Using Genebank diversity and state-of-the-art biotechnological approaches to improve breeding and food security

Dr. Goetz Hensel

BIOTECHNOLOGY
opportunity for intersectoral cooperation and technology transfer
Date: 19th September, 2018 ▪ Venue: Vodňany, MEVPIS – Na Valše 207

Leibniz Association

IPK GATERSLEBEN 1943–2018 75

Plant research as an instrument to handle environmental future tasks

The IPK sees itself as a **catalyst for the social transformation,** which aims at an efficient and sustainable supply of food, energy and raw materials. It creates solutions that are based on a knowledge-based conservation and exploration and exploiting of the **biodiversity of cultivated plants.**

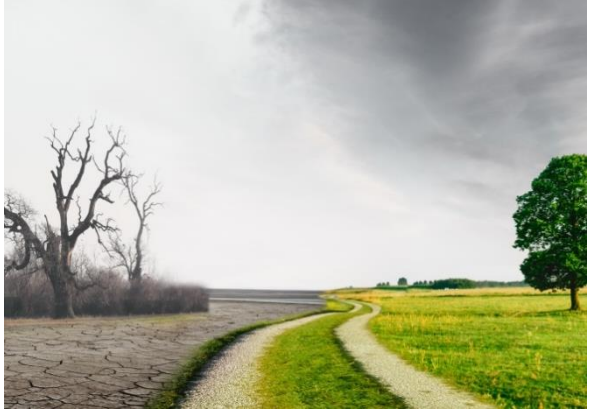
Scientific excellence and social relevance

Reliable supply of food to a growing world population

Advancement of a sustainable, resource-sparing plant production

Supply of raw and useful materials and renewable energy systems

Adapt of agricultural products to the consequences of climate change



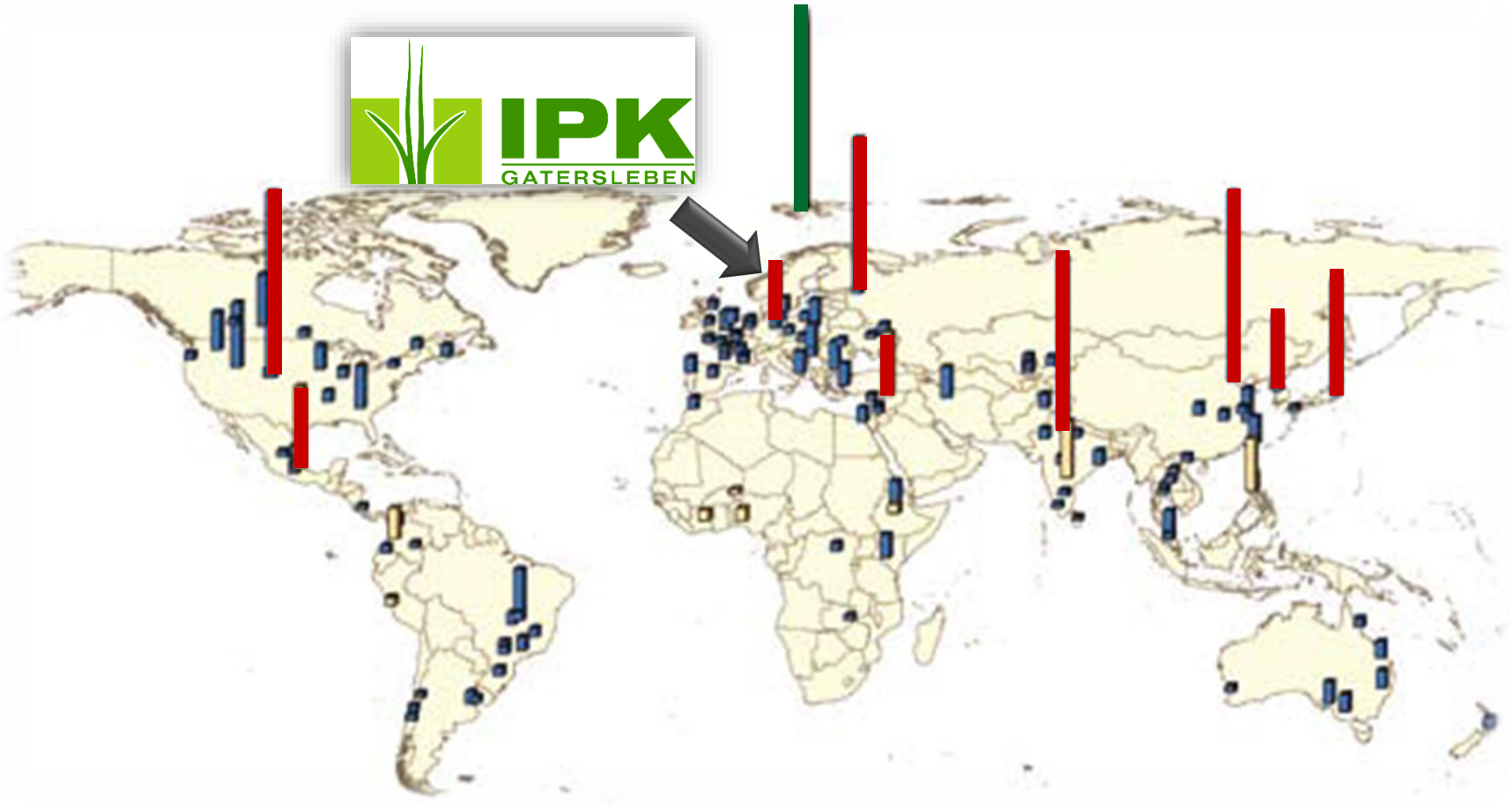
Establishment of IPK as

- a leading biological digital resource centre of knowledge-based use of biodiversity
- a Global trendsetter of genome analysis from Triticeae
- an innovation centre for the development of plant breeding technologies for wheat and barley
- an international beacon of elucidation of the molecular and physiological processes of agronomic characteristics

Departments and their focus

The **four scientific departments** of the IPK work on the elucidation of fundamental principles of the evolution, development and adaptability of important crops. On this basis the IPK develop innovative approaches for a knowledge-based conservation and exploitation of crop diversity to increase the resource efficiency and sustainability of plant-based production processes

Centres of plant conservation



Genebanks holding >10,000 accessions (blue); CGIAR Centers genebanks (beige); SGSV4 (dark green) (Source: FAO 2010)

IPK Genebank

Collections	Accessions
Cereals and Grasses	65,897
Wheat	28,206
Barley	23,607
Oat	4,849
Rye	2,410
Aegilops	1,526
Legumes	27,819
Vegetables	21,052
Oil-/ Fibercrops	5,478
Medicinal-/ Spiceplants	8,194
Forage crops	14,388
Potatoes	6,217
Total	**150,751**

Seed regeneration

Genebank – Field work



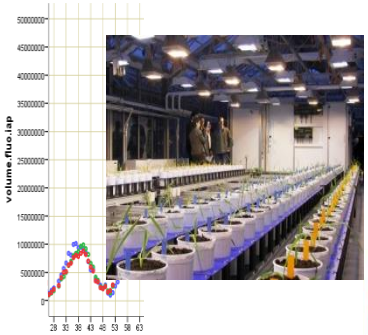



Genebank - …

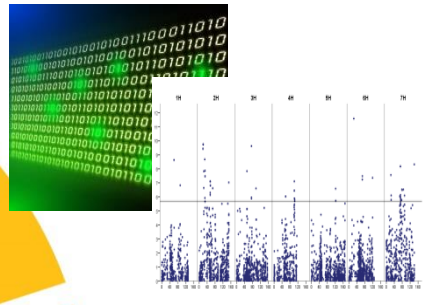
- Multiplication (6,164 acc)
- Cryopreservation (1,859 potatoes, garlic)
  - Field genebank (3,159 acc)
  - 420,000 voucher specimen
  - 154,000 reference samples (seed, fruits, spikes)

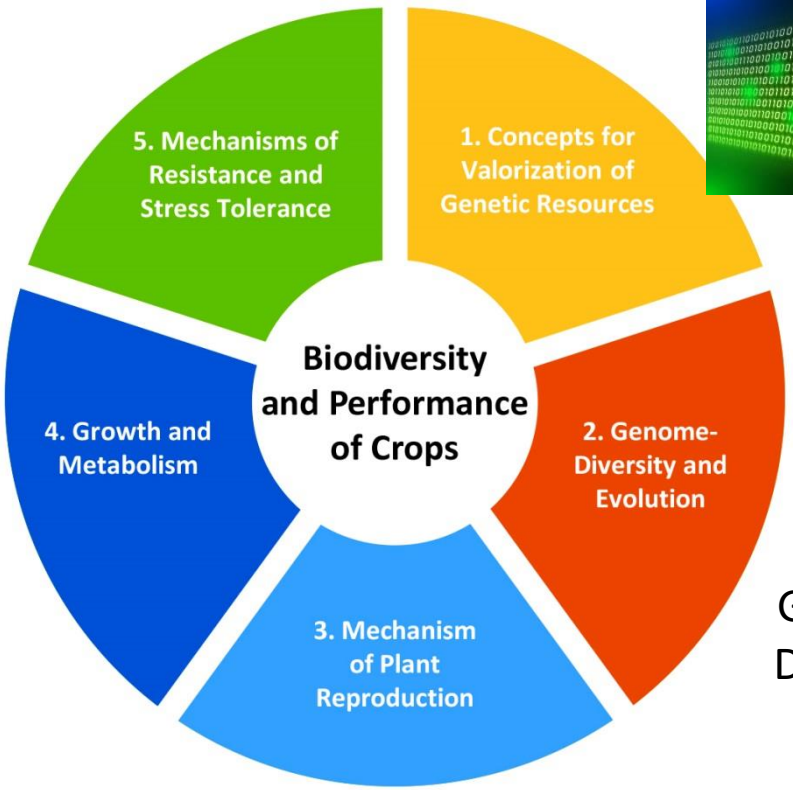
Research Themes

Sustainability and adaptation



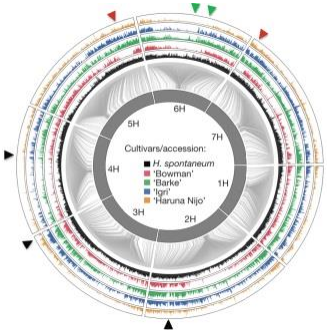
Delivery, valorization and utilization



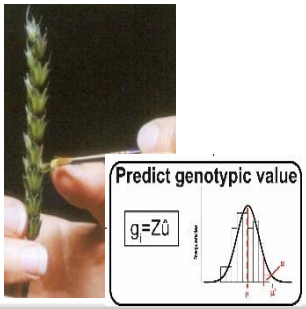


Plant performance

Genetic Diversity



Breeding technologies



Value capture of Genetic Resources

Conservation of Biodiversity

- conservation management
- distribution of samples

Biodiversity Informatics

Research

- „Omics“ data
- trait mapping
- gene isolation
- systems biology

Breeding

- breeding methodology
- enabling technologies

Crop Plants

Barley

Wheat

Corn

Legumes

Rapeseed

Model Plants

Arabidopsis thaliana

Tôbacco

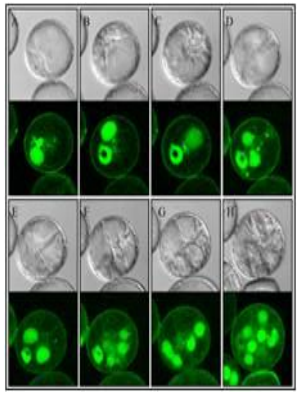
St. Jone‘s wort

Cress

Research Infrastructure

DNA Sequencing

- *ABI 3730 XL*
- *Roche 454 FLX*
- *Illumina HiSeq 2000*



Microscopy

- transmission and scanning electron microscopy
- Confocal laser scanning microscopy
- Confocal Spinning Disc Mikroskopy
- High-resolution microscopy

Computer systems

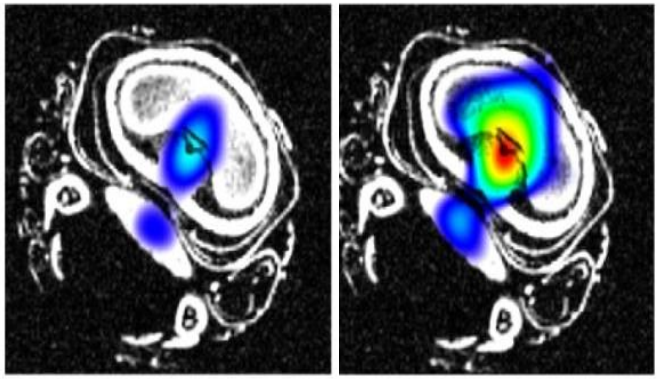
- *Cluster Computer with 200-core*
- *2 Server with main memory size (SMP)*
- *high-performance server*

Chromatography/Mass spectroscopy

- *Proteins (*Nano-HPLC + ESI-MS/MS, MALDI-TOF-MS)
- *Metabolites (*HPLC-MS, ICP-MS, EA-IRMS, GC-MS)

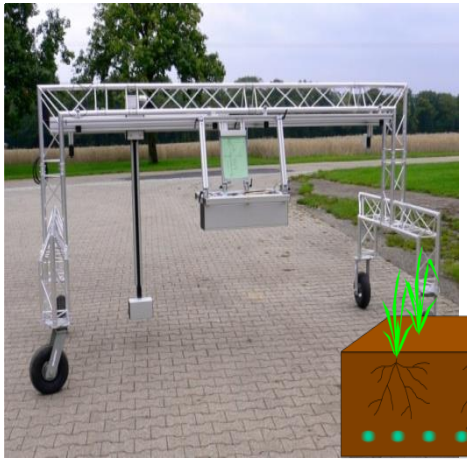
Plant Phenotyping

NMR:
Seed



Microscopy:
Leaves: Epidermis

Greenhouse:
Figures
RGB, Fluor, NIR, IR



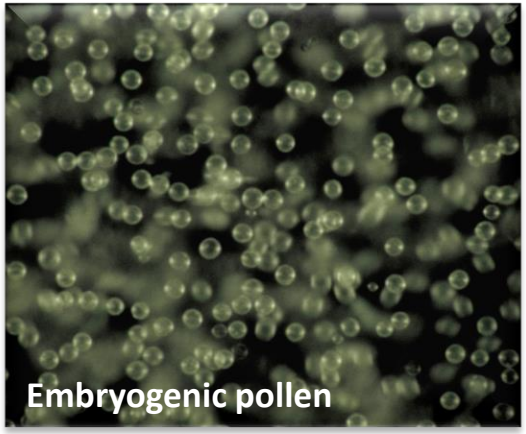
Field:
Figures
RGB, Fluor

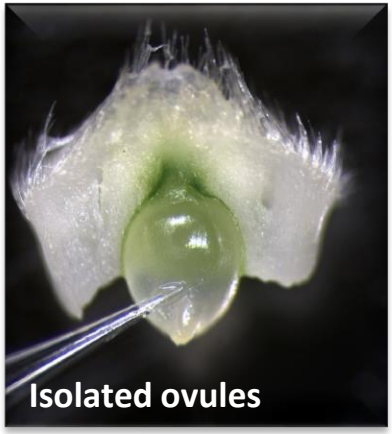
- Building high-quality technological platforms
- Protocol development for registration of plant parameters, growth and environmental conditions
- Image Analysis

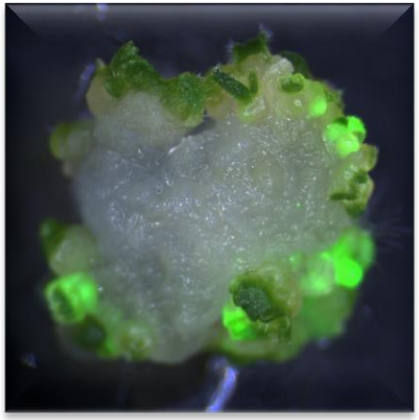
Deutsches Pflanzen Phenotypisierungs Netzwerk DPPN

Bundesministerium für Bildung und Forschung

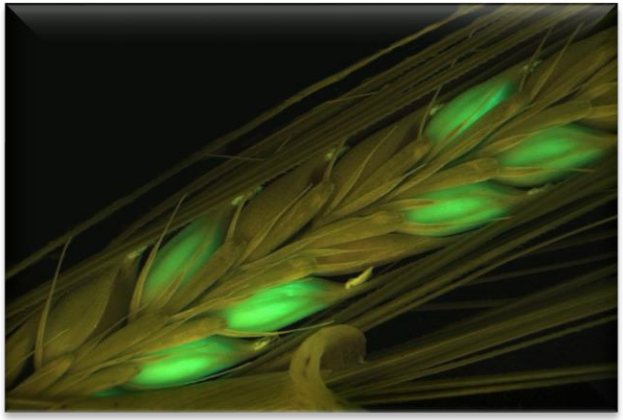
Transformation and regeneration







callus and shoot development



T_0 spike, genetic segregation

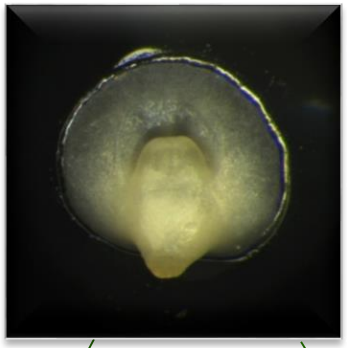
Agrobacterium-mediated gene transfer

Source: http://www.imageflora.com

Agrobacterium-mediated gene transfer to cereals

Hensel et al. 2009, Int J Plant Genomics

L. Gugsa, unpublished

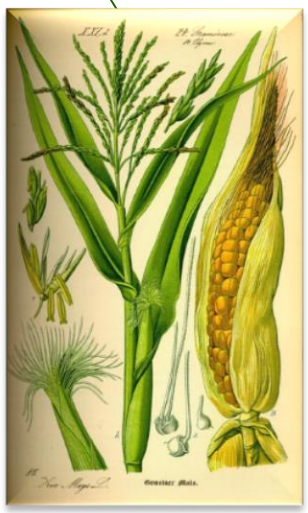


IEs

Hordeum vulgare

Hordeum spontaneum

Secale cereale



Zea maize

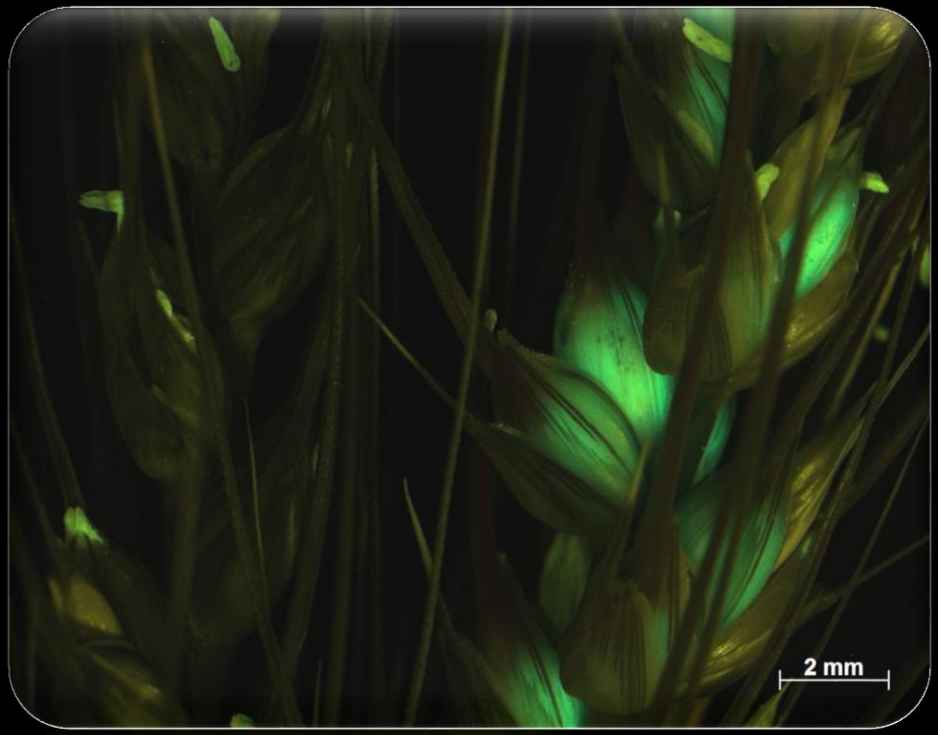
Triticum aestivum

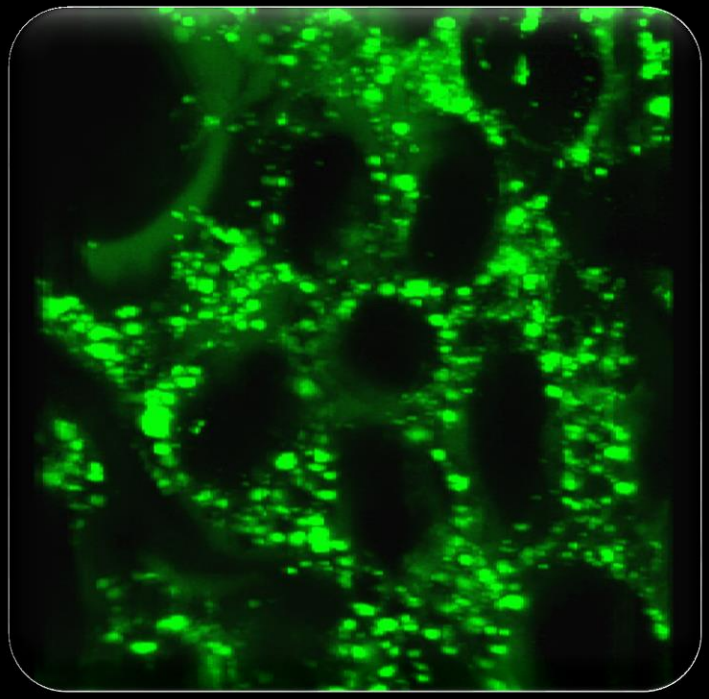
Eragrostis tef (Zucc.)

Cell and tissue-specific expression systems

Hensel et al. 2016, PLoS One

Endosperm-specific expression of AsGlo1P::gfp





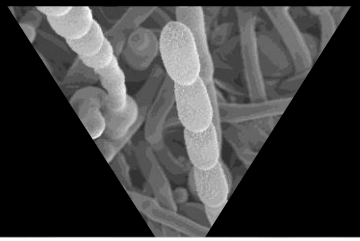
- metabolic engineering (e.g. carbohydrates, proteins)
- production of recombinant proteins (enzymes, antibodies, vaccines etc.)

Cell and tissue-specific expression systems

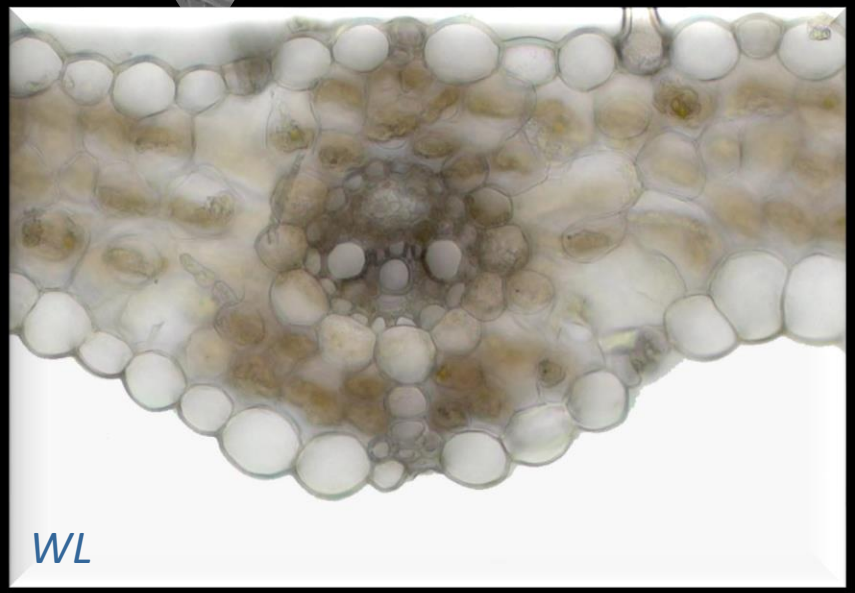
A. Himmelbach et al. 2010, Plant Cell

Co-operation with P. Schweizer Group, IPK

Epidermis-specific and pathogen-inducible expression of GER4P::GUS

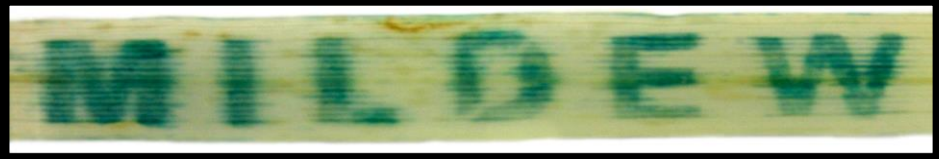


Pathogen



FUNGAL SPORES

GUS STAINING



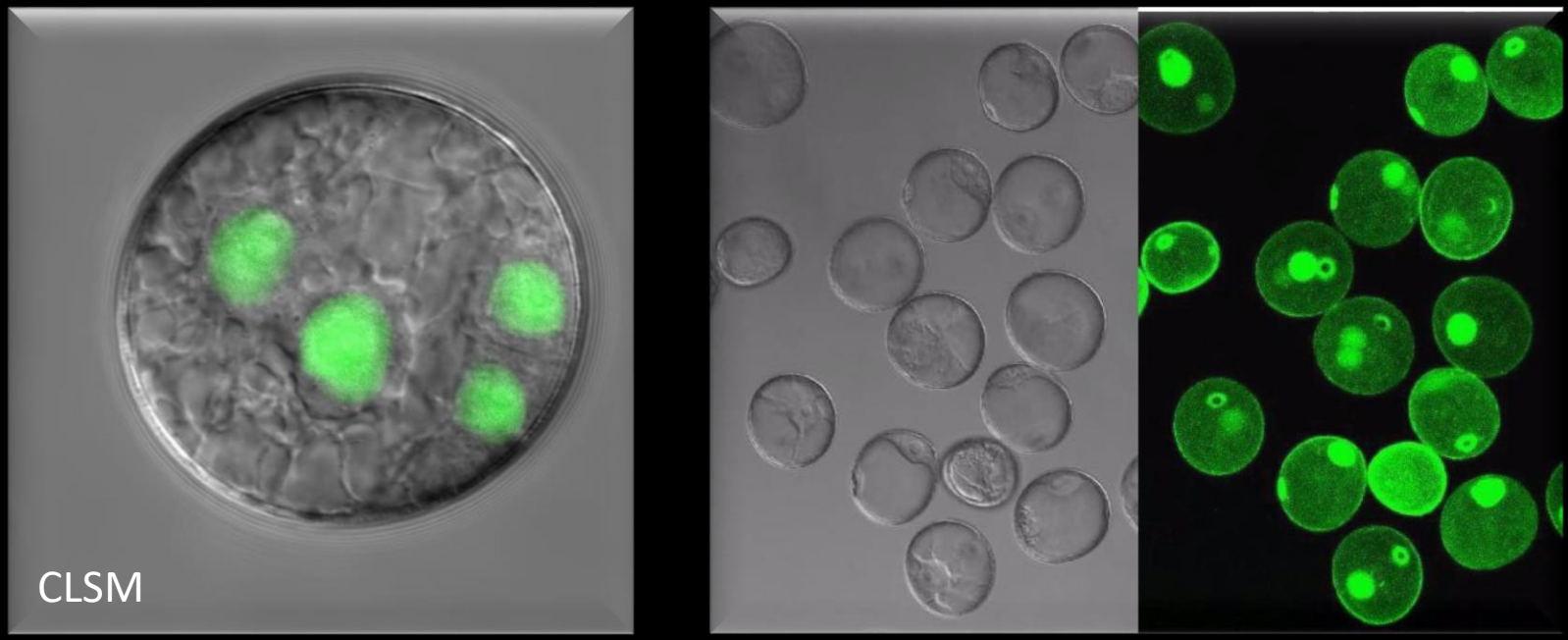
- functional analysis of genes involved in plant – pathogen interactions
- inducible expression to avoid pleiotropic effects

Cell and tissue-specific expression systems

Daghma et al. 2014, Frontiers in Plant Science

Microspore-specific expression

ZmUbi1P:NLS::gfp



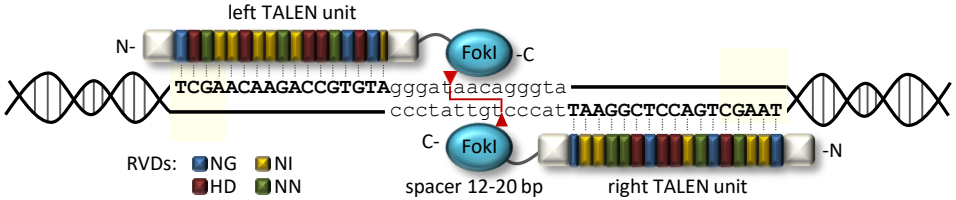
- functional analysis of POEM initiation
- production of doubled haploid plants for breeding processes

Site-directed mutagenesis using customized endonucleases

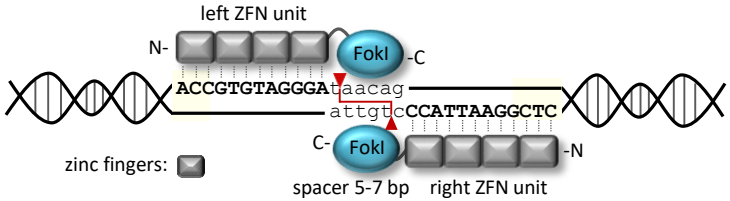
Hiekel et al, Acta Horticulturae 2015

Meganucleases

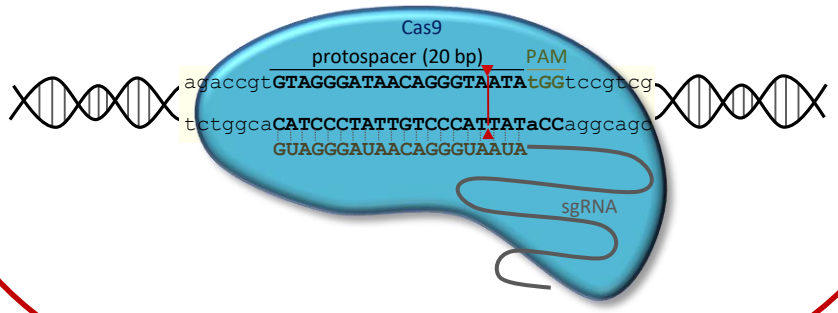
TALENs



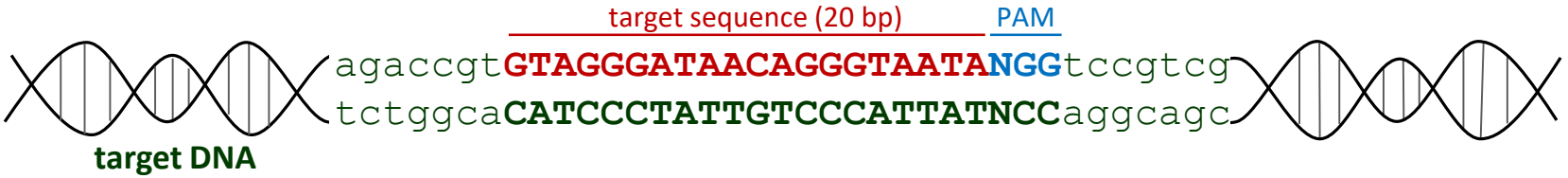
ZFNs

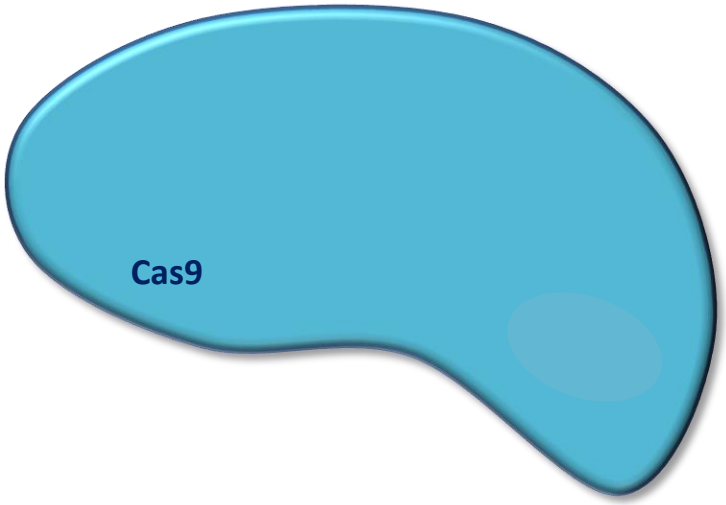


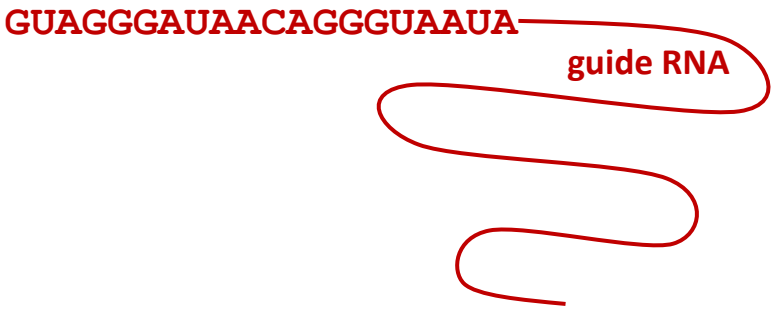
RGENs (CRISPR RNA/Cas)



CRISPR RNA-guided/Cas9-mediated mutagenesis







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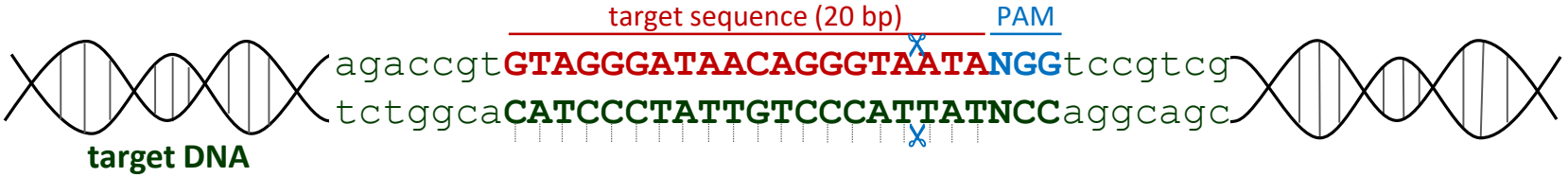

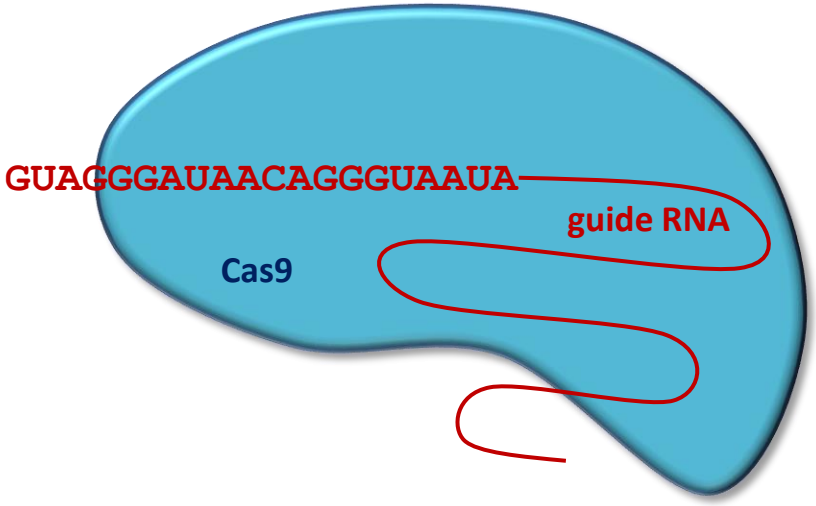

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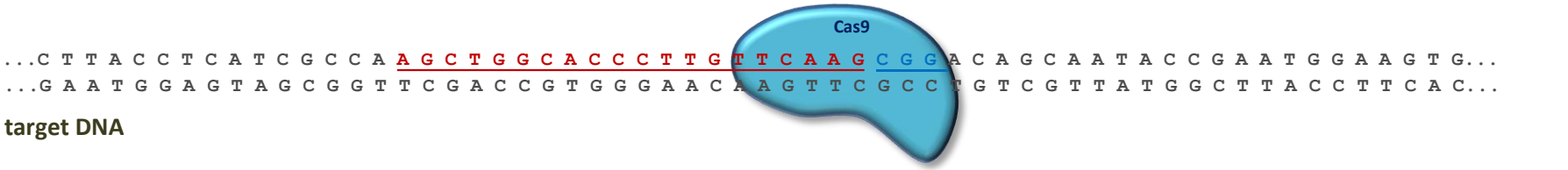
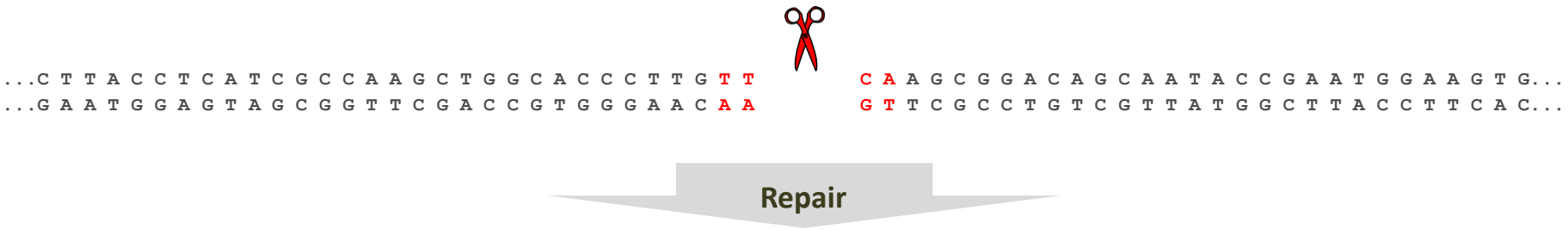




From 2-rowed to 6-rowed

Vrs1

2-rowed

domestication

vrs1

6-rowed

From 2-rowed to 6-rowed

Götz Hensel, Sabine Sommerfeld, Sibylle Freist, Jochen Kumlehn

gRNA/Cas9-triggered mutagenesis of *Vrs1*

Golden Promise WT, *Vrs1*

Golden Promise *vrs1*-KO
(awns of spikelets removed)

- **KO lines show fully developed lateral spikelets**

Comparison of different production systems

System	Overall costs	Production time	Scale-up capacity	Product quality	Contamination risk	Purification costs
Bacteria	low	short	high	low	medium	high
Yeast	low	short	high	medium	medium	high
Insects	medium	medium	medium	high	high	medium
Mammalian cells	high	long	medium	very high	very high	high
Plant cells	medium	medium	high	high	very low	medium
Whole plants	low	very long	very high	high	low	high

Source: Xu et al., (2011) 29:278-299, modified

Advantages of barley

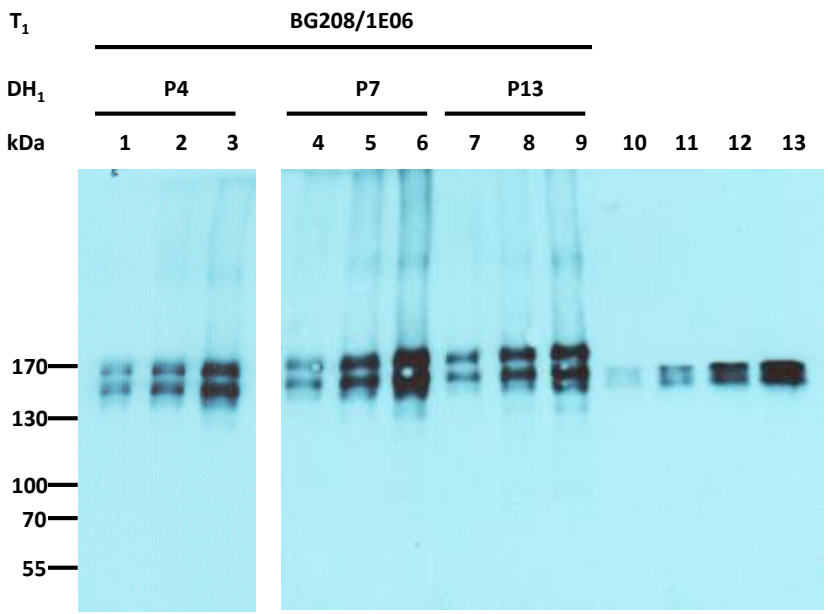
- Experimental model for small-grain cereals and agronomically important
- Exhibits a broad range of adaptability
- Relatively high protein content (12-15%)
- Caryopses are prone to be used as bioreactor
- Self-pollinating nature and no outcrossing
- G.R.A.S. (generally recognized as safe) status from FDA
- Low production costs due to a highly developed infrastructure for harvest, transportation and storage

Bioproduction of Recombinant Protein in Barley Grains

Hensel at al. 2015 PlOS One

Endosperm-specific expression of the HIV neutralizing antibody 2G12

- cause of AIDS (acquired immunodeficiency syndrome)
- antibody neutralize the virus by binding to gp120
- 160 g antibody per kg mature grains produced
- biacore binding assays were promising



Thanks to the Plant Reproductive Biology group members

Head: J. Kumlehn

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Somayeh Sardouei
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T. Schnurbusch
N. Stein
P. Schweizer

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BMBF
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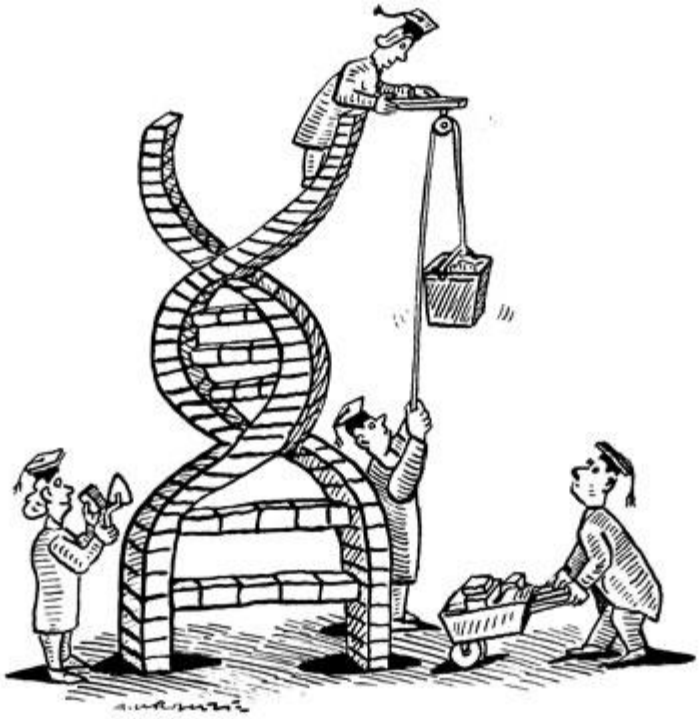
Thank you



http://www.the-scientist.com/images/December2012/Genome.jpg