



## Global overview on latest plant breeding methods: research, product development and regulatory frameworks

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[www.julius-kuehn.de](http://www.julius-kuehn.de)

### Domestication and breeding 10.000 years of success



#### How to create genetic diversity...

- Breeding with crossable species (within the species gene pool)
- Protoplast or Cytoplast-fusion (Species which are hard to cross)
- Radiation or chemical random mutagenesis or somaclonal variation
- Random introduction of foreign DNA (classical gene technology)
- Induction of targeted mutations (genome editing e.g. Crispr)



## Tools for Genome Editing

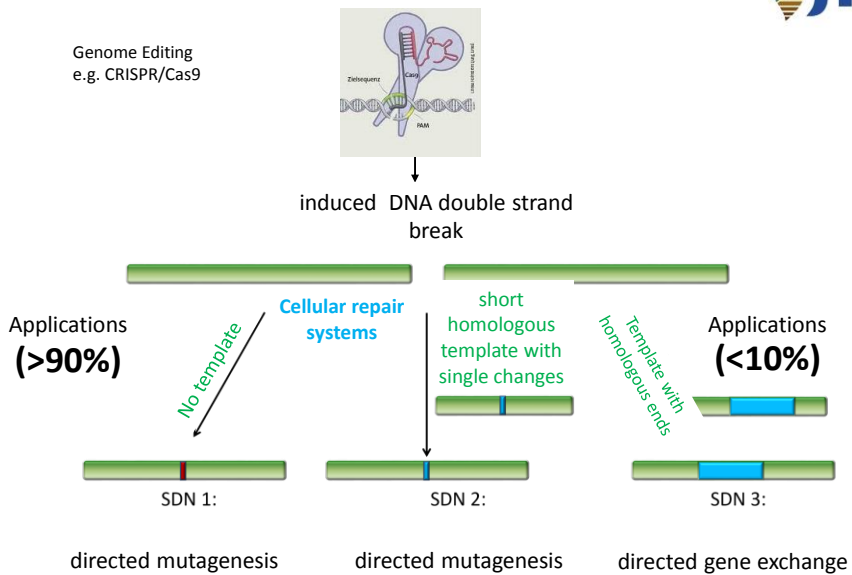


Genome Editing is a technique to introduce **specific** and **intended** alterations in a nucleic acid sequence

1. **Sequence-directed nucleases (SDN)**
  - four different types of nuclease systems
  - CRISPR/Cas9 , TALENs, ZFNs, Meganucleases
  - Variants like Base Editors or Nickases
2. **Oligonucleotide-directed mutagenesis (ODM), also called RTDS**
  - developed by Cibus (San Diego, USA)

CRISPR (clustered regulatory interspaced short palynidromic repeats; TALEN: Transcription activator like effector nucleases; ZFN: Zink finger nucleases, RTDS: Rapid trait development system [www.julius-kuehn.de](http://www.julius-kuehn.de)

## The application of genome editing can result in different products



## Systematic Map: Literature search



Time period: 1996 – May 2018

Literature search  
n=6000

Criteria: - **Model plant or crop**  
- **Genome Editing technique**  
- **Primary data**

- Scopus
- PubMed
- Science direct
- Agris
- Web of Science (WoS)
- Am I regulated (Aphis)
- Biological Abstracts
- BIOSIS Previews
- CAB Abstracts
- FSTA
- SciELO Citation Index

Relevant publications: n= 545  
Studies contained therein: n= 1305

➤ Data basis to answer the systematic map question

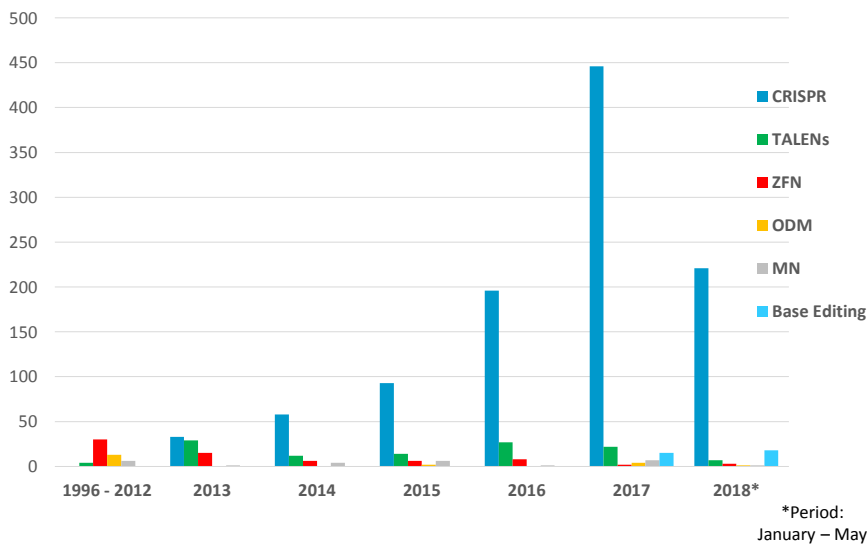
Example: Baltes et al. (2014):

- **One** publication
  - Application of **three Genome Editing techniques**
  - Application in **two model plants**
  - **Three sequences addressed**
- => **One publication contains four studies**

ZFN	Arabidopsis	ADH1
ZFN	Tabak	Zif268
TALENs	Tabak	ALS
CRISPR/Cas9	Tabak	ALS

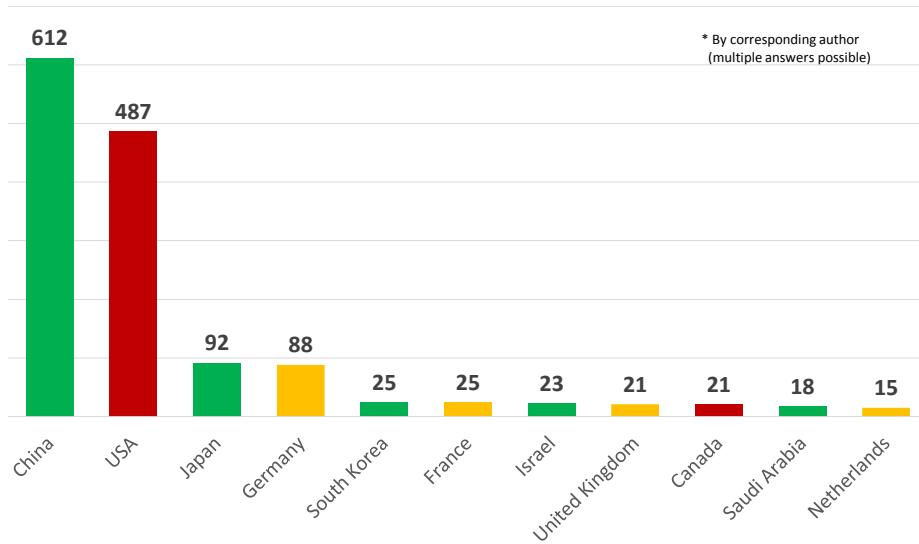
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## Studies presenting experimental data



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## China and the US leading in applications of Genome Editing\*

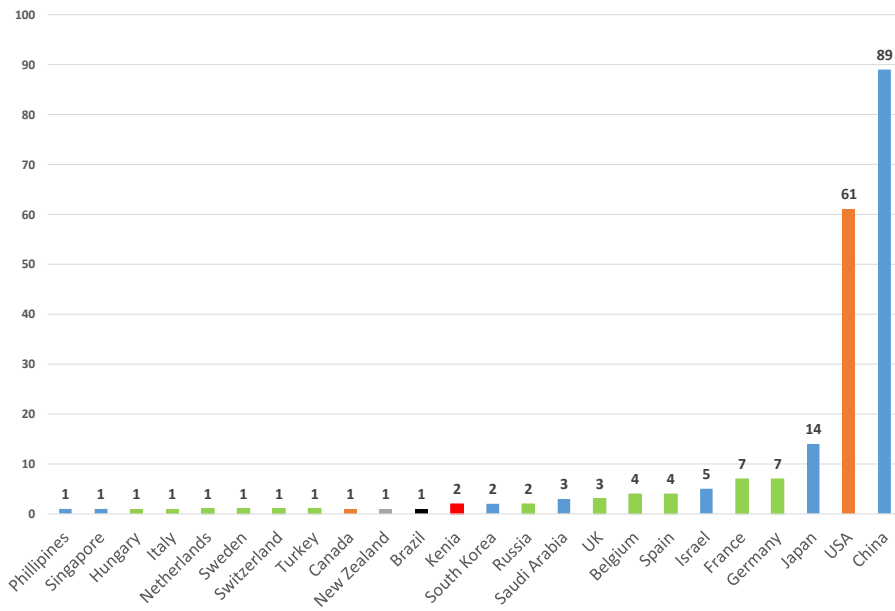


→ Studies from **33 different** countries

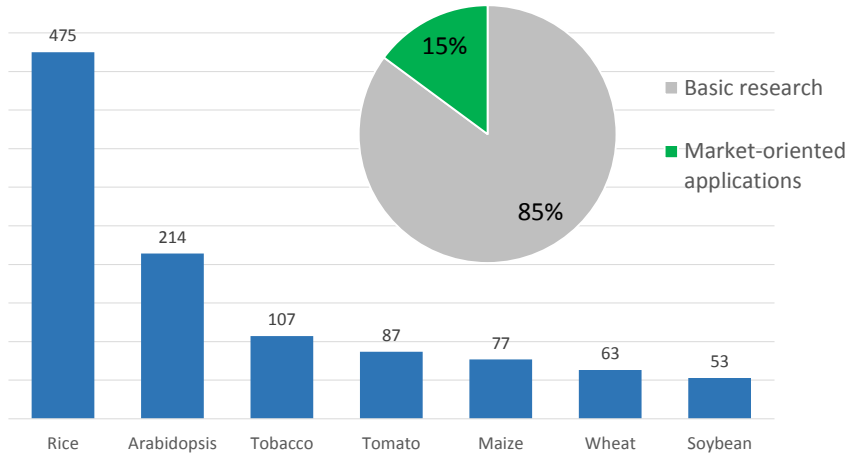
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## Novel Data – China/US again at the forefront

(May 2018- June 2019)



## 15 % of the studies in crops are market oriented

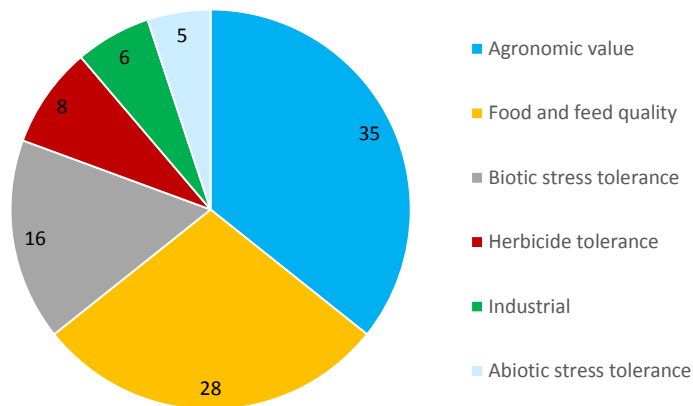


Applications identified in **46 different crops and model organisms**

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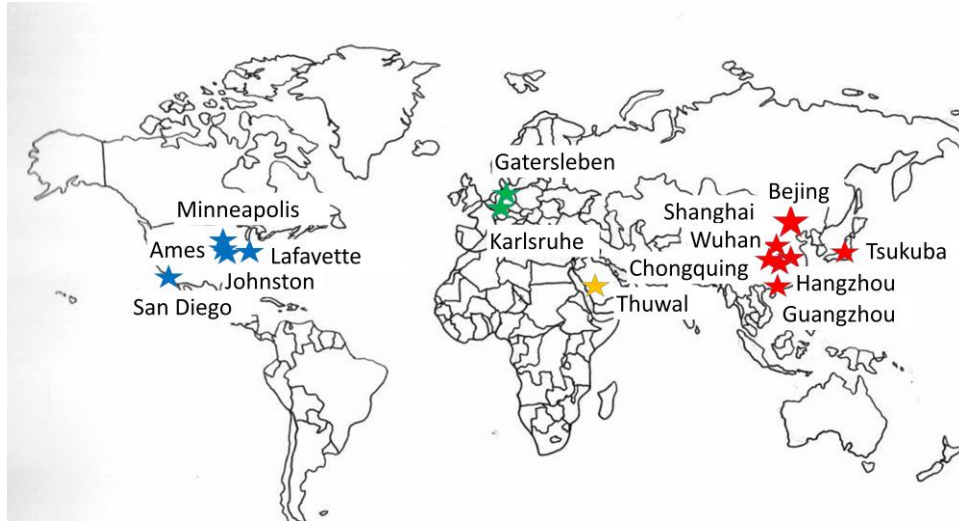
## Number of Market oriented applications according to Traits

(January 1996- May 2018)


















## Global Hotspots for Genome Editing Studies

(according to first author)



### The cities with the most publications in Genome Editing

1. Beijing	77		Rice, Maize, Tomato, Potato, Wheat, Vine, Soy, Salvia, A.th
2. Shanghai	26		Rice, A.th, Salvia, Maize, fungi
3. Hangzhou	22		Rice, A.th, Tomato
4. West Lafayette	18		Rice, A.th, Potato
5. Tsukuba	16		Rice, A.th, Tomato, N.bt
5. Minneapolis	16		Barley, Wheat, Tomato, Potato, A.th, Tobacco
6. Wuhan	15		Rice, Canola, A.th, Millet
7. San Diego	13		Rice, Maize, Algae, Wheat
8. Thuwal	11		A.th, N.Bt, Rice
9. Ames	9		Rice, Maize, Millet, N.bt
9. Johnston	9		Maize, Soy, Sorghum
9. Chongqing	9		Poplar, Canola, Citrus, Tobacco
10. Guangzhou	8		Rice, A.th, Peanut
10. Karlsruhe	8		A.th
10. Gatersleben	8		Barley, A.th, Tobacco



## European Hotspots for Genome Editing Studies

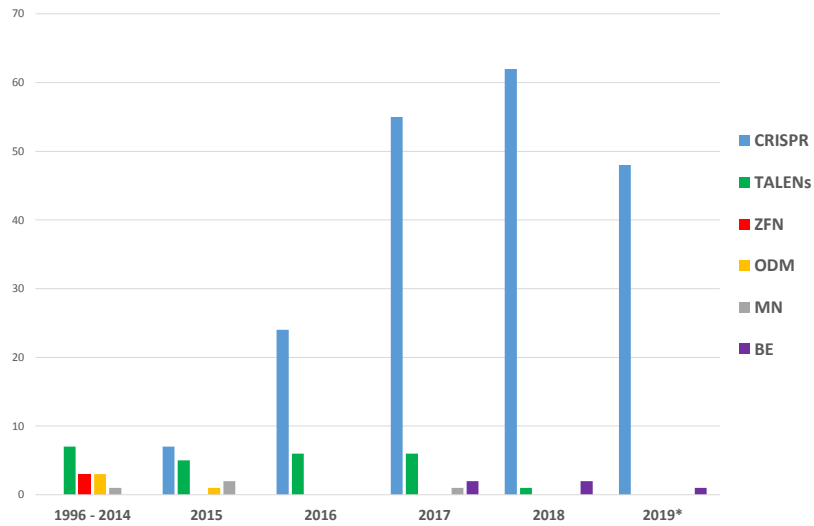


## Studies presenting experimental field trial data –June 19



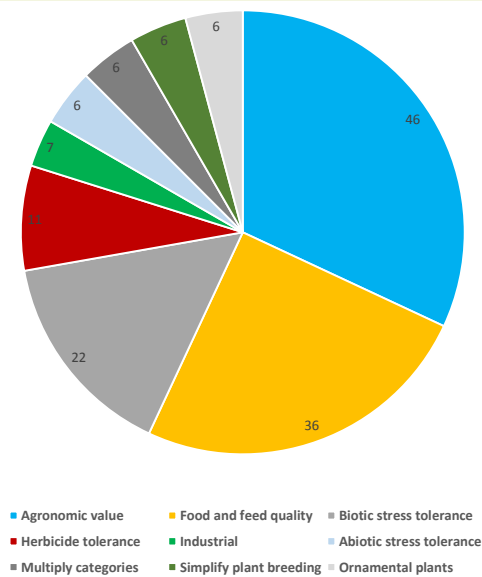
Edited after Metje-Sprink et al. 2020

### Number of applications with market relevance – according to tools used



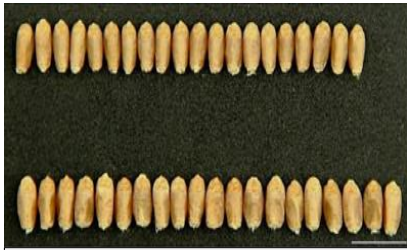
### Number of market oriented applications according to Traits

(Jan 1996- June 2019)





## Examples of studies with traits of Agronomic value



**Wheat:** Bigger grains, increased grain weight

[Zhang et al. 2018](#)



**Cucumber:** Only female flowers

<https://www.gartenlexikon.de/gartenpraxis/gemuese/gurkenpflanze.html>



**Canola:** Increased shatter resistance

[https://www.landwirt.com/Die-Rapserte-nicht-ueberstuerzen\\_6572\\_Bericht.html](https://www.landwirt.com/Die-Rapserte-nicht-ueberstuerzen_6572_Bericht.html)

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## Examples of studies with Traits for food and feed quality



**Soybean:** Improved oil quality

<https://eatsmarter.de/lexikon/warenkunde/soja-produkte/sojaeol>



**Rice:** Reduced arsenic content

<https://de.organic.org/arsenic-in-brown-rice-everything-you-need-to-know/>



**Wheat:** Reduced gluten content

[www.strengthfirst.de/guten-tag-oder-gluten-haben-beine-entscheidung/](http://www.strengthfirst.de/guten-tag-oder-gluten-haben-beine-entscheidung/)

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## Examples of studies with Traits for Stress tolerance



Grapefruit; Orange:  
Resistance to citrus canker

<http://www.apisnet.org/EDCENTER/ADVANCED/TOPICS/ECOLOGVANDEPIDEMIOLOGYNR/DISEASEPROGRESS/Pages/CitrusCanker.aspx>



Rice, Wheat, Tomato:  
Powdery mildew resistance

[www.transgen.de](http://www.transgen.de)



Grapevine: Tolerance to  
Botrytis cinerea

<https://www.winefrog.com/botrytis-cinerea-friend-or-foe/2/2168>



Maize, Wheat: Drought  
tolerance

<https://www.transgen.de>



Rice: Salt tolerance

<http://irri.org/news/119-wild-parent-spawns-super-salt-tolerant-rice>



Soybean: Drought and salt  
tolerance

<https://www.ifl.bayern.de/ipz/oelfruechte/113678/index.php>

## Conclusions



- Publications on genome editing applications are increasing continuously worldwide
- Crispr-Cas is the dominating tool that is used
- Most applications (90%) introduce targeted mutations, only 10% insert heritable (foreign) DNA
- China and US are the leading countries
- Applications address a huge diversity of different characteristics addressing all kinds of relevant agricultural or consumer traits
- More and more countries follow a differentiated regulatory approach taking into account the kind of genetic change (change within the plants genome versus introduction of heritable foreign DNA)



*Thank you very much for your  
attention*

Data published:

Modrzejewski et al. (2018): What is the available evidence for the application of genome editing as a new tool for plant trait modification and the potential occurrence of associated off-target effects: a systematic map protocol. In: *Environ Evid* 7 (1), S. 11. DOI: 10.1186/s13750-018-0130-6.

Modrzejewski et al. (2019): What is the available evidence for the range of applications of genome-editing as a new tool for plant trait modification and the potential occurrence of associated off-target effects: a systematic map. In *Environ Evid* 8:27 <https://doi.org/10.1186/s13750-019-0171-5>