Plant Breeding as an integral part of Sustainable Agriculture

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Picking Cotton
The choice between organic and genetically-engineered cotton for farmers in South India

Author: Reyes Tirado
Greenpeace Research Laboratories
University of Exeter, UK
GRL-TN 03/2010

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Sustainability (in agriculture)

- Environment
- Economics
- Social aspects

↔ GE crops (& food)
↔ Pesticides

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GE crops

Herbicide-tolerant or/ and Insecticide-producing
Concerns about GMOs

…and their deliberate release into the environment:

– consequences of the introduced trait (e.g. herbicide tolerance) or type of genetic material (e.g. antibiotic resistance genes)
– unforeseen interactions between
  • the new or altered gene(s) and the plants own genes;
  • genomic irregularities (e.g. fragments and rearrangements) and/or
– alterations to plant biochemical pathways can give rise
– …to unintended and unpredictable effects in GM plants
– retrievability, health, hindering solutions, failure to yield
New „Breeding techniques“ = new GE

Gene scissors (nucleases), Oligonucleotides (ODM, directed mutagenesis), (Cisgenesis) … and more to come

GE or not?

main criterion (for GE) is that an organism’s genetic material must have been altered using modern biotechnology to give rise to a novel composition, i.e. a sequence of nucleotides that did not arise by mating, “does not occur naturally” rather than “could occur naturally”

If “new plant breeding technologies” result in a novel combination of DNA, they are GE
New GE - concerns

- “gene scissors” might cut DNA in another place, ODM might induce a similar mutation elsewhere
- many of these “gene editing” techniques are new, it is not yet possible to fully evaluate the potential for unintended changes
- may be more precise, but unintended changes to genetic material can still be expected
- can give rise to plants displaying unexpected and unpredictable effects – only assessed under GMO regulation!

new GE (crops) need to be regulated as GMOs
(new) GE regulation

Classification as a GMO means (in the EU)
- Need for special authorization
- Risk assessment
- Monitoring
- Labeling (food/ feed/ seeds)
- Detection methods (?)
- Coexistence measures

freedom of choice for consumers and farmers
Marker Assisted Selection (MAS)

“Safe” biotechnology
…that works.
Smart Breeding

Can increase stress tolerance (Drought tolerance regulated up to 60 genes + complex interactions)

Respects species barriers (All genes incorporated present in natural gene pool)

Fewer safety concerns (backcrossing and introgression long history of safe use)
### MAS successes - examples

<table>
<thead>
<tr>
<th>Trait</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biotic Stress Resistance</strong></td>
<td></td>
</tr>
<tr>
<td>Insect resistance</td>
<td>maize, rice, wheat</td>
</tr>
<tr>
<td>Fungal resistance</td>
<td>barley, bean, chili, lettuce, pearl millet, rice, soybean, tomato, wheat</td>
</tr>
<tr>
<td>Bacteria Resistance</td>
<td>bean, lettuce, rice</td>
</tr>
<tr>
<td>Virus resistance</td>
<td>barley, bean, cassava, tomato, wheat, lettuce</td>
</tr>
<tr>
<td>Nematode resistance</td>
<td>barley, peanut, potato, soybean</td>
</tr>
<tr>
<td>Parasite resistance</td>
<td>sorghum</td>
</tr>
<tr>
<td><strong>Abiotic Stress Resistance</strong></td>
<td></td>
</tr>
<tr>
<td>Acid soil tolerance</td>
<td>barley, rice</td>
</tr>
<tr>
<td>Drought tolerance</td>
<td>maize, rice</td>
</tr>
<tr>
<td>Salt + flood tolerance</td>
<td>rice</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td></td>
</tr>
<tr>
<td>High protein grain</td>
<td>wheat</td>
</tr>
<tr>
<td>High quality protein</td>
<td>maize</td>
</tr>
<tr>
<td>Cooking quality</td>
<td>rice</td>
</tr>
<tr>
<td>Malting quality</td>
<td>barley</td>
</tr>
<tr>
<td><strong>Yield (!)</strong></td>
<td></td>
</tr>
<tr>
<td>High yield</td>
<td>rice, sorghum, tomato</td>
</tr>
</tbody>
</table>
**Genome Sequencing**

**Crops with published genome sequences**

<table>
<thead>
<tr>
<th>Year</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Rice (indica and japonica)</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>2006</td>
<td>black cottonwood</td>
</tr>
<tr>
<td>2007</td>
<td>grape</td>
</tr>
<tr>
<td>2008</td>
<td>papaya</td>
</tr>
<tr>
<td>2009</td>
<td>maize, cucumber, sorghum</td>
</tr>
<tr>
<td>2010</td>
<td>apple, castor bean, jatropha, soybean</td>
</tr>
<tr>
<td>2011</td>
<td>barbados nut, <strong>cacao</strong>, chinese cabbage, chinese plum, clementine mandarin, date palm, hemp, pigeon pea, potato, ...</td>
</tr>
<tr>
<td>2012</td>
<td>banana, barley, cassava, flax, foxtail millet, melon, neem, tomato, watermelon, wheat</td>
</tr>
<tr>
<td>2013</td>
<td>chickpea, lupin, sweet orange, peach, pear, kiwifruit, norway spruce, rubber tree</td>
</tr>
<tr>
<td>2014</td>
<td>i.e. <strong>cotton</strong></td>
</tr>
</tbody>
</table>

(Li et al., 2014)
Breeding for sustainable agriculture

- Non GE (neither „classic“ nor „new“)
- Classic, „safe“ breeding methods (considered „natural“ or „history of safe use“)
- non-invasive biotechnology: MAS
- Open source – no patents on life
- Participatory: in cooperation with farmers for local needs
- For „sustainability“ traits/
  organic (ecological) agriculture
Plant Breeding as an integral part of Sustainable Agriculture

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Sustainable solutions

→ Agroecology

UN-report 2011

NEWS RELEASE

Eco-Farming Can Double Food Production in 10 Years, says new UN report

GENEVA – Small-scale farmers can double food production within 10 years in critical regions by using ecological methods, a new UN report* shows. Based on an extensive review of the recent scientific literature, the study calls for a fundamental shift towards agroecology as a way to boost food production and improve the situation of the poorest.

*To feed 9 billion people in 2050, we urgently need to adopt the most efficient farming techniques.
Ecological, „diversity“ farming

Shift from high inputs of Agrochemicals to knowledge-based agriculture, using agroecological principles (including free „ecosystem services“)

… and „diversity farming“

• **Increases resilience** to erratic weather changes

• **Reduces pests and diseases** by diluting their hosts

• **Prevents soil erosion** + **increases soil organic matter** + **improves water use efficiency**

• **Increases productivity** + **maximises yield over years**, decreasing crop failure in bad years
RICH
HIGH DIVERSITY

POOR
LOW DIVERSITY

CROP GENETIC DIVERSITY

RICE OF DIFFERENT VARIETIES

RICE OF SINGLE VARIETY

CROPPING DIVERSITY AT THE FARM

MAIZE AND BEANS INTERCROP PLUS AGROFORESTRY

MAIZE IN MONOCULTURE

FARM DIVERSITY AT THE REGION
Agroforestry

Malawi: Maize + *Faidherbia albida*; Maize-yields +280%

„Milpa“

Maize + beans + pumpkins

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„Push-Pull“

Main Crop

Trap Crop

Attract natural enemies

Moths are pushed away

Attract moths

Desmodium intercrop

Integrating livestock in farming
i.e. Rice-Duck/-Fish-Systems
Conclusions

- Non-GE-breeding is (just) one element of sustainable agriculture
- Diversity and agroecology are key to sustainable farming systems
Literature new GE and MAS

http://www.greenpeace.org/eu-unit/Global/eu-unit/reports-briefings/2016/Joint%20position_New%20techniques%20of%20genetic%20engineering_March%202016-1.pdf


http://www.greenpeace.org/international/en/publications/Campaign-reports/Agriculture/Smart-Breeding/