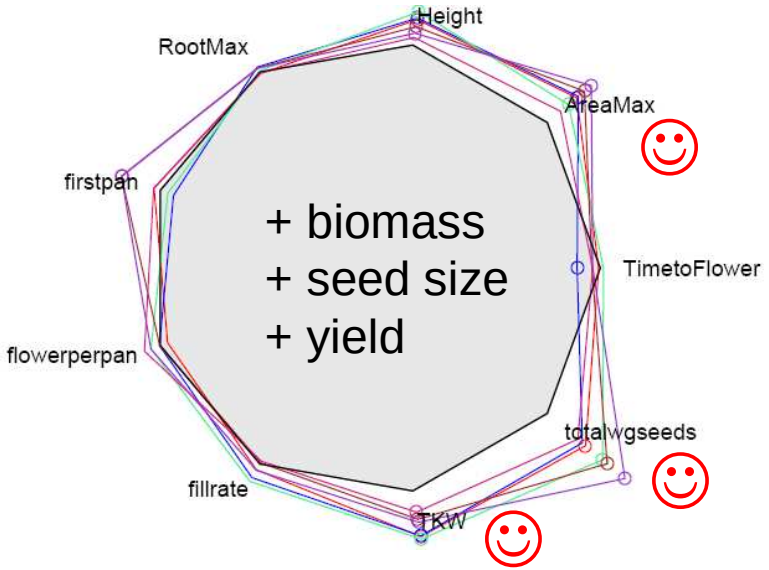
A “Phenotype tool kit”

cropdesign
a BASF Plant Science Company



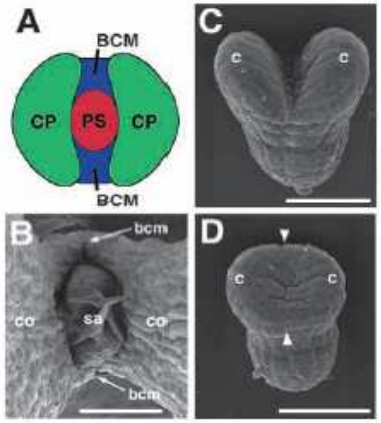




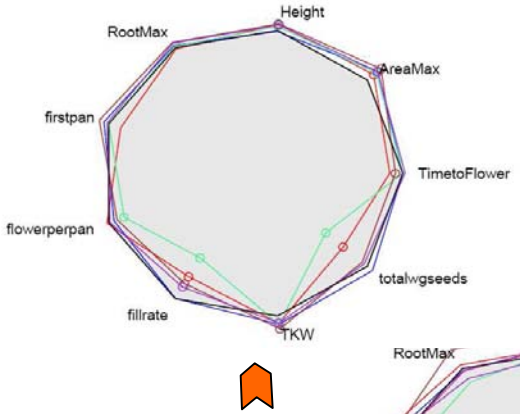


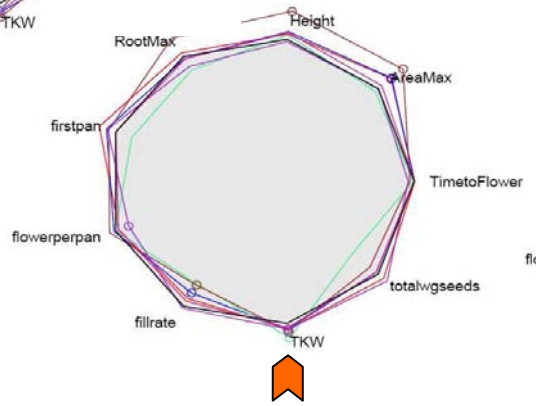
Family stories..

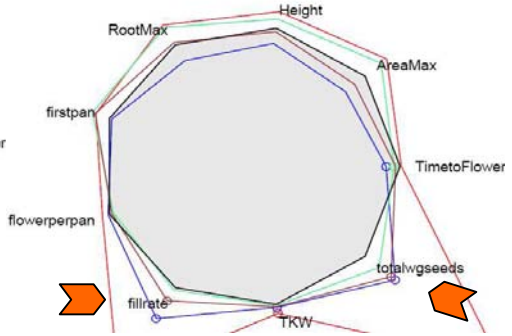
cropdesign
a BASF Plant Science Company

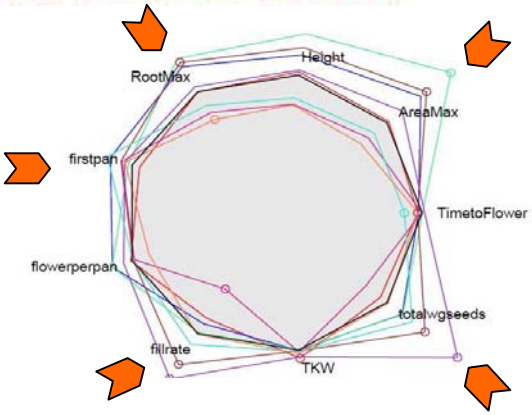


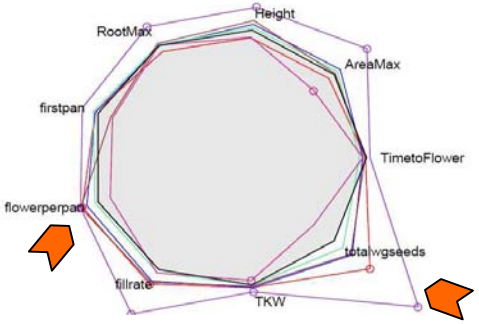
NAC genes







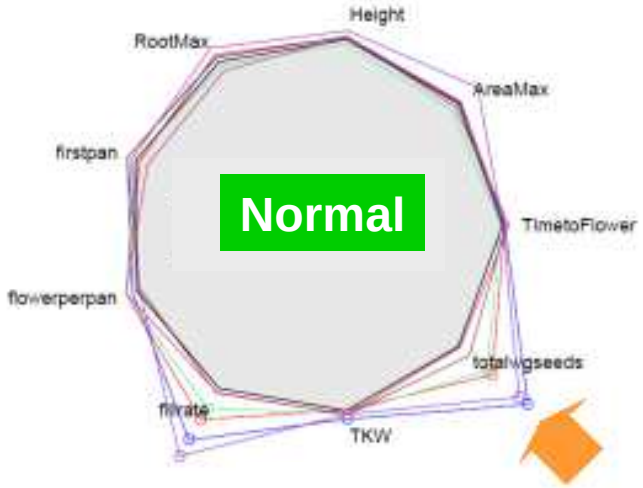


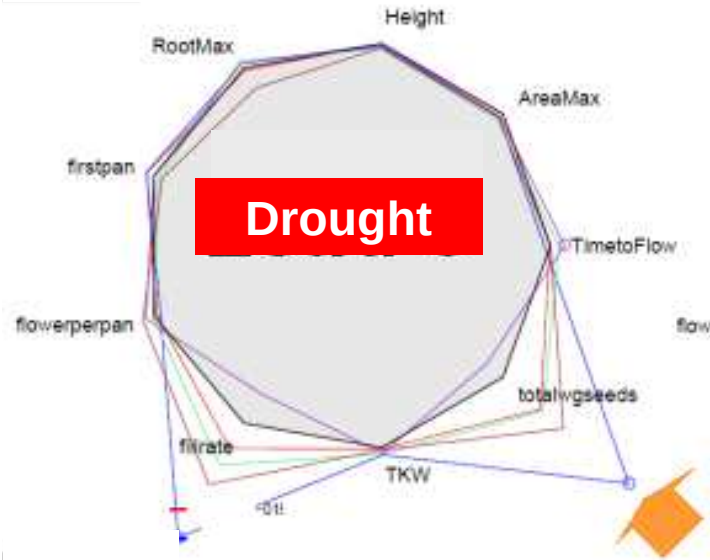


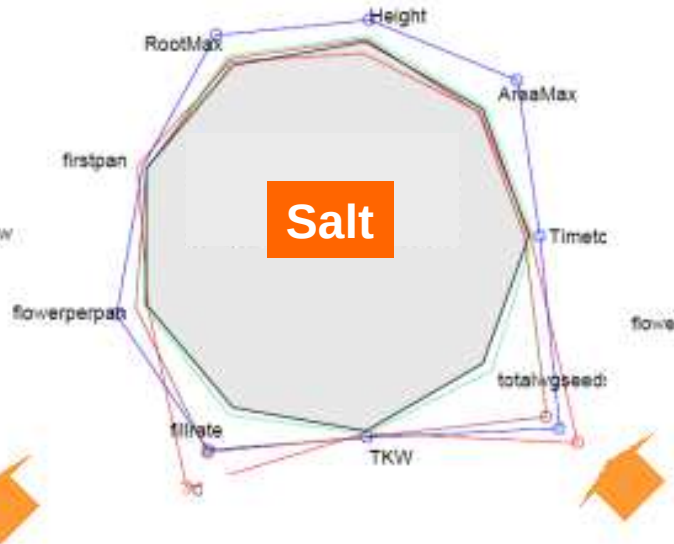
Yield stability..

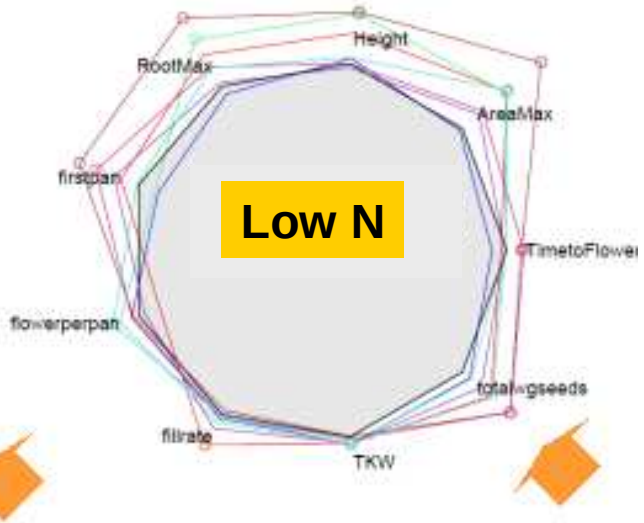
cropdesign
a BASF Plant Science Company

Lead “C”



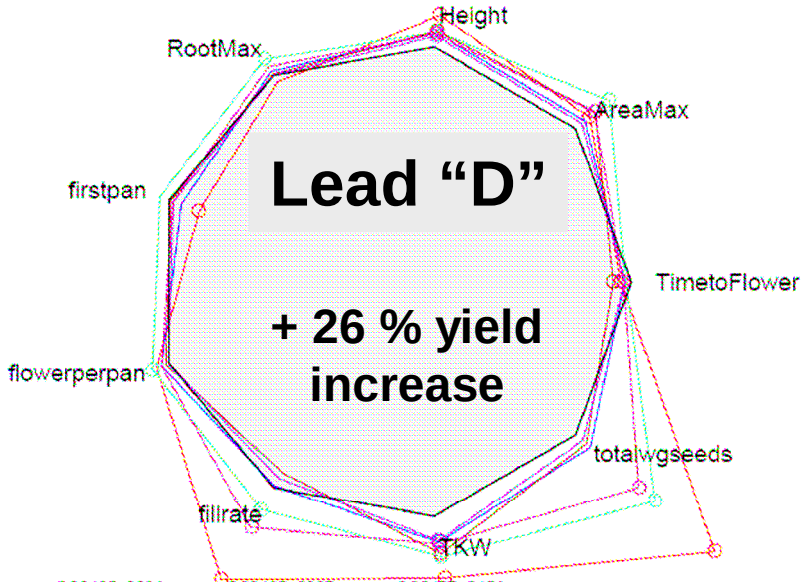


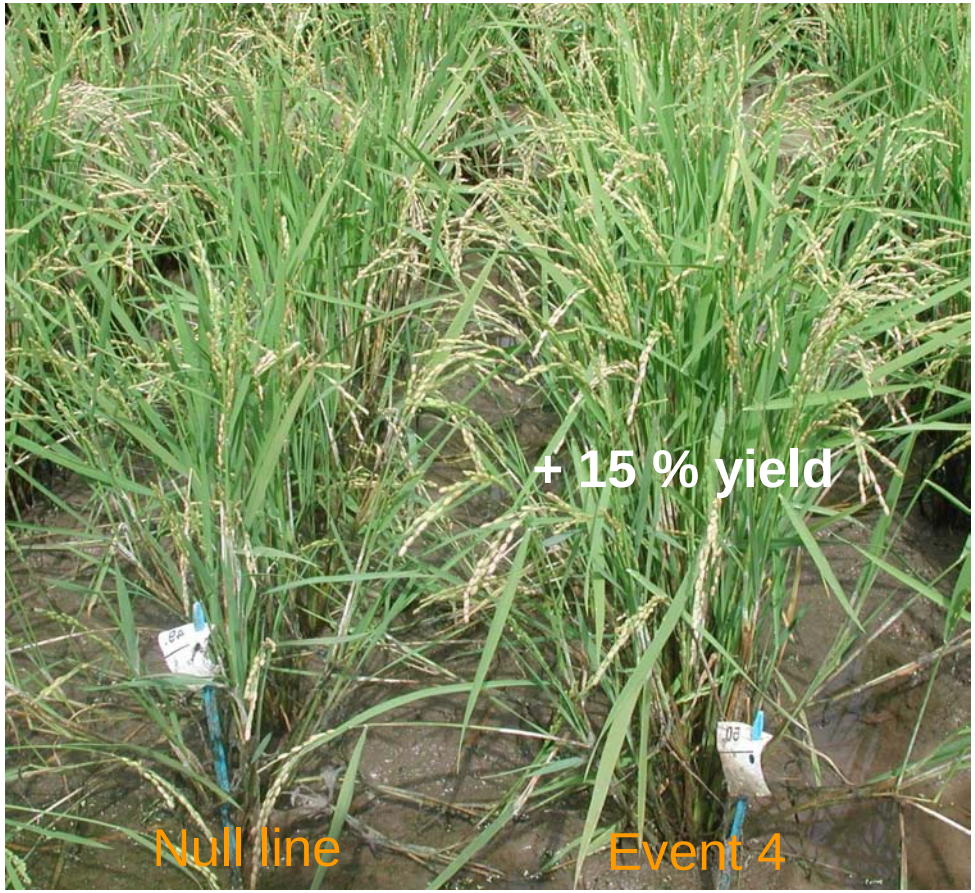




And in the field..

cropdesign
a BASF Plant Science Company

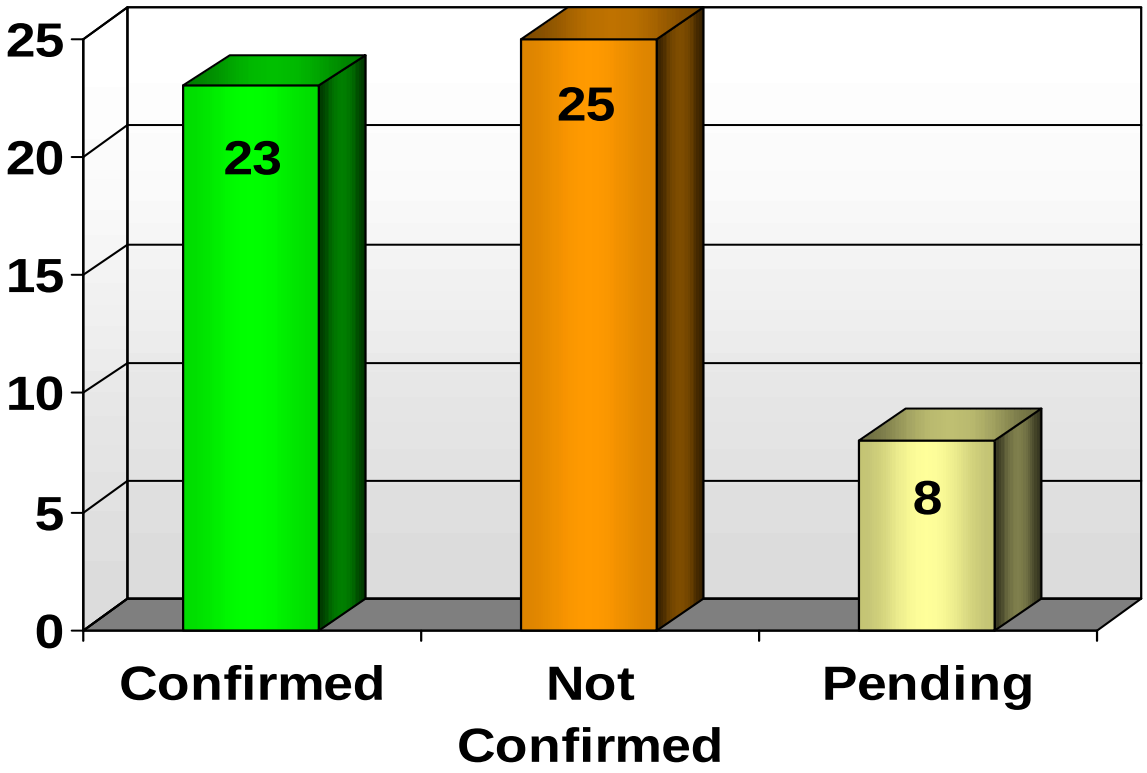




Field Validated Leads

cropdesign
a BASF Plant Science Company

- By end of 2006, 56 Leads tested in at least 1 field trial
- Field confirmation rate close to 50 %



Lead confirmed in field:
positive phenotype observed in TraitMill™ confirmed in 2 field trials

Lead not confirmed in field:
positive phenotype observed in TraitMill™ not confirmed in 2 field trials

Pending:
1 field trial result or conflicting results after 2 trials

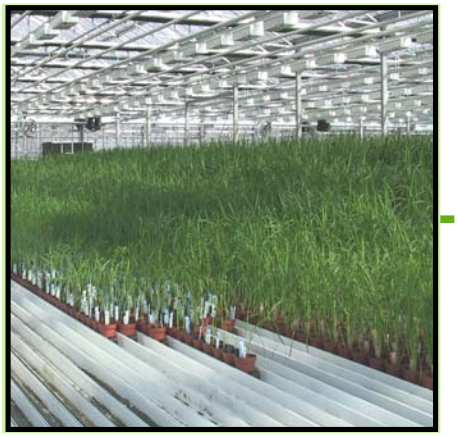
cropdesign
a BASF Plant Science Company

- Introducing BASF Plant Science
- Phenotyping, for what purposes?
- What are the challenges?
- High-throughput phenotyping
  The TraitMill example
- What is the output?
  Some lead examples
- Future developments

BASF
The Chemical Company

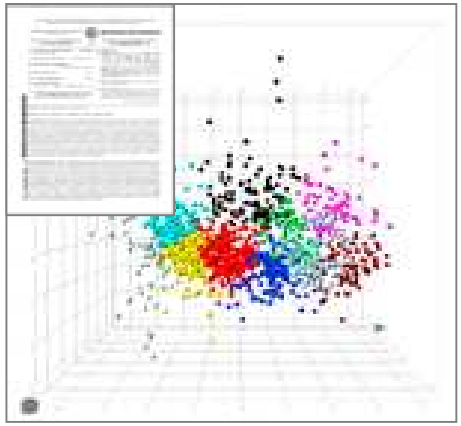
Integration of Phenotyping & Metabolic Profiling Create Unique Opportunities

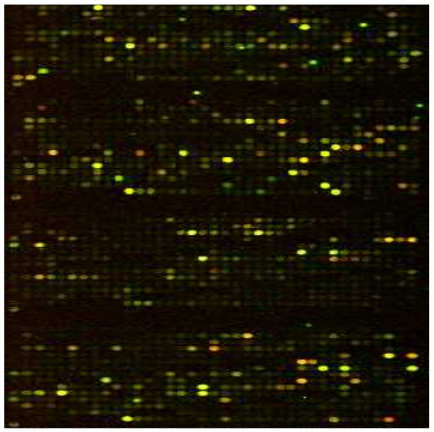
Analyze phenotype



Determine yield

Metabolic profiling





Expression profile

- **Identify important pathways**
- **Characterize mode of action**
- **Rational identification of new lead genes based on pathway knowledge**
- **Increased efficiency & efficacy of gene discovery**

R&D Commercialization Collaboration with Monsanto

- **Trait: High yield and abiotic stress tolerance**
  - Independent gene discovery programs
  - Joint research pipeline
  - Commercialization through Monsanto
- **Crops: corn, soybean, cotton, canola**
- **Revenue sharing: 60/40 (Mon/BASF)**
- **Additional coop:** Soybean cyst nematode

BASF
The Chemical Company

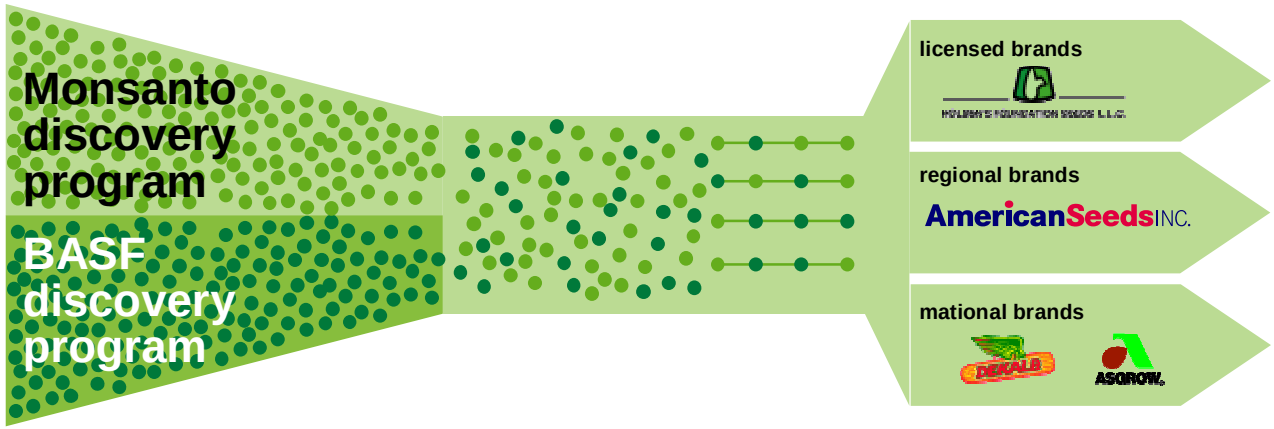
Monsanto Collaboration

From Discovery through Commercialization

Focus:

- Establishment of a joint technology & commercialization collaboration
- Combination of BASF and Monsanto expertise
- R&D-pipeline for yield and stress tolerance traits
- Corn, soybean, canola, cotton

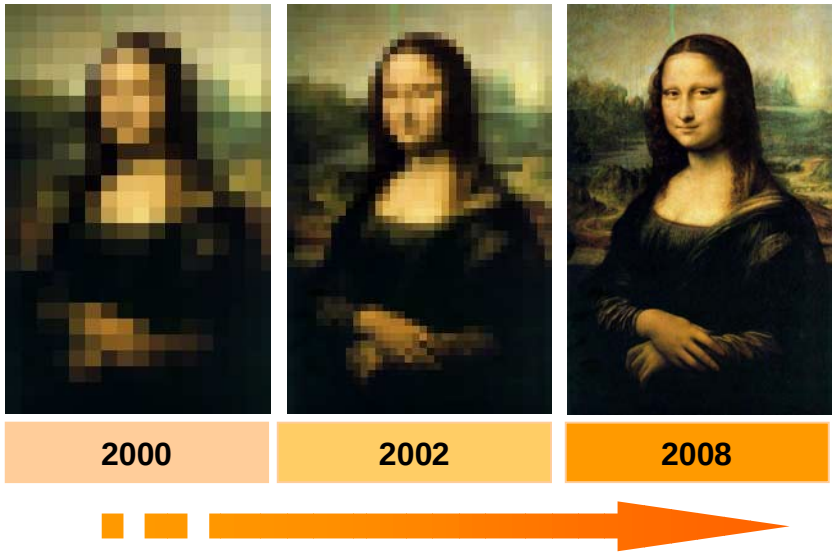
Structure:



Discovery	Development	Commercialization
■ Maintenance of independent discovery programs in each company	■ Funding at 50-50 cost sharing	■ Emerging products distributed by Monsanto across its three existing commercial channels
■ Nomination of projects for development to jointly managed board	■ Potential overall budget of €1.2 billion/ $1.5 billion through all phases of development	■ Value sharing at 60% for Monsanto and 40% for BASF

Conclusions

TraitMill: result of continuous improvements



- Example of cost-effective, highly automated platform for screening yield-enhancement genes
- Large effects (>20%) on yield
- Different yield components: opportunities for trait stacking
- In some cases, increased yield stability
- Phenotypes in the greenhouse confirm under field conditions
- Transferability of transgenic traits to other crops is ongoing

Thank you

BASF
The Chemical Company