Plant Breeding Potential to Improve Energy Crops for the Use in Biogas

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CO₂ + H₂O + light + chlorophyll = (CH₂O) + O₂

Crop plants

Vegetable oil

Starch
Breeding Progress

Grain yield on the farm level: „Besondere Ernteermittlung“ 1952-2002

Winter barley

Ertrag [dt/ha] = -1471.95 + 0.77 * jahr
R-Quadrat = 0.92

+0.8 dt/ha/yr

Winter wheat

Ertrag [dt/ha] = -2092.79 + 1.08 * jahr
R-Quadrat = 0.95

+1.1 dt/ha/yr
Energy crops

Plants cultivated for energy production purposes:

- **Trees (wood)** $\implies$ solid fuel, Biomass-to-Liquid (BtL)
- **Oilseeds (rapeseed)** $\implies$ liquid fuel = Biodiesel (RME)
- **Cereals** (e.g. wheat, triticale) $\implies$ Bioethanol
- **Grasses** as biomass source (e.g. Miscanthus) $\implies$ Biogas
- **Silage maize** $\implies$ Co-substrate for fermentation: Biogas
## Crop Cultivation for Renewable Resources

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Basic area (ha) 2002*</th>
<th>Set-aside area (ha)</th>
<th>5-years-increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>125.000</td>
<td></td>
<td>101,6</td>
</tr>
<tr>
<td>Sugar</td>
<td>7.000</td>
<td></td>
<td>100,0</td>
</tr>
<tr>
<td><strong>Rapeseed oil</strong></td>
<td><strong>320.000</strong></td>
<td><strong>344.930</strong></td>
<td><strong>357,2</strong></td>
</tr>
<tr>
<td>Sunflower oil</td>
<td>20.000</td>
<td>4.080</td>
<td>104,4</td>
</tr>
<tr>
<td>Linseed oil</td>
<td>15.000</td>
<td>277</td>
<td>15,8</td>
</tr>
<tr>
<td>Vegetable fibre</td>
<td>2.000</td>
<td>0</td>
<td>49,7</td>
</tr>
<tr>
<td>Medicinals</td>
<td>4.000</td>
<td>400</td>
<td>90,9</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>3.919</td>
<td>1911,7</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>493.000</strong></td>
<td><strong>353.606</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td></td>
<td><strong>846.606</strong></td>
<td><strong>190,3</strong></td>
</tr>
</tbody>
</table>

1) Germany; Source: BMVEL, Ref. 535 (2002); *)estimated
Global Production of Oil Crops

Oil seeds are globally produced on more than 200 Mio ha. Since the 1990s production has increased more than the cultivation area! Soybean is clearly the most important oil seed of the world.

http://www.ufop.de/Bioproduktion.pdf
Oilcrops for Europe

- Oilseed Rape
- Sunflower

=> Vegetable oil
=> Biodiesel (RME)
Genetic variation for height and biomass in oilseed rape
(dwarf cv. Lutin)
Cereals (whole crop), Grasses, etc.:

=> Biomass => Fuel
Means and range of biomass yield of annual energy crops, Germany 1994-96

Quelle: Jürgen Maier¹; Dr. Reinhold Vetter¹; Volker Siegle²; Dr. Hartmut Spliethoff², ¹Institut für umweltgerechte Landbewirtschaftung (IfUL), Müllheim, ²Institut für Verfahrenstechnik und Dampfkesselwesen (IVD), Universität Stuttgart: Anbau von Energiepflanzen - Ganzpflanzengewinnung mit verschiedenen Beerenmethoden (ein- und mehrjährige Pflanzenarten); Schwachholzverwertung.
Abschlußbericht Ministerium Ländlicher Raum Baden-Württemberg, 1998
Estimated biogas and electricity yield

Richtwerte für Gasausbeuten (abgeleitet aus Gärversuchen)

Methanertrag (y1)
Ertrag elektr. Strom (y2)

Mittel ca. 300 IN/kg oTS Methan

Ertrag elektr. Strom, 32 % BHKW-WG (kW/h FM)

Rindergüte 87
Korn Getreide 40
Grassilage 25
Maisilage 35
Sudanras 18
Silage maize
(Energy maize)

=> Biomass => Biogas
Breeding goals

- Yield output
- Yield stability
- Product quality
Recent yield progress of winter oilseed rape in Germany

Source: NPZ 2001, Statistisches Bundesamt, Statistisches Landesamt, Landessortenversuche
Heritability ($h^2$) vs. Selection gain

> Agronomy

> Plant breeding
Heritability and Gain of Selection

\[ h^2 = \frac{s_g}{s_p} \]

\[ G = i \cdot h^2 \cdot s_p \]

G=Gain, i=selection intensity, \( h^2 = \) heritability, \( s_p = \) phenotypic standard deviation
Silage maize (Energy maize)

Biomass yield of different *maize hybrid types* (German, French, Italian varieties) at different *locations* (dry vs. favourable conditions)

http://www.kws.de/
Effect of the previous crop – maize or mixtures of maize with Italian ryegrass and forage rye - on methane yield of maize

http://www.kws.de/
Schmidt, W.: Hybridmaiszüchtung bei der KWS Saat AG
(Gumpenstein 2003)
Hybrid breeding
Grain yield of winter oilseed rape variety types at varying N-supply

Grain yield $N_0$ (dt/ha)

Hybrid cultivars
- Artus

OP cultivars
- Express
- Lirajet
- Lisabeth
- Maplus

Semi-synthetic lines
- Joker
- Life
- Synergy

DH lines
- Maplus

Grain yield $N_{160}$ (dt/ha)
Rapeseed

Molecular markers: AFLPs

Mapping population:

**F₂-Population:**
Express 617 x 1012-98
22 Primer combinations

**DH-Population:**
T-25629-3 x DH26-96
20 Primer combinations
Genomic regions (QTL) relevant for fibre content

Molecular genetic map of maize (1-10 chromosomes)

Conclusion

• Crop plants have a great potential for the production of energy (Biomass, Bioethanol, Biodiesel, etc.)

• Crop and energy yield depends on heritable (genetic) and environmental effects (heritability => gain of selection)

• Heritable variation has long been exploited by breeding

• Plant breeding efficiency can be increased by molecular (genetic) tools today
Thanks ... 

Co-workers

Funding
BMBF, DFG, DAAD, UFOP, Marie-Curie-Foundation, a.o.
IFZ
Research Centre for Biosystems, Land Use & Nutrition

Justus-Liebig-University
Giessen (Germany)